ICAO

Doc 10126, CAEP/11

第十一次会议

2019 年 2 月 4 日 — 15 日，蒙特利尔

航空环境保护委员会

报告

经航空环境保护委员会批准并根据理事会决定出版。

报告中表达的观点应视为专家委员会向理事会提出的
建议，但不应视为代表本组织的观点。

本报告的补篇说明了理事会就此报告采取的行动。

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国际民用航空组织

航空环境保护委员会（CAEP）第十一次会议

2019 年 2 月 4 日至 15 日，蒙特利尔

第 1 号补篇

1. 理事会在其 2019 年 6 月 7 日举行的其第 217 届会议第九次会议上，就航空环境保护委员会第十一次会议（CAEP/11）的各项建议采取了行动，如下所示。

2. 对标准和建议措施及程序（RSPP）的修订建议

2.1 建议 3/1，第 3-9 页
建议 3/4，第 3-10 页
建议 4/1，第 4-2 页

2.2 理事会注意到，空中航行委员会审查了上述各项建议，并同意应将其送交各成员国和各国际组织。在收到意见之后，委员会将做出详细审查，随后将向理事会提出其行动建议。

3. 不涉及标准和建议措施及程序的建议

3.1 秘书长将按照以下所采取的行动所示，对所有经批准的建议安排任何后续行动。

报告的出处		理事会（C） 空中航行委员会 （ANC）的行动	建议之标题和所采取的行动
建议号	页码		
1/1	iii-5	理事会	**国际民航组织 Doc 9988 号文件：《关于制定国家二氧化碳减排活动行动计划的指导》** 批准该建议并请秘书长采取必要行动。
1/2	iii-6	理事会	**提交国家行动计划** 批准该建议并请秘书长采取必要行动。
1/3	iii-6	理事会	**国家行动计划结对子伙伴关系** 批准该建议并请秘书长采取必要行动。
2/1	1-9	航委会	**核准全球环境趋势评估** 批准该建议并请秘书长采取必要行动。
2/2	1-9	航委会	**公布独立专家关于发动机和航空器的综合技术目标评估和审查** 批准该建议并请秘书长采取必要行动。
2/3	1-9	航委会	**接受航空环境保护委员会第十一次会议为发动机和航空器设定的综合噪声和排放技术目标** 批准该建议并请秘书长采取必要行动。
3/2	3-10	理事会	**使用非挥发性微粒物质标准** 批准该建议并请秘书长采取必要行动。

报告的出处		理事会（C） 空中航行委员会 （ANC）的行动	建议之标题和所采取的行动
建议号	页码		
3/3	3-10	理事会	**修订《环境技术手册》第 II 卷—《航空器发动机排放审定程序》** 批准该建议并请秘书长采取必要行动。
3/5	3-11	理事会	**修订《环境技术手册》第 III 卷—《飞机二氧化碳排放合格审定程序》** 批准该建议并请秘书长采取必要行动。
3/6	3-11	理事会	**修订国际民航组织 Doc 9889 号文件 —《机场空气质量手册》** 批准该建议并请秘书长采取必要行动。
4/2	4-2	理事会	**修订《环境技术手册》第 I 卷 —《航空器噪声合格审定程序》** 批准该建议并请秘书长采取必要行动。
5/1	5-1	航委会	**航空系统组块升级组块 1 环境分析** 批准该建议并请秘书长采取必要行动。
5/2	5-2	航委会	**全球空中交通管理效率和无偿性业务量增长的环境影响** 批准该建议并请秘书长采取必要行动。

报告的出处		理事会（C）空中航行委员会（ANC）的行动	建议之标题和所采取的行动
建议号	页码		
5/3	5-4	理事会	**环保业界参与基于性能的导航** 批准该建议并请秘书长采取必要行动。
5/4	5-5	理事会	**气候适应综述** 批准该建议并请秘书长采取必要行动。
5/5	5-6	理事会	**生态机场工具包电子文献集** 批准该建议并请秘书长采取必要行动。
5/6	5-7	理事会	**航空器报废和回收** 批准该建议并请秘书长采取必要行动。
8/1	6-7	理事会	**修订《环境技术手册》第 IV 卷** 批准该建议并请秘书长采取必要行动。
8/2	6-8	理事会	**技术咨询机构（TAB）议事规则** 批准该建议并请秘书长采取必要行动。
9/1	9-2	理事会	**附件 16 第 IV 卷参照的国际民航组织文件：“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划可持续性标准”** 批准该建议并请秘书长采取必要行动。

报告的出处		理事会（C）空中航行委员会（ANC）的行动	建议之标题和所采取的行动
建议号	页码		
9/2	9-5	理事会	**附件 16 第 IV 卷参照的国际民航组织文件：“国际航空碳抵消和减排计划可持续性合格审定计划的合格性框架和要求”** 批准该建议并请秘书长采取必要行动。
9/3	9-7	理事会	**附件 16 第 IV 卷参照的国际民航组织文件：“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划默认生命周期排放值”** 批准该建议并请秘书长采取必要行动。
9/4	9-7	理事会	**附件 16 第 IV 卷参照的国际民航组织文件：“国际航空碳抵消和减排计划计算实际生命周期排放值的方法”** 批准该建议并请秘书长采取必要行动。
9/5	9-7	理事会	**国际航空碳抵消和减排计划辅助文件：“国际航空碳抵消和减排计划合格燃料 — 生命周期分析方法”** 批准该建议并请秘书长采取必要行动。
10/1	10-2	理事会	**航空噪声影响白皮书** 批准该建议并请秘书长采取必要行动。
12/1	12-4	理事会	**航空环境保护委员会第十二次会议工作方案** 批准经修改的工作方案。

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航空环境保护委员会（**CAEP**）
第十一次会议（**2019** 年）

送文函

收件人：　理事会主席

发件人：　航空环境保护委员会（CAEP）主席（2019 年）

我谨荣幸地提交 2019 年 2 月 4 日至 15 日在加拿大蒙特利尔召开的航空环境保护委员会（CAEP）第十一次会议的报告。

主席
Tan Kah Han 先生

2019 年 2 月 15 日，蒙特利尔

目录

建议清单[1]

1. 标明“RSPP”的建议（关于标准、建议措施和程序的建议）涉及对某一附件中关于空中航行服务的标准、建议措施和程序或者指导材料的修订提案。

航空环境保护委员会（CAEP）

第十一次会议

2019 年 2 月 4 日至 15 日，蒙特利尔

会议简况

1. 会期

1.1 2019 年 2 月 4 日 14 时，理事会主席于加拿大蒙特利尔宣布航空环境保护委员会（CAEP）第十一次会议开幕。此次会议于 2019 年 2 月 15 日闭幕。

2. 出席情况

2.1 出席此次会议的有 30 个成员国和 10 个国际组织指派的成员和观察员，以及顾问和其他人员，人员名单如下：

成员	顾问	提名方
Carlos Ruben Fernandez	Maria Fabiana Loguzzo	阿根廷
Lachlan Phillips （候补）		澳大利亚
Ricardo Antonio Binotto Dupont	Bruno Franciscone Daniel Ramos Longo Dario Taufner Guilherme Lima Renato Godinho	巴西
Gilles Bourgeois	Alissa Boardley David Bilcock David Branton-Brown Jon Albert Obnamia Kerri Henry Prem Lobo Ted McDonald Wendy Bailey Yves Cousineau	加拿大
刘晓杰 杨晓军 （2019 年 2 月 4 日至 6 日担任候补成员）	Henry Chiu 杨晓军 马晓宁	中国
Abdelghafar Elsayed Abdelhalim （候补）		埃及

成员	顾问	提名方
Robert Mauri	Anouck Barreaux Bruno Hamon Claire Rais Assa Jonathan Gilad Pierre Primard	法国
Frauke Pleines-Schmidt	Georg Naumann Petra Bollich Stefan Bickert	德国
Rohit Thakur （候补）	Rajasekar Ganesan	印度
Fransiscus Budi Prayitno （候补）	Avirianto Suratno Budi Djatmiko Chandra Apriyatno Kusmini Kusmini Margaretta Rozetta Nurdini Tambunan Pintanugra Persanta Putu Eka Cahyadhi Sayuta Senobua Sigit Hani Adiyanto Wendy Aritenang	印度尼西亚
Silvia Egoli Giovanni Barraco （2019 年 2 月 4 日至 8 日担任候补成员）	Alberto Anglade Giovanni Barraco	意大利
Koichi Minato	Kotaro Yamamoto Masato Takehisa Naoya Takahashi Shion Kanamori Shoji Kawamori Shomei Tanamachi Takahiro Nakashima Takashi Hongo Yoshikazu Makino	日本
Michael Lunter	Beatrice Adolehoume	荷兰
Tadeusz Reklewski	——————	波兰
Artur Mirzoyan	Agrafena Kotova Aleksei Sipatov Galina Kirichenko Iurii Khaletskii Ivan Belyaev Liudmila Rostovtseva Victor Kopiev	俄罗斯联邦

成员	顾问	提名方
Mohammed Habib	Adnan Alotaibi Danh Alkurdi Mohammed Alsalama	沙特阿拉伯
Tan Kah Han	Qing Ming Go （候补）	新加坡
Gabriel Bestbier	Chinga Mazhetese	南非
Alfredo Iglesias Sastre	Arturo Benito César Velarde Catolfi-Salvoni Juan Hermira	西班牙
Eva Marie Hankanen	Carola Lindberg Emma Jeppsson Henrik Ekstrand Therése Sjöberg	瑞典
Urs Ziegler	Catherine Marthe Theodor Rindlisbacher	瑞士
Oleksandr Zaporozhets	Ivan Iatsenko Svitlana Marunych	乌克兰
Maryam Al Balooshi	Rebekah Marshall	阿拉伯联合酋长国
Jennifer Raynor	Alexandra Chittenden Bethan Owen Darren Rhodes David Lee David Moroz Ian Jopson Nicholas Cumpsty	联合王国
Kevin Welsh	Bryan Manning Charlie Ashley Cullen Leggett Dimitri Mavris Donald Scata Gregg Fleming James Hileman John Mueller Molly Peters-Stanley Peter Coen Philippe Bonnefoy Ralph Iovinelli Rebecca Cointin Roger Schaufele Victor Sparrow	美国

观察员	顾问	提名方
Cesar Mac-Namara Alberto Mena （2019 年 2 月 4 日至 8 日担任候补观察员）	Alberto Mena Patricio Arancibia Jose E. Sanhueza Flores	智利
Konstantina Chrysikopoulou Georgia Lykou （2019 年 2 月 4 日至 8 日担任候补观察员）	Georgia Lykou	希腊
Hilde Hoiem	Jyrki Laitila	挪威
——————		马来西亚
——————		秘鲁
Artur Sousa	Ana Barbosa	葡萄牙
Deniz Kaymak	Ibrahim Sahinkaya	土耳其
Juliana Scavuzzi	Glynys Jones Guillaume Rodier Jeeyoon Jung Kathleen Henderson Mary Eagan Melinda Pagliarello Philippe Villard	国际机场理事会
Adil Bouloutar		阿拉伯民用航空组织
——————		民用空中航行服务组织
Isabelle Besson	Andrei Mungiu Andrew Watt David Brain Grégoire Le Comte Illimar Bilas Ivan de Lépinay Marco Paviotti Rachel Burbidge Richard Clarkson Stephen Arrowsmith	欧洲联盟
Michel Adam	Aaron Robinson Thomas Roetger Tim Pohle Ray Brown Nancy Young	国际航空运输协会
Bruce M Parry	Alexandra Grose Eli Cotti Kahina Oudjehani Leo Knaapen	国际公务航空理事会

观察员	顾问	提名方
Daniel Carnelly （2019 年 2 月 4 日和 5 日） Arnaud Bonnet （2019 年 2 月 6 日至 15 日担任候补观察员）	Amr Ali Arnaud Bonnet Brian Kim Bruno Pasturel Carlos Grandi Charles Etter Dale Smith Daniel Allyn Daniel Bassani Danielle Patton David Hyde David Lye Dominique Collin Eli Dourado Eric Jacobs Eric Upton Eugene Kors Hideki Moriai Jan Pie Jason Matisheck Jeffrey Peters John Morgenstern Jose Alonso Joseph Zelina Julien Dezombre Kevin Morris Kian Mccaldon Larry Gray Maria Chiara Detragiache Michel Wachenheim Miguel F. García Claro Minoru Hanakata Muni Majjigi Olivier Husse Olivier Penanhoat Paul Madden Peter Iosifidis Pierre Lempereur Raymond Russell Robby Lapointe Robert Cowart Rudy Dudebout Scott Piercy Sean Newsum Simone Rauer Thierry Percheron Tsutomu Oishi Vincent De Vroey Yoshiharu Sasaki	航空航天工业协会国际协调理事会

观察员	顾问	提名方
Tim Johnson	Amy Malaki Andrew Murphy Bill Hemmings Brad Schallert Dan Rutherford Hongming Liu John Holler Kristin Qui Pedro Piris-Cabezas	可持续航空国际联盟
Robert Brons	——————	航空公司驾驶员协会国际联合会
Gabriel Labbate	——————	联合国环境规划署
Katia Simeonova	Perumal Arumugam	联合国气候变化框架公约
Jane Hupe	Bruno Silva Chrystelle Damar Demi Tighe Joonas Laukia Manuel Caballero Alarcon Mathias Grossmann Neil Dickson Sean Donovan Stelios Pesmajouglou Tetsuya Tanaka Yury Medvedev	秘书处

3. 官员和秘书处

3.1 Tan Kah Han 先生当选为会议主席，Frauke Pleines-Schmidt 女士当选为会议副主席。J. Hupe 女士担任会议秘书，她得到环境标准科科长 N. Dickson 博士和气候变化科科长 T. Tanaka 先生的协助并得到 B. Silva 先生、M. Caballero 先生、C. Damar 女士、S. Donovan 先生、J. Laukia 先生和 Y. Medvedev 先生的支持。出席会议的还有航空运输局局长 Boubacar Djibo 先生、空中航行局局长 Stephen Creamer 先生和法律局 Andrew Opolot 先生。

4. 会议议程

4.1 2018 年 3 月 9 日国际民航组织理事会批准下列会议议程[2]。

议程项目 1： 评估航空器噪声和排放的当前与未来影响

议程项目 2： 环境模型和数据库

议程项目 3： 航空器发动机排放

议程项目 4： 航空器噪声

议程项目 5： 机场与运营

议程项目 6： 国际航空碳抵消和减排计划 — 监测、报告和核查（MRV）

议程项目 7： 国际航空碳抵消和减排计划 — 排放单位

议程项目 8： 国际航空碳抵消和减排计划 — 登记册

议程项目 9： 可持续航空燃料

议程项目 10： 有关航空器噪声和排放的科学现状

议程项目 11： 理事会有关航空环保委的职权范围（TOR）、结构、成员组成和工作方法的决定以及选举主席和副主席

议程项目 12： 今后的工作

5. 工作安排

5.1 技术委员会作为单一机构召开会议，酌情设立特设起草小组。主要会议的讨论均以阿、中、英、法、俄和西班牙文进行。一些工作文件只以英文本提供。报告草稿只以英文本印发。

6. 航空环境保护委员会第十一次会议的职权范围

6.1 进行理事会批准的有关管制航空器噪声和航空器发动机气体排放问题的具体研究。

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2. 2018 年 8 月 14 日和 2019 年 2 月 1 日理事会又对议程作出修订和取得一致意见。

6.2 委员会应在其工作中考虑到以下各点：

a) 从技术可行性、经济合理性和有待实现的环境效益的角度讨论合格审定机制的有效性和可靠性；

b) 其他相关领域的发展情况，如土地使用规划、减噪运行程序、通过运行措施管控排放等；

c) 国际和国内关于控制航空器噪声和管控航空器发动机气体排放的研究方案；和

d) 为控制噪声和管控发动机排放所采取的各项措施之间的潜在相互依赖性。

6.3 航空环境保护委员会的新职权范围于 2019 年 2 月 1 日获得批准，可在国际民航组织的公共网站查阅 [3]。

7. 航空环境保护委员会管理规则

7.1 为航空环境保护委员会制定了具体指令，成为航空环境保护委员会指令，这些指令于 2011 年 6 月得到理事会批准。理事会嗣后在 2018 年 11 月审查了这些指令，并于 2019 年 2 月 4 日作为定本印发。

8. 航空环境保护委员会第十一次会议（CAEP/11）工作方案

8.1 委员会本周期的工作方案是在航空环境保护委员会第十次会议期间商定的，并在随后举行的指导小组会议期间做出调整，以便纳入国际民航组织大会第 39 届会议的要求。下列各表（只有英文版）反映了经过更新的工作方案：

航空环境保护委员会第十一次会议第 1 工作组 — 噪声技术 — 工作方案				
任务编号	任务标题	任务说明	交付	交付日期
N.01	协调	与其他各工作组报告员进行协调： + 与技术、运行问题和目标有关的相互依存性及统一目标制定进程 + 与管理有关的相互依存性和更新噪声和排放数据库 + 与环境影响有关的相互依存性，包括严格度问题 + 为未来超音速飞机制定噪声和排放的标准和建议措施的方案	协调	进行中

3. https://www.icao.int/Pages/default.aspx

航空环境保护委员会第十一次会议第 1 工作组 — 噪声技术 — 工作方案

任务编号	任务标题	任务说明	交付	交付日期
N.02	附件和《环境技术手册》的维护	维持和更新附件 16 第 I 卷和《环境技术手册》第 I 卷。	更新《环境技术手册》 更新附件 16	SG2018 CAEP/11
N.03	噪声分贝	确保国际民航组织噪声审定数据库的过程完整性和数据更新。	更新国际民航组织的噪声分贝	进行中
N.04.01	监测研究和发展	监测和报告各国和国际研究方案的目标和里程碑。当有可用的新技术时，审查有关新技术的数据。	报告	CAEP/11
N.05.01	监测爆音研究	监测及报告描述、量化和测量（包括度量标准）超音速飞行的爬升和航路噪声包括马赫分界点条件及其可接受性的研究，同时协助促进并界定此类研究。	报告	CAEP/11
N.05.02	超音速运输机标准制定（亚音速和超音速体系）	继续就超音速航空器噪声审定标准开展工作： 1)基于地方机场噪声的亚音速噪声标准，它可能包含将可变噪声降低系统（VNRS）技术作为“可接受的合规方式”和 2) 基于 N.05.01 项下的发展所宣示的一个超音速飞行新体系。	进度报告	CAEP/11
N.05.03	超音速运输机协调	利用超音速工作队关于超音速运输机噪声活动进展的报告向空中航行委员会介绍最新情况。	向空中航行委员会报告情况	2016 年 5 月/6 月
N.05.04	监测超音速运输机项目	监测并报告超音速运输机项目的现况和超音速发展的预期。	报告	CAEP/11
N.06.01	支持：了解标准对全球机队演变的影响	在一项分析中支持建模和数据库小组，以便更好地了解标准是否正在推动所需的行为以及来自其他因素的潜在影响；例如，燃料价格变化、全球经济衰退等。	支持	
N.06.02	支持：全球航空环境计划（GAEP）	支持秘书处制订全球航空环境计划（GAEP）。与全球空中航行计划（GANP）类似，这将允许以协调的方式制定计划进行的附件 16 修正案的时间表。建议将拟议进行的噪声和排放技术审查作为制订全球空中航行计划的基础。	支持	进行中

航空环境保护委员会第十一次会议第 1 工作组 — 噪声技术 — 工作方案				
任务编号	任务标题	任务说明	交付	交付日期
N.07.01	无人航空器（UA）噪声监测	监测无人航空器噪声方面的发展并酌情向秘书长建议具体工作。	报告	
N.07.02	无人航空器（UA）噪声审定合格	为附件 16 中的噪声要求的适用性制定非零权重的建议。	改变的提案	
N.08.01	直升机噪声相关性	类似于对喷气机进行的研究，调查将审定合格噪声水平关联到运行噪声水平的可行性，以便更好地评估直升机噪声审定合格机制及其与日常运行的相关性。	报告	SG2017
N.08.02	直升机悬停噪声	审查过去对悬停状况的噪声审定合格机制的任何评估，并评估当前的直升机噪声审定合格机制是否适用于评估悬停噪声，包括与一个或多个现有参考条件相关的充分性。	提交 SG2017 的工作文件	SG2017
N.09	对发动机和航空器进行综合独立专家（IE）技术目标的评估和审查	与第 3 工作组协调，进行独立专家（IE）技术评估和审查 发动机：提供燃烧技术的评估，包括 NOx 和 nvPM，并在现有航空环境保护委员会标准和航空环境保护委员会 NOx 目标的范围内考虑。 航空器：飞机水平：提供航空器亚音速技术的评估，包括燃油效率和噪音。在现有航空环境保护委员会标准和航空环境保护委员会目标的范围内审议这些问题。	拟议提供给 SG2016 报告	CAEP/11
N.10	适用于重新审定合格的衍生飞机	审查第 4 章和第 14 章中关于重新审定合格的衍生飞机所需标准的适用性语言。	向 SG2016 提交关于审查结果和正在审议的修正案的影响的报告在 SG2016 作出决定前，对附件 16 第 I 卷的拟议修订案和《环境技术手册》	CAEP/11

航空环境保护委员会第十一次会议第 **2** 工作组—机场与运行—工作方案				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
O.01	环境社区参与基于性能导航	为编制提交指导小组第 2 次会议的报告，收集有关基于性能导航实施挑战、需求和潜在解决方案的信息，包括跨行业协作和结构化社区参与的方法。	1. 汇编与实施基于性能导航的方法有关的信息； 2. 查明任何差距/需要和建议的以后步骤以补充最近发布的第 2 工作组社区参与通告和相关格式； 3. 制定有关如何散发交付成果的提案	CAEP/11
O.02	减少航空器噪声的运行机会	类似国际民航组织第 10013 号文件“减少燃油燃烧和排放的运行机会”，编制有关噪声排放的文件。这项任务的目的是确定和突出良好做法和运行机会，在符合实际和满足运行安全的情况下，尽量减少航空器运行产生的噪音。	1. 主题章节的框架； 2. 参考材料； 3. 向航空环境保护委员会提出可能需要展开进一步工作的报告	向 CAEP/11 提出报告草稿 向 CAEP/12 提出最后报告
O.03	运行的相互依存性 – 评估相互关系信息	运行的相互依存性 — 评估 — 继续进行 CAEP/10 任务 O.02，评估国际民航组织文件中相互关系的信息，以便确定任何不一致和/或差距，并酌情为改善提出建议	提交指导小组的报告	SG2017

航空环境保护委员会第十一次会议第 **2** 工作组—机场与运行—工作方案				
任务编号	任务标题	任务说明	交付	交付日期
O.04	航空系统组块升级（ASBU）组块 1 的分析	ASBU 组块 1 — ASBU 分析任务在 CAEP/11 继续进行，旨在分析目前和计划实施的 ASBU 组块 1 模块可能产生的环境效益	在 CAEP/11，对计划实施组块 1 模块可能产生的效益的环境评估提出报告	CAEP/11
O.05	经改进的静态空中交通管理（ATM）和航空器技术情景	经改进的静态空中交通管理（ATM）和航空器技术情景 — 进行从上到下的分析，以确定空中交通管理（ATM）需要加以缩小和应成为 ASBU 模块实施目标的低效水平。这项分析将在 CAEP/8 周期进行的工作上开展。	在指导小组第 1 次会议，提出根据文献审查进行的可行性研究，以确定存在何种数据和方法。 如果显示可行，有可能向 CAEP/11 提交以下成果：a) 有关全球（无）效率估计的新数据，最好按地区分列；和 b) 静态空中交通管理（ATM）不作为案例的新评估	SG2016 CAEP/11
O.06	《机场规划手册》第 II 部分的新附录	《机场规划手册》第 II 部分附录 — 继续进行 CAEP/10 任务 O.06，以完成：a) 根据 CAEP/10 进行的审查，更新剩余章节；和 b) 编制遗产考虑和气候变化复原力和适应性的新章节和《机场规划手册》第 II 部分的 3 份新附录。附录 1 将包括促进环境管理的机场基础设施的案例研究、附录 4 将包括遗产管理的案例研究和附录 5 将包括气候适应的案例研究。	为《机场规划手册》第 II 部分编制的三份新附录	SG2018

航空环境保护委员会第十一次会议第 2 工作组—机场与运行—工作方案				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
O.07	气候适应综述	汇总航空部门预计的各种气候影响的现有信息，以更好地了解机场和空中航行服务提供者（ANSP）的规划、基础设施和运营的风险，包括提请国际民航组织的相关机构注意它们与安全、能力和效率的关系。	载有汇总信息和建议步骤的 CAEP 报告	CAEP/11
O.08	“绿化你的机场”电子文献集	一组实用且随时可用的信息，用于支持机场基础设施项目的规划和实施。每份出版物将具体针对机场环境规划的一个方面。	在国际民航组织环境网站上提供一系列出版物，以构成电子文献集。	进行中
O.09	航空器的寿命终止和回收利用	评估和整理目前关于航空器寿命终止管理技术的最佳做法和建议指导材料。	报告和指导材料	CAEP/11
O.10	更新“航空和全球大气”	对更新信息做出贡献。	不断给予支持	进行中
O.11	更新 Doc 9889 号文件	支持第 3 工作组更新国际民航组织 Doc 9889 号文件，以取代目前已经过时的排放技术信息。	向第 3 工作组提供 Doc 9889 号文件与运行有关的信息	根据要求，在 CAEP/11 举行之前提出更新的最后文件
O.12	支持国际民航组织秘书处	继续支持国际民航组织秘书处传播第 2 工作组的任务成果，包括对 ASBU 的分析和 APM 的更新。	航空系统组块升级的分析结果。对《机场规划手册》的意见。	按照要求

航空环境保护委员会第十一次会议第 3 工作组 — 排放技术 — 工作方案				
任务编号	**简称**	**任务说明**	**交付**	**交付日期**
E.01	相互依存性	与其他工作组报告员就涉及 (a) 技术、运行问题和目标，(b) 噪声和排放数据库的管理和更新，(c) 环境影响，(d) 未来超音速运输航空器的标准和建议措施的相互依存性问题进行协调。	向每一指导小组提交协调报告	进行中
E.02	燃料成分和排放	监测以下趋势：1) 以石油为基础的航空煤油燃料供应组成；2) 以航空代用燃料为基础的煤油燃料供应；和 3) 混合燃料类型。评估排放和排放审定合格的后果。包括燃料含硫量的全球调查，以支持全球和地区硫氧化物（SOx）排放估计。	报告	CAEP/11 期间
E.03	排放审定合格的要求 — 新飞机的应用和概念	监测飞机和发动机的应用和概念的发展，例如货机应用或技术发展，如复合式机翼机体或非传统机体和机翼结构以及开放式旋翼发动机等，并制定排放审定合格的方法。	报告	CAEP/11
E.04	附件 16 排放部分的维护	维护附件 16 有关排放部分	对附件作出拟议改变	CAEP/11
E.05	《环境技术手册》排放部分的维护	维护《环境技术手册》排放部分	对《环境技术手册》作出拟议改变	CAEP/11
E.06	排放数据库维护	维护排放审定合格数据库	更新数据库	CAEP/11
E.07	增长和替换数据库维护	审查和更新“增长和替换”数据库，以便支持拟定用于更新未来机队和替换退役航空器的模型。与微粒物质任务组、第 1 工作组和支援小组协调，确保各项假设的一致性。	更新增长和替换数据库	CAEP/11 期间

航空环境保护委员会第十一次会议第 3 工作组 — 排放技术 — 工作方案				
任务编号	**简称**	**任务说明**	**交付**	**交付日期**
E.08	巡航 — 爬升阶段 NOx 的关系	审查阶段性燃烧中起降阶段 NOx 与巡航爬升阶段 NOx 排放之间的关系和未来发动机技术，以量化对飞行任务中 NOx 排放的控制，确定有关起降阶段和爬升或巡航阶段的相互关系的任何方法问题和量化与其他排放的相互依存性。	报告	CAEP/11
E.09	审定合格要求 — 超音速运输机	监测超音速技术的趋势并评估发动机排放和审定合格标准的影响。	对附件 16 的拟议改变	CAEP/11
E.10	低功率排放建模	为建模和数据库小组低功率排放建模提供指导。		
E.11.01	微粒物质 — 非挥发性	在 2017 年 2 月以前为评估大于 26.7kN 的涡扇/涡喷发动机的质量和数目的 nvPM 排放标准提供代表性的发动机数据。向 SG2017 提供关于[新型和生产中的发动机]技术因应办法、严格度选项和适用性的建议。	报告	2017 年 2 月
E.11.02	微粒物质 — 非挥发性	为大于 26.7kN 的涡扇/涡喷发动机开发基于航空器发动机的着陆和起飞 nvPM 质量和数量标准。	附件 16 第 II 卷	CAEP/11 期间
E.11.03	微粒物质 — 非挥发性	调查可能替换≥26.7kN 发动机类别和其他<26.7kN 发动机类别的发烟指数标准。	附件 16 第 II 卷	CAEP/11 期间
E.11.04	微粒物质 — 非挥发性	根据影响与科学小组的咨询建议，为当地空气质量模型，并根据需要，为全球气候模型，制定经改进的非挥发性微粒物质模型（nvPM model）的意见。包括对发动机<26.7kN、≥26.7kN、直升机发动机和辅助动力装置（APU）等微粒物质排放分配的调查。继续与建模和数据库小组合作。注意到影响与科学小组关于非挥发性微粒物质（nvPM）影响的意见。	第 3 工作组报告	CAEP/11 期间

航空环境保护委员会第十一次会议第 3 工作组 — 排放技术 — 工作方案				
任务编号	简称	任务说明	交付	交付日期
E.12	更新和审查 Doc 9889 号文件	更新 Doc 9889 号文件以反映业界的最好做法、现代航空器和机场排放来源的新排放数据、影响航空排放的机场运行信息和排放建模方法。	Doc 9889 号文件的更新	CAEP/11
E.13	发动机黑碳排放的特性	测量支持影响与科学小组（ISG）回答有关航空器发动机的 nvPM 和黑碳排放的规模和规模分布、密度、形态和内部结构的问题。	报告	SG2016
E.14	对发动机和航空器进行综合独立专家（IE）技术目标的评估和审查	与第 1 工作组协调，进行独立专家（IE）技术评估和审查。 发动机：提供燃烧技术的评估，包括 NOx 和 nvPM，并在现有航空环境保护委员会标准和航空环境保护委员会 NOx 目标的范围内考虑。 航空器：飞机水平：提供航空器亚音速技术的评估，包括燃油效率和噪音。在现有航空环境保护委员会标准和航空环境保护委员会目标的范围内审议这些问题。	报告	CAEP/11
E.15	更新“航空和全球大气”	对更新信息做出贡献。	指导小组 2016 年会议的计划提交航空环境保护委员会第十一次会议的报告	进行中
E.16	了解标准对全球机队演变的影响	在一项分析中支持建模和数据库小组，以便更好地了解标准是否正在推动所需的行为以及来自其他因素的潜在影响；例如，燃料价格变化、全球经济衰退等。	全面机队演进研究报告、中期分析报告和最后报告	指导小组第 1 次会议 — 全面机队演进研究报告；指导小组第 2 次会议 — 机队数据库；指导小组第 3 次会议 — 初步分析报告；航空环境保护委员会第十一次会议 — 最后报告

航空环境保护委员会第十一次会议第 **3** 工作组 — 排放技术 — 工作方案				
任务编号	简称	任务说明	交付	交付日期
E.17	全球航空环境计划（GAEP）	支持秘书处制订全球航空环境计划（GAEP）。与全球空中航行计划（GANP）类似，这将允许以协调的方式制定计划进行的附件 16 修正案的时间表。建议将拟议进行的噪声和排放技术审查作为制订全球空中航行计划的基础。	报告	CAEP/11
E.18	提交的后续二氧化碳标准	在航空环境保护委员会指导小组 2016 年会议举行之前，完成与 CO_2 标准实施相关的工作；完成 CO_2 标准豁免程序和环境技术手册第 III 卷的案文。在航空环境保护委员会指导小组 2017 年会议举行之前，确定 CO_2 审定合格数据库的结构，提供可能纳入豁免飞机信息的意见。	修订《环境技术手册》第 III 卷； CO_2 审定合格数据库	SG2016； SG2017

航空环境保护委员会第十一次会议航空碳计算器支助小组（**ACCS**）的工作方案				
资源提供方：巴西、可持续航空国际联盟				
任务编号	简称	任务说明	交付	交付日期
C.01	得到航空抵消数据	协助国际民航组织收集用于航空的抵消数据，包括强制性基于市场的措施（MBM）、大型抵消提供者和自愿航空公司计划。	可得的来源清单	指导小组 2016 年会议：初步清单 指导小组 2017 年会议：更新清单 指导小组 2018 年会议：更新清单
C.02	加强旅客碳排放计算器	审查公开可用的数据来源和当前的乘客方法，以确定改进的领域。	建议由秘书处对碳排放计算器作出改进	SG2017
C.03	加强货物碳排放计算器	根据在航空环境保护委员会第十次会议周期为开发货物碳排放计算器方法的经验，确定需要改进的领域。	为加强货物碳排放计算器提出建议	SG2017

航空环境保护委员会第十一次会议预测和经济分析支持小组工作方案				
注：在航空环境保护委员会第十一次会议期间预测和经济分析支持小组和建模和数据库小组会议背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
F.01	审查经济模型	审查航空环境保护委员会第十一次会议分析所需的经济模型。需要审查机队演变建模工具使用的基本经济成本假设。这些假设包括机组、航线、资本和着陆成本，所有这些都需要与新机队预测的开发一起进行重新估算和更新。	报告	SG2018 CAEP/11
F.02	新的航空环境保护委员会的预测与航空数据和分析专家组（ADAP）的长期业务量预测多学科工作组（MDWG-LTF）开发的长期运量预测一致	使用预测与航空数据和分析专家组（ADAP）的长期业务量预测多学科工作组（MDWG-LTF）作出的长期（旅客和货物）运量预测，制定新的航空环境保护委员会的预测，以支持航空环境保护委员会第十一次会议的分析（例如，客机和货机机队预测、对少于 20 个座位的航空器的预测、除役曲线）。	预测和报告	SG2017
F.03	分析经验教训	审查从以前的各次分析中学得的教训，以期改善未来经济评估严格度选项的进程。	报告	SG2016
F.04	微粒物质潜在政策选项的成本效益分析	对航空环境保护委员会第十一次会议审议的微粒物质（PM）潜在政策选项进行成本效益分析。	报告草稿 最后报告	SG2018 CAEP/11
F.05	航空数据和分析专家组的参与	预测和经济分析支持小组/建模和数据库小组确保与国际民航组织航空数据和分析专家组（ADAP）长期运量预测多学科工作组（MDWG-LTF）的协调。	状况报告	依照国际民航组织航空数据和分析专家组（ADAP）长期运量预测多学科工作组（MDWG-LTF）的日程表
F.06	更新“航空和全球大气”	对更新信息做出贡献。	指导小组 2016 年会议的计划 提交航空环境保护委员会第十一次会议的报告	进行中
F.07	评价成本效益分析	评价成本效益评估如何能支持航空环境保护委员会作出的决定。	报告	CAEP/11

航空环境保护委员会第十一次会议建模和数据库小组工作方案				
注：在航空环境保护委员会第十一次会议期间预测和经济分析支持小组和建模和数据库小组会议背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
M.01	相互依存性	与其他工作组报告员就涉及技术、运行问题、目标、环境影响以及噪声和排放数据库管理和更新的相互关联性问题进行协调。	协调工作文件	每次指导小组会议和提交 CAEP/11 的报告
M.02	分析经验教训	审查从以前的各次分析中学得的教训，以期改善未来各次分析的进程。这应包括查明在分析假设、数据库和工具方面的各种差距。	报告	SG2016
M.03	国际民航组织环境趋势预测	对 201x 年基线案例和预测、为虑及技术、运行改进（基础设施和运营人启动的改善）和替代燃料生命周期的各类案例和为噪声、NOx、微粒物质、燃料燃烧和 CO2 进行最新趋势预测。趋势预测会酌情呈现以下信息： 1. 静态空中交通管理（ATM）（第 2 工作组告知）和静态航空器技术情景 2. 为实现国际民航组织全球理想环境目标（即提高 2%年度燃料效率和 2020 年开始实现碳中和增长）取得进展 3. 预期为实现各国在其自愿行动计划设定的目标取得进展 4. 为实现这些目标（即可行性分析结果）所需作出的其他努力 5. 为落实 ASBU 组块 0 和 1 作出的努力 建模和数据库小组的燃料趋势结果将以结构化查询语言（SQL）制作的数据库公布，它能供航空环境保护委员会其他各个小组的专家方便查询。	包括以图形说明趋势和数据库的报告	CAEP/11
M.04	确定评价工具	建模和数据库小组配合影响与科学小组一起确定和评估用于包括噪声、当地空气质量（LAQ）和温室气体（GHG）影响（包括货币化）工具，以用作未来航空环境保护委员会评估的一部分。		CAEP/11

航空环境保护委员会第十一次会议建模和数据库小组工作方案				
注：在航空环境保护委员会第十一次会议期间预测和经济分析支持小组和建模和数据库小组会议背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
M.05	现有模型和数据库管理	维持用于支持航空环境保护委员会专门分析的模型和数据库的版本控制。决定更新模型或数据库是否需要重新评价，包括向国际民航组织秘书处提供关于它们维护的航空环境保护委员会使用的数据库的反馈意见。为支持航空环境保护委员会第十一次会议工作方案，已经确定了以下对空气质量和/或温室气体模型的具体改进办法： 1. 能够在整个飞行状态下对 nvPM 进行建模（与第 3 工作组一起） 2. 低功率设定排放建模的增强和标准化 3. 排放扩散模型 为了支持航空环境保护委员会第十一次会议的工作方案，已经确定了对机队数据库的以下具体改进：1. 更完整的小型航空器（例如公务机、涡轮推进和直升机）；2. 载荷和座位信息协调 — 通常发送到相关的增长和替换数据库；3. 更好地跟踪和监控包含在共同运行数据库（COD）中的公务机尾编号，因为航班编号明显会增加价值。	更新模型和数据库 进度报告	每次指导小组会议和提交 CAEP/11 的报告
M.06	新模型评价	如果采用新的模型支持航空环境保护委员会第十一次会议，继续候选模型的评价过程，该评价过程要求进行敏感性试验、与“黄金标准”数据进行比对和分析抽样问题。根据相关标准酌情完善过程，以便让航空环境保护委员会更好地了解哪些工具足够有力、严谨和有透明度，适合进行哪些分析，以及为什么建模结果可能存在差异。	报告	完成模型评价 提交航空环境保护委员会第十一次会议的报告

航空环境保护委员会第十一次会议建模和数据库小组工作方案				
注：在航空环境保护委员会第十一次会议期间预测和经济分析支持小组和建模和数据库小组会议背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
M.07	Doc 9911 号文件的更新	需要对国际民航组织 Doc 9911 号文件作出更新。应该确定和考虑更新的潜在领域（与第 1 工作组和影响与科学小组协调）包括： 1. 国际民航组织 Doc. 9911 号文件与所有模型协调和实施，包括扩展水平线段的实施、最新的起飞侧滚动方向性以及噪声功率距离（NPD）曲线的速度变化效应； 2. 直升机噪声建模的标准方法； 3. 减少推力偏离的建模； 4. 爆音建模； 5. 商用航天器和无人驾驶飞行器（UAV）的噪声建模；和 6. 改进的噪声传播建模，可能包括地形效应	Doc 9911 号文件的更新	CAEP/11
M.08	新的排放数据库	与第 3 工作组合作，根据共同运行数据库（COD）中观察到的所有航空器类型的 CO、HC、NOx、微粒物质、燃料流量和 CO_2 的起降周期内的运行模式，制定航空器排放指数的综合数据库。该数据库将加强国际民航组织的发动机排放数据库，并将支持航空环境保护委员会的分析和外部模型开发人员。	数据库	SG2017
M.09	支持国际民航组织	支持国际民航组织秘书处散发建模和数据库小组的成果。	根据需要	根据需要
M.10	微粒物质标准	依照航空环境保护委员会和指导小组的指示，对可能的微粒物质排放标准的环境效益和相互关联性进行抽样问题和政策选项分析。与航空环境保护委员会的工作小组合作。	报告	CAEP/11
M.11	航空系统组块升级分析	估算实施航空系统组块升级组块 1（ASBU Block 1）的好处，以便在更新后的趋势评估图表上显示[重点是燃料燃烧和和 CO_2，并在可行的情况下根据分析考虑噪声和当地空气质量（LAQ）]。注：第 2 工作组在这项任务中担任领导作用，这项任务的成功取决于各国是否提供充分和及时的投入。	报告	SG2018

航空环境保护委员会第十一次会议建模和数据库小组工作方案				
注：在航空环境保护委员会第十一次会议期间预测和经济分析支持小组和建模和数据库小组会议背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
M.12	共同运行数据库的改进	开发和维护 201x 年共同运行数据库（COD）（最好包括全部 52 个星期的运行）和管理取得和处理增加的国家数据。两种形式的共同运行数据库将得到维护： 1. 国际民航组织秘书处以及向共同运行数据库（COD）提供数据的国家可以使用的版本，其中已经删除或取消了敏感数据；和 2. 仅限已签署适当协议的组织的版本。 这项任务还应包括共同运行数据库（COD）与 WISDOM 进行比较，例如，使用 2012 年运量，并确定应用于生成数据库的流程中作出改进的部分。可以开展进一步工作，以完善和协调基准年运营的航空器的描述（机身、发动机、机龄、座位/货运能力)，这有助于提高未来机队和运营预测的真实性。	数据库	SG2017
M.13	达到国际民航组织气候变化目标的可行性	（如大会第 39 届会议提出要求）根据任务 M.03 得到的最新趋势，分析达到国际民航组织的国际航空和气候变化目标的可行性。	报告草稿 最后报告	SG2017 CAEP/11
M.14	航空数据和分析专家组的参与	预测和经济分析支持小组/建模和数据库小组确保与国际民航组织航空数据和分析专家组（ADAP）长期运量预测多学科工作组（MDWG-LTF）的协调。	根据需要	根据需要
M.15	机场数据库	与国际民航组织秘书处和相关专家组合作，增加纳入国际民航组织 Doc 7910 号文件（位置标识符）中的数据，以增加支持航空环境保护委员会分析所需的信息。	机场数据库	在开始需要数据进行分析之前
M.16	支持全球基于市场的措施（GMBM）	根据要求，为国际航空制定全球基于市场的措施提供技术支持。	根据需要	根据需要

航空环境保护委员会第十一次会议建模和数据库小组工作方案				
注：在航空环境保护委员会第十一次会议期间预测和经济分析支持小组和建模和数据库小组会议背对背举行				
任务编号	任务标题	任务说明	交付	交付日期
M.17	评估 CO_2 目标	在航空环境保护委员会第十一次会议周期开展范围界定工作，以评估 CO_2 标准对国际民航组织全球理想目标的贡献。		CAEP/11
M.18	了解标准对全球机队演变的影响	进行一项分析，以便更好地了解各项标准是否正在推动所需的行为以及来自其他因素的潜在影响；例如，燃料价格变化、全球经济衰退等。	全面机队演进研究报告、中期分析报告和最后报告	指导小组第 1 次会议 — 全面机队演进研究报告；指导小组第 2 次会议 — 机队数据库；指导小组第 3 次会议 — 初步分析报告；航空环境保护委员会第十一次会议 — 最后报告
M.19	更新“航空和全球大气”	对更新信息做出贡献。	指导小组 2016 年会议的计划 提交航空环境保护委员会第十一次会议的报告	进行中
M.20	达到国际民航组织气候变化目标的可行性	影响与科学小组、代用燃料工作组和建模和数据库小组负责将国际航空排放纳入 1,000 Gt 预算（1.5/2°C 情景）的工作范围。	工作范围	SG2016

航空环境保护委员会第十一次会议影响和科学小组工作方案				
任务编号	任务标题	任务说明	交付	交付日期
I.01.01	协调(内部小组)	协调活动	协调	进行中
I.01.02	协调（国际民航组织内部）	与其他工作组、任务工作队、调研联络人等、报告员和国际民航组织秘书处进行活动协调。	协调	进行中
I.01.03	影响和科学小组成员组成	根据影响和科学小组的职权范围，影响和科学小组联合报告员将与国际民航组织秘书处一起确定合适的科学专家。这将涉及要求航空环境保护委员会成员和观察员提名具有适当资格并在与航空环境保护委员会第十一次会议工作方案相关的主题领域开展研究的专家。	组成成员	SG2016

航空环境保护委员会第十一次会议影响和科学小组工作方案				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
I.02	航空噪声	影响和科学小组将举办“噪声影响讲习班”并更新航空环境保护委员会第十一次会议当前正在制定的有关航空噪声的白皮书（与第 1 工作组和第 2 工作组一起）。	提交航空环境保护委员会的工作文件	提交指导小组 2018 年会议的草稿 提交航空环境保护委员会第十一次会议的最后报告
I.03	适应	协助第 2 工作组评估当前对气候变化对航空风险的理解，并制定关于适应最佳做法的指导材料。	报告和指导材料	提交指导小组 2018 年会议的草稿 提交航空环境保护委员会第十一次会议的最后报告
I.04	发动机黑碳排放的特性	［**第 3 工作组领导，参考任务 E.13**］作为一项与气候相关的活动，影响和科学小组将支持第 3 工作组提供 nvPM 的规模和规模分布、密度、形态和内部结构以及航空器发动机的黑碳排放的估算。协助第 3 工作组提供与估算有关的科学不确定性的详情。酌情利用外部专业知识支持任何独立专家的审查（例如 NOx/PM）。	报告	SG2017
I.05	更新“航空和全球大气”	对更新信息做出贡献。	指导小组 2016 年会议的计划 提交航空环境保护委员会第十一次会议的报告	进行中
I.06	更新 Doc 9889 号文件	为更新国际民航组织 Doc 9889 号文件，向第 3 工作组提供特定支持和咨询意见，以取代目前已经过时的排放技术信息。	报告	进行中
I.07	成本效益分析（CBA）范围	建模和数据库小组配合影响与科学小组一起确定和评估用于包括噪声、当地空气质量（LAQ）和温室气体（GHG）影响的工具（包括用作未来航空环境保护委员会评估的货币化工具）。	报告	CAEP/11
I.08	达到国际民航组织气候变化目标的可行性	影响与科学小组、代用燃料工作组和建模和数据库小组负责将国际航空排放纳入 1,000 Gt 预算（1.5/2°C 情景）的工作范围。	工作范围	SG2016

航空环境保护委员会第十一次会议代用燃料任务组（**AFTF**）工作方案				
注：在航空环境保护委员会第十一次会议期间代用燃料任务组会议和全球基于市场措施技术工作队会议将背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
S.01	计算用于全球基于市场措施(GMBM)的监测、审查和核查（MRV）的替代燃料土地使用变化排放	在航空环境保护委员会第十一次会议期间，代用燃料任务组（AFTF）的后续工作将对所有世界区域的替代燃料的诱发土地利用变化排放进行计算，以便用于全球基于市场措施（GMBM）的监测、审查和核查（MRV）的替代燃料排放报告。	默认值清单	CAEP/11
S.02	计算用于全球基于市场措施(GMBM)的监测、审查和核查（MRV）的替代喷射燃料寿命周期的排放	在航空环境保护委员会第十一次会议期间，代用燃料任务组（AFTF）的后续工作将计算运营人用来报告使用替代燃料排放的“核心”寿命周期分析默认值。“核心”生命周期排放是指从原料生产到航空器油箱的排放，排除土地使用变化排放。	默认值清单	CAEP/11
S.03	更新“航空和全球大气”	对更新信息做出贡献。	不断给予支持	进行中
S.04	关于部署航空可持续替代燃料的潜在政策和协调方法的指导	概述鼓励部署可持续替代燃料的现有政策工具，以及具有相似特征和性质的不同类型或类别的阻碍或抑制机制。作为第二步，提供给指导小组的工作应确定已证明可行、有效和实用的“潜在政策”。这种识别应通过航空环境保护委员会根据最佳做法、经验教训以及实施这些政策工具所证实的积极成果进行评估，这些政策工具可能包括为其他部门制定的适用于航空运输的政策。根据上述评估和已实施政策的分析，报告共同要素和一般性建议，以促进成员国或区域实施这些政策和激励机制，并在认为有益时，采用有效的政策方法。	步骤 1: SG 2016 步骤 2: SG 2017 步骤 3: SG 2018 最后报告： CAEP/11	CAEP/11

航空环境保护委员会第十一次会议代用燃料任务组（**AFTF**）工作方案				
注：在航空环境保护委员会第十一次会议期间代用燃料任务组会议和全球基于市场措施技术工作队会议将背对背举行				
任务编号	任务标题	任务说明	交付	交付日期
S.05	可持续性标准	目标是在承认全球基于市场措施（GMBM）的背景下，就替代燃料的可持续性标准提出建议。这项工作首先需要制定环境标准，之后在后一阶段制定社会和经济标准。计划尽可能建立现有可持续性标准和框架，并对其进行分析和比较，以便为航空环境保护委员会制定建议。	报告: SG 2016 报告: SG 2017 报告: SG 2018 最后报告: CAEP/11	CAEP/11
S.06	圆桌会议	秘书处组织了一系列圆桌讨论或研讨会，将相关专家聚集在一起，进一步讨论共同报告员可能认为需要在主要工作流之外开展的具体科学/技术讨论。	按照要求	按照要求
S.07	达到国际民航组织气候变化目标的可行性	影响与科学小组、代用燃料工作组和建模和数据库小组负责将国际航空排放纳入 1,000 Gt 预算（1.5/2°C 情景）的工作范围。	工作范围	SG2016

航空环境保护委员会第十一次会议全球基于市场的措施技术任务组（**GMTF**）的工作方案				
注：在航空环境保护委员会第十一次会议期间代用燃料任务组会议和全球基于市场措施技术工作队会议将背对背举行				
任务编号	任务标题	任务说明	交付	交付日期
G.01	监测、审查和核查：负责实体	就如何应用负责实体的申报流程、如何汇集负责实体以及如何将负责实体归属各国的办法制定建议。	对负责实体申报流程和确定/分配办法提出其他建议	SG2016

航空环境保护委员会第十一次会议全球基于市场的措施技术任务组（GMTF）的工作方案				
注：在航空环境保护委员会第十一次会议期间代用燃料任务组会议和全球基于市场措施技术工作队会议将背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
G.02	监测、审查和核查：监测计划	进一步评估实施排放监测计划的要素和程序，并编制初步指导。	就执行监测计划的程序提出更多建议和提出关于程序和监测计划的初步指导意见	SG2016
G.03	监测、审查和核查：监测燃料的使用	建立监测方法的不确定性阈值。分析应用第 2 类监测资格的阈值、创建实施不同监测方法的步骤并分析轮挡飞行小时燃料方法。	提出有关资格阈值和实施程序的建议	SG2016
G.04	监测、审查和核查：报告	确定哪些实体应开发、维护和更新在线工具、通用报告语言和报告模板，并提出建议。修订和更新有待报告的最小数据集。	提出排放报告的建议	SG2016
G.05	监测、审查和核查：透明度和保密性	考虑到各国需要就监测、审查和核查（MRV）相关事项交换信息，继续就向不同利益攸关方提供何种数据的问题开展工作。	关于数据透明度的建议	SG2016
G.06	监测、审查和核查：核查	酌情根据相关的 ISO 标准，继续为该途径的每个步骤制定具体建议和指导。	关于核实的建议	SG2016
G.07	监测、审查和核查：简化履约程序	为小型排放器制定简化的监测、审查和核查程序。进一步分析资格阈值和简化的排放估算方法。	提出简化程序的建议	SG2016
G.08	监测、审查和核查：替代燃料	拟定关于监测、报告和核实替代燃料排放的技术建议。	关于监测、审查和核查替代燃料程序的建议	SG2016
G.09	监测、审查和核查：行政管理	支持继续对其他公开问题进行监测、审查和核查，包括与行政管理相关的问题，例如履约周期、作用和职责。	关于监测、审查和核查其他公开问题的建议	进行中

航空环境保护委员会第十一次会议全球基于市场的措施技术任务组（GMTF）的工作方案				
注：在航空环境保护委员会第十一次会议期间代用燃料任务组会议和全球基于市场措施技术工作队会议将背对背举行				
任务编号	**任务标题**	**任务说明**	**交付**	**交付日期**
G.10	监测、审查和核查：实施	编制监测、审查和核查实施指南。	指导文件	SG2016
G.11	排放单位标准：资格标准	根据巴黎 COP-21 的成果，审查修订各项建议的必要性。	提出关于资格标准的建议	供 GMTF/8 审查和 SG2016 核准
G.12	排放单位标准：排放单位的供应、需求和价格	根据巴黎 COP-21 的成果和市场的最新发展，审查修订评估的必要性。分析国际民航组织定期监测可能提供价格保障信息的排放单位价格的可行性（这些措施应包括在全球基于市场的措施的设计中）。	评估排放单位的供应、需求和价格	供 GMTF/8 审查和 SG2016 核准
G.13	排放单位标准：及早采取行动的工作	制定建议以支持及早作出决定和制定方案以及符合资格标准的潜在项目类型。分析并建议任何关于排放单位方案和潜在项目类型资格的早期决定的适用期限。	摘要报告以及包含符合资格标准的方案和潜在项目类型清单及其适用期限。	SG2016
G.14	登记册：设计要素	继续进行关于登记册的工作。联系登记册开发人员和专家，以了解和制定全球基于市场措施的登记册的设计元素和时间安排。	切实落实全球基于市场措施登记册系统的计划	SG2016
G.15	登记册：登记册的开发	评估开发全球基于市场措施登记册系统的成本和技术规范。	就全球基于市场措施登记册系统提出的建议	CAEP/11
G.16	支持实施基于市场的措施	支持理事会提出的落实全球基于市场措施的要求。	信息文件	按照要求
G.17	支持技术分析	支持理事会提出的对义务分配给予更多技术分析的要求。在报告中总结航空环境保护委员会第十次会议期间进行的所有分析工作。	信息文件	按照要求
G.18	全球基于市场措施工作队（GMTF）词汇	进一步改善全球基于市场措施工作队词汇。	词汇	按照要求

9. 理事会主席的开幕致词

9.1 各位女士、各位先生，早晨好。我荣幸地欢迎你参加今天举行的国际民航组织航空环境保护委员会第十一次会议。

9.2 近几十年来，环境保护的全球重要性大幅增加，随之而来的是国际民航组织在尽量减少全球民用航空对环境的影响方面的重要性和相关性。

9.3 改善航空的环境绩效是国际民航组织和所有相关利害攸关方非常重视的一项挑战。在履行其职责时，国际民航组织有三个主要环境目标，旨在限制或减少：

1) 受严重航空器噪声影响的人数；

2) 航空排放对当地空气质量的影响；和

3) 航空温室气体排放对全球气候的影响。

9.4 我们一起面对的最新挑战涉及监测和减缓气候变化对航空活动的影响，我感到鼓舞的是你们已经开始进行一些与极端气候事件风险识别和适应有关的重要工作。

9.5 在这次航空环境保护委员会周期，我们面对的主要挑战是减少航空温室气体排放对全球气候造成的影响。

9.6 如你所知，国际民航组织已经制定一系列措施，其中包括侧重于新机身和发动机技术的活动和解决方案、更加简化的运营模式、可持续的航空燃料以及称为“CORSIA”的国际航空碳抵消和减排计划。

9.7 每类措施都有助于我们减少航空运输系统的 CO2 排放和实现国际民航组织的全球理想目标的总体努力。我欣慰地看到每项措施都取得了进展，其中我特别希望提到委员会的工作，由于这些工作，我们在 2018 年 6 月通过了关于国际航空碳抵消和减排计划的附件 16 第 IV 卷。

9.8 在祝贺这一重大成就的同时，我也要感谢你们在困难和艰巨的时间压力下做出的努力。我希望本次会议将在国际航空碳抵消和减排计划的关键实施要素方面取得进一步进展。

9.9 航空环境保护委员会第十一次会议的另一个重要议题涉及新的 nvPM 排放标准的选项，它将补充附件 16 第 II 卷的适用范围。这扩大了航空环境保护委员会第十次会议开展的工作，自那时以来，我们一直都在寻求进一步制订标准的工作，并分析这项标准在广泛的适用性和严格性选项方面取得的成本效益。这项技术工作要求航空环境保护委员会克服在建模和测量方面的重大挑战。

9.10 关于国际航空碳抵消和减排计划，我确信我们大家对其实施的第一阶段取得的进展以及国际民航组织 ACT-CORSIA 能力建设方案非常成功的结果感到鼓舞。

9.11 理事会和我期待看到你们对国际航空碳抵消和减排计划排放单位、理事会技术咨询机构（TAB）以及可持续航空燃料进行讨论的结果。航空环境保护委员会第十一次会议还将审议有关国际航空碳抵消和减排计划的合格燃料的可持续性标准及其可持续性审定合格机制的重要问题。

9.12 关于可持续航空燃料，重要的是应该指出，它们是国际民航组织减少国际航空 CO2 排放的一揽子措施的关键要素。最近这个领域的一个重大步骤是 2017 年 10 月在第二次国际民航组织航空与代用燃料会议通过的国际民航组织 2050 年愿景，以及我们继续期望它们对国际航空环境目标作出非常有意义的贡献。

9.13 我现在想花一点时间祝贺你们通过附件 16 第 I 卷 50 周年纪念。

9.14 过去 50 年已经取得重大进展，因为今日的航空器已比 20 世纪 60 年代的航空器安静 75％，尽管航空器噪声仍然是国际民航组织的一个重要课题。

9.15 在这个航空环境保护委员会周期期间，你们还将继续推进超音速飞机噪声和排放标准方面的工作。当然，随着未来几年新型超音速飞机的开发和开始投入使用，这项工作将变得更加重要。

9.16 我们期望航空环境保护委员会第十一次会议将在这个领域保持势头，努力解决当前国际民航组织在排放和噪声标准方面存在的若干差距，并为航空环境保护委员会第十二次会议周期取得进一步进展建立坚实的基础。

9.17 不过，我们应该注意到，航空环境保护委员会不仅需要关注超音速飞机的问题，还需要研究为应对环境挑战而出现的其他新兴技术和创新，例如混合动力和电动航空器。了解它们产生的环境影响和效益，并确定其审定合格的基础，这将是航空环境保护委员会下一个周期的重要挑战。

9.18 我理解在本次会议期间将讨论有关更新温室气体排放、噪声和当地空气质量的新趋势评估，并且理事会也期待这些评估结果。这些趋势是大会相关讨论的重要支柱，提供了将国际民航组织的环境工作置于当前和未来挑战的适当背景下所需的信息。我要感谢那些慷慨地为航空环境保护委员会的工作提供重要工具和数据库的国家，以及最终使国际民航组织成员国能够做出明智决定并采取有意义的行动来解决它们的航空活动产生的环境影响。务使国际民航组织的趋势和国际民航组织的工具维持最新、及时和高质量的信息和数据，这对实现国际民航组织在不让任何国家掉队倡议下的目标非常宝贵。

9.19 各位女士，各位先生，在国际民航组织的航空环境保护委员会存在的整个期间，它向理事会提供了技术建议，这些建议对促进政治决策至关重要。航空环境保护委员会作为世界领先的一个专家论坛，不断交付成果，国际民航组织及其成员国和航空利害攸关方也继续期待你们在审议技术可行性、环境效益、经济合理性以及各种措施之间的相互关系和权衡折中时，只提供最好的技术成果。

9.20　航空环境保护委员会为支持全球航空环境计划（GAEP）的概念和发展已开展了重要的分析工作，我赞赏来自航空、经济、机场和业界各方面专家提出的建议。全球航空环境计划（GAEP）将成为全球航空环境框架中新的关键部分。

9.21　在结束发言之前，我想借此机会对理事会去年 11 月为修订航空环境保护委员会的指令和职权范围的某些方面作出的决定说几句话。我想重申，作出这些改变的目的是为了帮助提高航空环境保护委员会在国际民航组织所有成员国中的可见度和重要性，并鼓励我们 192 个会员国更加积极地参与这个委员会。此外，这些修订旨在提高各个级别包括与理事会的透明度和沟通，以便推动各项相关决定。因此，你们现在就需要采取行动，以确保有效执行理事会的决定。

9.22　在航空环境保护委员会成立以来的 35 年中，你们的工作范围及其涵盖的技术领域都已扩大。然而，尽管面临着巨大挑战，航空环境保护委员会仍然是国际合作的一个重要典范，巩固了按时交付高质量工作的卓越声誉。

9.23　你们未来两周的工作将在今后许多年内产生持久的影响，在此，我再次感谢你们作出的奉献、支持和技术的卓越。祝本次会议高效合作和富有成效，也期待看到会议结果。谢谢你们！

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概况

1. 航空环境保护委员会的组成成员和活动的出席情况

1.1 委员会目前由来自国家和国际组织的 25 名成员和 18 名观察员组成。自 2018 年 6 月举行上次指导小组会议以来，航空环境保护委员会的四个成员国代表有了改变，即巴西、埃及、俄罗斯联邦和联合王国。此外，沙特阿拉伯得到航空环境保护委员会成员的资格。两个观察员代表有了变化，即阿拉伯民用航空组织（ACAO[1]）和希腊。马来西亚和联合国环境规划署（UNEP）也获得航空环境保护委员会观察员地位。

2. 联合国其他机构的近况

2.1 航空环境保护委员会秘书更新了有关与联合国（UN）机构和其他国际组织合作的会议以及与国际民航组织环境工作相关的最新进展。

2.2 联合国气候变化框架公约（UNFCCC）

2.2.1 特别是，国际民航组织密切监测和参加联合国气候变化框架公约（UNFCCC）会议的必要性得到国际民航组织上届大会的认可并得到国际民航组织理事会的肯定，会议收到有关 2018 年 12 月在波兰卡托维兹举行的联合国气候变化框架公约第二十四次缔约方会议（COP24）的信息。会议讨论了一些有关《巴黎协定》执行情况的问题，其中国际民航组织最感兴趣的是制定有关合作办法和建立《巴黎协定》第 6 条所述的新市场机制的指导意见。

2.2.2 国际民航组织参加了 COP24 有关《气候公约》的相关讨论，以便了解国际民航组织进行的国际航空碳抵消和减排计划（CORSIA）所涉的问题，特别是重复计算排放单位的问题，展示国际民航组织最近在国际航空和气候变化方面取得的进展，以期这些成就获得全面认可，确保国际航空不会不成比例地被视为向其他部门调动气候融资的潜在收入来源。由于 COP24 没有设定《巴黎规则手册》，因此一些可能对国际航空碳抵消和减排计划（CORSIA）产生影响的实施问题尚不明确。

2.2.3 国际民航组织向会议指出，它关切地注意到，在 COP24 多场会外活动提出的许多研究报告都误导了各方对国际航空排放的影响和未来份额的了解。因此，国际民航组织以及涉及这项进程的各个方面都应比以往更需要发出明确的信息，并在必要时利用航空环境保护委员会所做的出色工作，提供以技术为基础并在政治上无偏见的坚实方法。国际民航组织秘书处指出，需要在航空环境保护委员会第十一次会议审议议程项目 1、10 和 12 以及进行有关外联问题的讨论时，进一步审议这一问题。

[1] 2018 年，阿拉伯民用航空委员会（ACAC）改名为阿拉伯民用航空组织（ACAO）。

2.2.4 着重指出了国际民航组织秘书处和联合国气候变化框架公约秘书处之间的良好合作。气候公约观察员发了言，向航空环境保护委员会第十一次会议介绍了 COP24 的结果和对 COP25 的展望。该发言与航空环境保护委员会第十一次会议的文件都在 CAEP/11 加密网站提供。

2.3 世界卫生组织（WHO）

2.3.1 国际民航组织一直努力就制定"世界卫生组织欧洲区域环境噪声指导意见"的工作与世卫组织 — 欧洲进行协调。国际民航组织 2016 年以来一直要求参与这项研究。2018 年 2 月世卫组织与包括国际民航组织在内各个利害攸关方分享了一份指导意见草案，供大家提出意见，因为这份文件草案载有与航空器噪声和运输政策有关的建议；国际民航组织提供了一份广泛的意见清单，供世卫组织审议。提出的意见对噪音与健康联系起来的这个错误科学证据作了解释，而这项错误的证据曾被用来制定报告中的建议。此外，虽然这些建议对航空部门产生重大影响，但至今没有进行过成本效益分析来支持这些建议。

2.3.2 国际民航组织正式要求世卫组织在公布这些指导意见之前进行适当的协调和审议提出的意见。尽管如此，世卫组织于 2018 年 10 月公布了最后的指导意见，并且没有对国际民航组织提出的意见作出具体反馈。世卫组织总干事最近在回复国际民航组织秘书长表示关切的信中表示打算加强与国际民航组织在实施这项指导意见方面的合作。

2.4 政府间气候变化专门委员会（IPCC）

2.4.1 政府间气候变化专门委员会 2018 年 10 月 6 日在大韩民国仁川举行的第 48 届会议批准了《全球变暖 1.5°C 的特别报告》。决策者摘要（SPM）介绍了特别报告的主要结论，这项摘要可通过气候变化专门委员会的网站查阅：http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf.

2.5 联合国环境管理小组（EMG）

2.5.1 国际民航组织出席了 2018 年 9 月 24 日在纽约举行的联合国环境管理小组（EMG）第 24 届高级官员会议（SOM）。国际民航组织强调了它在航空环境保护领域采取的举措以及与气候中立联合国倡议有关的努力，例如使用国际民航组织碳计算器。航空环境保护委员会秘书向在 2019 年 9 月联合国大会之前举行的 2019 年联合国气候峰会作了通报。

2.6 人人享有的可持续出行（Sum4All）

2.6.1 2017 年 1 月，50 多个多边开发银行、联合国机构、双边捐助组织、非政府组织、民间社会和学术机构建立了 SuM4All 全球伙伴关系。这个伙伴关系旨在通过制定一份题为"实现可持续出行的全球行动路线图"（GRA）的文件及其六份配套文件，促使各国和私营部门参与实现可持续出行的可能行动的讨论。这些文件确定了政策目标并指出了推动普及、高效、安全和环境的各项措施，这些措施将指导各国将运输部门迈向可持续出行。

2.6.2 国际民航组织根据其成员国的发展情况为这些文件提供了投入。应该指出的是，虽然通过根据 SuM4All 制定的这些文件，可以在不同的运输模式（例如汽车、铁路、航运、航空）之间探索各种环境行动的积极协同作用，但国际民航组织一直强调准确反映国际民航组织各项具体政策、协议、标准和措施的重要性，特别是国际民航组织成员国在 SuM4All 公布的任何文件中已经商定的国际民航组织理想目标的重要性，这是国际民航组织与本报告相关的最重要条件。

讨论和结论

2.6.3 会议感谢国际民航组织秘书处在与其他联合国机构合作并向航空环境保护委员会通报正在进行的相关讨论方面所做的出色工作。

2.6.4 会议对国际民航组织进行的协调表示赞赏，并注意到对世卫组织指导意见提出的信息、对国际航空可能产生的影响以及在没有与国际民航组织及其成员国进行适当协调的情况下避免推行此类政策建议的必要性。会议同意在议程项目 4 和 12 下讨论世卫组织的指导意见。

2.6.5 会议鼓励航空环境保护委员会成员和观察员采取行动，宣传国际民航组织及其成员国在噪声、当地空气质量和气候变化等方面开展的所有工作。

3. 国际民航组织的发展情况

3.1 各国的行动计划

3.1.1 国际民航组织继续与会员国直接合作，以便支持制定各国的行动计划。国家行动计划倡议是本组织全面能力建设和援助战略的关键要素，以支持成员国实施从国际民航组织一揽子措施中选择的二氧化碳减排措施。通过 2018 年 11 月 2 日，占国际航空收入吨公里（RTK）[2] 91.8%的 110 个会员国已自愿向国际民航组织提交行动计划。有人指出，最近又有一个国家向国际民航组织提交了行动计划，迄今共有 111 份行动计划已提交。这些可喜的结果表明国际民航组织成员国对这项倡议的高度兴趣和参与，以及国际民航组织的援助和能力建设活动的影响。

3.2 国际民航组织国家行动计划的“伙伴”方案

3.2.1 关于国际民航组织国家行动计划的伙伴方案，大会第 A39-2 号决议进一步鼓励已经提交行动计划的国家分享其行动计划所载的信息，并与其他成员国建立伙伴关系，以便支持那些尚未编制行动计划的国家。迄今为止，已根据国际民航组织国家行动计划方案建立了六个伙伴关系 [3]。

2. 根据 2015 年的收入吨公里（RTK）。
3. https://www.icao.int/environmental-protection/Pages/ActionPlan-Questions.aspx。

3.3 更新国际民航组织 Doc 9988 号文件

3.3.1 国际民航组织还参与了 Doc 9988 号文件"关于制定国家二氧化碳减排活动行动计划的指导"的更新。这份文件在 2013 年首次发布，并于 2016 年更新，它为国际民航组织成员国逐步说明在制定国际航空二氧化碳减排活动行动计划时应该采取的行动。此次作出的更新旨在反映国际民航组织大会第 39 届会议以来在实施国际民航组织一揽子措施的环境保护领域作出的关键决定。归根结底，Doc 9988 号文件的更新还将整合国际民航组织从实施能力建设和援助项目汲取的经验教训。

3.3.2 向会议提交了展示对各国已提交行动计划的初步评估的综合报告，预期在更新后将提交第 40 届会议。

3.4 国际民航组织 — 欧盟能力建设和援助项目

3.4.1 在国际民航组织 — 欧盟能力建设和援助项目的框架内，国际民航组织继续支持 14 个选定国家实施其行动计划中的缓解措施。作为减少国际航空 CO_2 排放的缓解措施的一部分，在喀麦隆和肯尼亚落实了两个采用太阳能光电系统和登机门电气化设备的"登机口太阳能"试点项目。2018 年 12 月 12 日在肯尼亚蒙巴萨和 2019 年 1 月 10 日在喀麦隆杜阿拉举行了太阳能项目的启用典礼。

3.5 国际民航组织 — 开发计划署/全球环境基金的能力建设项目

3.5.1 国际民航组织 — 联合国开发计划署（UNDP）的能力建设项目在全球环境基金（GEF）提供资金的情况下，已达到交付所有成果的最后阶段，包括在牙买加的两个国际机场落实"登机口太阳能"试点项目和出版四份独特的出版物，协助国际民航组织成员国制定环境政策和决策，以及设立一个在线平台实现知识共享。根据亚洲和太平洋地区小岛屿发展中国家表达的强烈兴趣，目前正在探索各种备选方案，以便与开发计划署和全球环境基金及其他潜在资金来源方进一步合作，扩大小岛屿发展中国家和其他非洲国家的"登机口太阳能"项目，将其作为这些国家国际航空 CO_2 减排活动的关键组成部分。

讨论和结论

3.5.2 会议注意到与国家行动计划倡议有关的最新进展以及在国家一级制定与所有货款利害攸关方有关的国际航空 CO_2 排放长期战略的效益。会议还注意到，完全量化的国家行动计划对评估国际航空部门在实现国际民航组织全球理想目标方面取得集体进展至关重要。欧洲民用航空会议（ECAC）国家表示失望的是，国际民航组织无视其在行动计划中提供的强有力的数据，理由是它是欧洲民用航空会议 44 个国家汇总的数字。它们强调，这导致严重低估欧洲对实现国际民航组织目标作出的贡献，总体而言，这低估了实现国际民航组织目标的水平。它们要求秘书处纠正这一点。

3.5.3 在认识到欧洲地区在量化该地区排放量方面所做的良好工作和努力的同时，航空环境保护委员会秘书指出，大会第 A39-2 号决议和所有相关指导意见都侧重于国家一级的方法，这种方法在能力建设和作出准备方面已主要给发展中国家带来了实质性的好处。此外，只有将一揽子措施的各个组成要素取得的效益分开，国际民航组织才能对大会第 A39-3 号决议第 6 和第 7 段的要求作出回应。此外，还有人指出，通过发布个别行动计划，在执行环境措施方面具有丰富经验的国家也应提供可供其他国家借镜的最佳做法的最新实例。

3.5.4 会议认识到个别行动计划的价值，鼓励国际民航组织考虑如何识别和整合地区一级汇总的数据，并将其纳入国际民航组织对行动计划的总体评估。会议同意应尽快公布国际民航组织 Doc 9988 号文件的最新版本（第三版），并强调说明编制中的数据能如何整合其中，以及能如何纳入这份文件的未来修订版本。

3.5.5 会议欢迎国际民航组织在实施国家行动计划倡议方面作出的努力，该倡议导致至今已有 111 个国家提交计划以及制定和更新指导意见和工具，指出这些努力得到了国际民航组织能力建设和援助项目以及国家行动计划伙伴方案的补充。虽然国际民航组织 Doc 9988 号文件的更新仅与国际民航组织成员国进行，但一位观察员重申，其组织愿意为国际民航组织 Doc 9988 号文件的更新作出贡献，并强调业界参与制定和实施国家行动计划的重要性。

3.5.6 会议鼓励国际民航组织及其成员国采取进一步行动，增加提交完全量化的行动计划的国家数量。

3.5.7 **建议**

3.5.7.1 鉴于前述讨论，会议拟定了以下建议：

建议 1/1 — 国际民航组织 Doc 9988 号文件 —《关于制定国家二氧化碳减排活动行动计划的指导》

尽快发布国际民航组织 Doc 9988 号文件最新版本（第三版）。

建议 1/2 — 提交国家行动计划

请各国根据最新的国际民航组织 Doc 9988 号文件（第三版）所载的指导意见，向国际民航组织提交全面量化的国际航空二氧化碳减排国家行动计划，并且此后每三年更新一次国家行动计划。

建议 1/3 — 国家行动计划结对子伙伴关系

鼓励在制定国家行动计划方面具有专门知识的国家通过建立结对子伙伴关系对其他国家提供支持。

4. 国际航空碳抵消和减排计划（CORSIA）的发展情况

4.1 通过附件 16 第 IV 卷

4.1.1 国际民航组织理事会在 2018 年 6 月举行的第 214 届会议上通过了附件 16 —《环境保护》第 IV 卷—《国际航空碳抵消和减排计划（CORSIA）》的第一版，该计划于 2018 年 10 月 22 日生效，随后于 2019 年 1 月 1 日起适用。此外，国际民航组织《环境技术手册（ETM）》第 IV 卷—《显示符合国际航空碳抵消和减排计划（CORSIA）的程序》（Doc 9501 号文件）第一版于 2018 年 7 月出版。

4.2 国际航空碳抵消和减排计划实施要素

4.2.1 在附件 16 第 IV 卷的第一版获得通过之后，理事会批准了 2018 年版的国际民航组织国际航空碳抵消和减排计划（CORSIA）二氧化碳排放核算和报告工具（CERT）及其技术方法。2018 年 8 月初，这些方法可在国际民航组织国际航空碳抵消和减排计划（CORSIA）公共网站上查阅，并且此刻航空环境保护委员会正在制定国际民航组织国际航空碳抵消和减排计划（CORSIA）二氧化碳排放核算和报告工具（CERT）的 2019 年版本，它将提供必要的输出数据，以便将其纳入 2019 年的飞机运营人年度排放报告。会议还获悉理事会批准国际航空碳抵消和减排计划（CORSIA）中央登记处（CCR）的功能要求，并在 2020 年初中央登记处（CCR）开始运作之前，由国际民航组织采购程序选择的一个供应商在 2019 年底之前对其进行开发和测试。

4.2.2 关于在国际航空碳抵消和减排计划（CORSIA）合格排放单位方面取得的进展，2018 年 11 月理事会第 215 届会议注意到航空环境保护委员会根据排放单位标准（EUC）对排放单位方案进行非正式测试的结果，并同意在技术咨询机构（TAB）成立时，航空环境保护委员会方案检测组（PTG）的工作成果应作为技术咨询机构开展工作的起点。会议还获悉理事会根据航空环境保护委员会的建议批准了技术咨询机构（TAB）的基本职权范围（ToR）以及理事会国际航空碳抵消和减排计划（CORSIA）咨询小组（AGC）提出的修正案。

4.2.3 根据理事会的要求，国际民航组织发出了国家级信件 ENV 6/1-18/110 号，邀请各国提名专家加入技术咨询小组（TAB）并向各国通报与排放单位标准（EUC）有关的发展和邀请它们对其提出意见。对技术咨询小组（TAB）的提名人选和对排放单位标准（EUC）提出的意见将在理事会第 216 届会议（2019 年 3 月）期间供其审议。会议获悉理事会要求航空环境保护委员会在理事会第 216 届会议期间提供补充技术咨询小组基

本职权范围的附加议事规则，供其审议和核准。理事会还要求航空环境保护委员会作为其工作方案的一部分，审议如何监测和审查理事会已确定符合国际航空碳抵消和减排计划（CORSIA）资格的排放单位方案的持续资格，并在适当时候向理事会提出报告。

4.3 国际航空碳抵消和减排计划（CORSIA）的外联活动和能力建设

4.3.1 在理事会第 214 届会议期间，理事会批准了国际民航组织的国际航空碳抵消和减排计划援助、能力建设和培训方案（ACT-CORSIA），强调了在国际民航组织下协调一致的方法以协调和汇集所有相关行动并促进能力建设一致性的重要性。有人提醒会议，理事会还要求各国之间的任何双边或多边伙伴关系应与国际民航组织协调，以便在国际航空碳抵消和减排计划援助、能力建设和培训方案（ACT-CORSIA）下对这种协调努力的全球进展加以监测和确认。会议获悉在国际航空碳抵消和减排计划援助、能力建设和培训方案（ACT-CORSIA）框架内建立的国际航空碳抵消和减排计划结对子伙伴关系的现状，在这方面，捐助国与国际民航组织秘书处密切协调，向受援国提供援助，以建立其实施国际航空碳抵消和减排计划的国家能力；目前建立的国际航空碳抵消和减排计划结对子伙伴关系涉及 15 个捐助国，它们向 96 个受援国提供支助，其中 71 个已获得就地培训。

4.3.2 会议获悉，国际民航组织秘书处通过其全球航空培训（GAT）办公室正处于开发国际民航组织国际航空碳抵消和减排计划核证课程的最后阶段，旨在帮助核证机构增加对国际航空碳抵消和减排计划及相关核证要求的了解。航空环境保护委员会秘书强调，该课程就在航空环境保护委员会第十一次会议开始之前完成了验证交付会议，各国代表和核证机构的代表都作出了贡献，预计该课程将于 2019 年 4 月开始实施。

4.3.3 应理事会有关加强秘书处与公众沟通的要求，秘书处对国际民航组织国际航空碳抵消和减排计划公共网站（www.icao.int/corsia）进行了重组和更新，提供了有关国际航空碳抵消和减排计划援助、能力建设和培训方案（ACT-CORSIA）和相关国际航空碳抵消和减排计划结对子伙伴关系的最新材料；研讨会和讲习班；和包括有关国际航空碳抵消和减排计划常见问题（FAQ）、小册子、视频和传单等外联材料。会议还获悉将于 2019 年 3 月 21 日至 4 月 12 日在五个地点举办五场国际航空碳抵消和减排计划地区讲习班，航空环境保护委员会的专家对其持续作出贡献至关重要。

讨论和结论

4.3.4 秘书处在回答一名成员提出的问题时提醒会议指出，国家和运营人在使用 2018 年版的国际民航组织的国际航空碳抵消和减排计划的二氧化碳排放核算和报告工具（CERT）后发现任何问题，他们可以通过国际民航组织国际航空碳抵消和减排计划公共网站载列的电邮地址向秘书处提出报告。

4.3.5 会议认可航空环境保护委员会成员国和观察国以及国际组织 2018 年 6 月成功通过第一版附件 16 第 IV 卷以及建立国际民航组织国际航空碳抵消和减排计划援助、能力建设和培训方案（ACT CORSIA）和相关结对子伙伴关系所做的重大努力和贡献，以期在短时间内在各个地区支持国际航空碳抵消和减排计划（CORSIA）的实施。会议感谢秘书处为各国准备国际航空碳抵消和减排计划（CORSIA）的实施提供的巨大支持，并感谢各国在国际航空碳抵消和减排计划（CORSIA）结对子伙伴关系中分享信息的重要性。

4.3.6 会议鼓励航空环境保护委员会有更多成员国和观察员国家参与国际民航组织的国际航空碳抵消和减排计划的援助、能力建设和培训方案（ACT-CORSIA），并考虑与其他国家建立结对子伙伴关系，以支持国际航空碳抵消和减排计划的实施，同时认识到在国际民航组织下采取协调方法的重要性。会议鼓励尚未提名国际航空碳抵消和减排计划联络点的航空环保委员会成员国和观察员国尽快依照国家级信件 ENV 6/6-18/1 号提名其联络点。

4.3.7 会议还认识到航空环境保护委员会专家继续为国际民航组织秘书处未来的外联和落实国际航空碳抵消和减排计划（CORSIA）能力建设活动所作的贡献，包括即将举行的 2019 年国际航空碳抵消和减排计划地区讲习班，以及下一阶段国际航空碳抵消和减排计划援助、能力建设和培训方案（ACT CORSIA）和相关结对子伙伴关系。

4.3.8 关于理事会向航空环境保护委员会提出的与技术咨询机构（TAB）有关的要求，会议注意到，在航空环境保护委员会成员的同意下，已成立一个航空环境保护委员会成员组成的小组，以便在制定技术咨询机构议事规则方面取得进展。会议感谢航空环境保护委员会西班牙成员 Alfredo Iglesias 先生同意在航空环境保护委员会第十一次会议期间领导小组讨论，并指出小组将由来自阿根廷、澳大利亚、巴西、加拿大、中国、埃及、法国、日本、俄罗斯联邦、新加坡、西班牙、瑞士、阿拉伯联合酋长国、联合王国和美国的航空环境保护委员会成员组成。会议还注意到小组讨论的成果将在会议的后一阶段提供会议审议。

4.3.9 会议注意到理事会提出的另一个要求，即要求作为航空环境保护委员会工作方案的一部分，审议如何监测和审查理事会已经决定的根据国际航空碳抵消和减排计划（CORSIA）审查排放单位方案的持续资格的指导意见，并在适当时候向理事会提出报告，以及会议同意在航空环境保护委员会第十二次会议议程项目 12 下，审议国际航空碳抵消和减排计划未来工作的提案。

5. 全球航空环境计划（GAEP）

5.1 在 2018 年航空环境保护委员会举行指导小组会议（SG2018）期间，航空环境保护委员会讨论了全球航空环境计划（GAEP）的概念。这导致对全球航空环境计划的制定给予广泛而谨慎的支持，以及需要思考这一计划的磋商和批准的最佳进程，这将超越航空环境保护委员会的范围，使所有国家和各利害攸关方都参与进来。大家一致认为，大会第 40 届会议预期的应该是全球航空环境计划的概念，而不是全球航空环境计划本身。理事会在第 214 届会议期间，注意到航空环境保护委员会已对国际民航组织的全球航空环境计划的可能制订进行了初步讨论，并且 2019 年 2 月举行的航空环境保护委员会第十一次会议将对详细的概念和制定方法进行审议。在这方面，理事会要求它能密切参与国际民航组织全球航空环境计划的任何制定方法。在这个基础上，向航空环境保护委员会第十一次会议提交了全球航空环境计划概念文件，该文件提供了有关全球航空环境计划的可能结构、内容和通过进程的背景信息。配合这份概念文件还提出了一份有助于进一步奠定全球航空环境计划的基础以及提供有关国际航空循环经济的信息的广泛资源清单。

5.2 全球航空环境计划概念文件围绕四个主要部分构建：1) 国际民航组织全球航空环境计划（GAEP）简介；2) 对环境可持续的国际航空部门的愿景；3) 实施战略；4) 制定和批准国际民航组织全球航空环境计划的拟议进程。

5.3　一些成员和观察员指出，目前全球航空环境计划的拟议目标过于广泛和模糊，对拟议的全球航空环境计划的任务授权及其对国际民航组织成员国的影响表示关切。此外，成员和观察员指出，目前无法证明需要全球航空环境计划。他们还提出国际民航组织成员国为制定全球航空环境计划所需的资源，并指出这一进程应由各国在国际民航组织秘书处的支持下进行。成员和观察员指出，制定全球航空环境计划的决定必须由各国成员推动、对国际民航组织各成员国有净效益并且不会用罄与其他项目相互竞争的有限资源。成员和观察员表示，他们不认为这些因素已得到满足，因此，不支持进一步制定全球航空环境计划。

5.4　在成功实施国际民航组织的全球航空安全计划（GASP）和全球空中航行计划（GANP）的基础上，秘书处指出，全球航空环境计划可以生成一份文件，说明国际民航组织协助成员国落实国际民航组织的政策、标准和建议措施及指导材料所进行的环境保护工作的现状。会议同意在航空环境保护委员会第十一次会议议程项目 12 下进一步讨论全球航空环境计划概念文件，以便对其需要和范围作出决定。

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议程项目 1：评估航空器噪声和排放的当前与未来影响

1.1 全球环境趋势

1.1.1 建模和数据库小组共同报告员介绍了评估未来航空器噪声、影响当地空气质量的航空器发动机排放以及影响全球气候的航空器发动机排放的趋势的结果。

1.1.2 影响当地空气质量（LAQ）的航空器发动机排放

1.1.2.1 评估当地空气质量（LAQ）的趋势包括评估氮氧化物（NOx）和微粒物质（PM）的排放量。图 1 介绍了航空器在国际航空 3 000 英尺以下的氮氧化物（Nox）的排放量。根据情景的不同，技术的改进可使 2050 年国际航空和全球（国际加国内）航空的 NOx 排放量分别再减少 0.35 百万吨和 0.46 百万吨。运营改进小于技术可以实现的改进，即 2050 年的国际航空和全球航空可分别减少 0.15 百万吨和 0.23 百万吨。

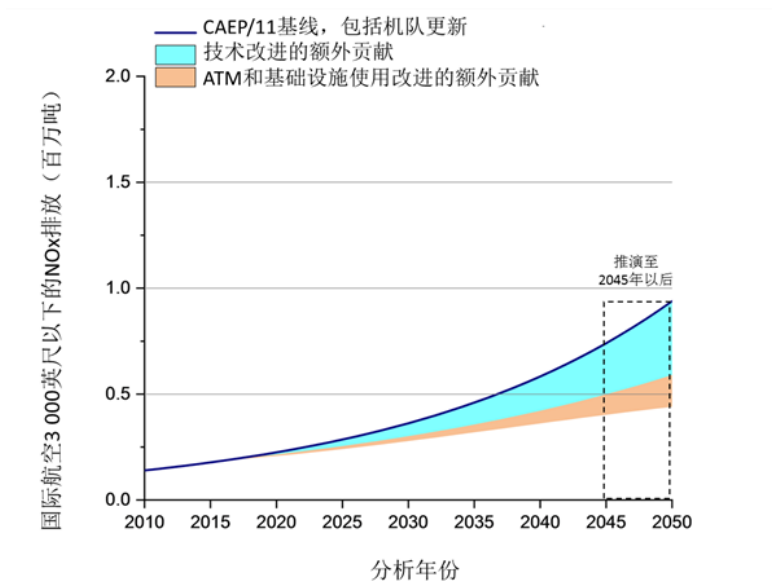


图 1. 国际航空在 3 000 英尺以下的 NOx 排放量，2010 年至 2050 年

1.1.2.2 图 2 介绍国际航空在 3 000 英尺以下微粒物质（PM）的全部排放量（挥发性和非挥发性）。运营改进可使 2050 年国际航空和全球航空的 PM 排放量分别再减少 1 160 吨和 3 100 吨。没有对 PM 技术情景作出评估。

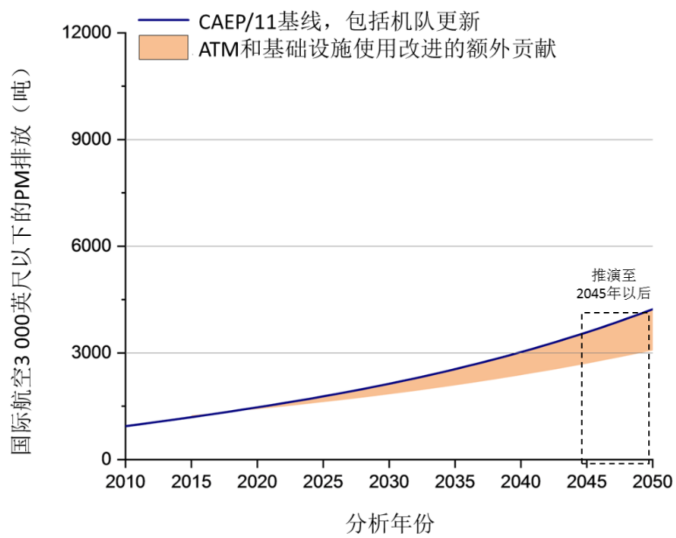


图 2. 国际航空 3 000 英尺以下的 PM 排放量，2010 年至 2050 年

1.1.3 影响全球气候的航空器发动机排放趋势

1.1.3.1 在趋势评估中，温室气体（GHG）部分评估了运营和技术改进对减少燃料需求和未来相关排放的潜在贡献。评估结果包括常规燃料消耗、净 CO_2 排放量（即仅在飞行期间排放的 CO_2）和 NOx 排放量。

1.1.3.2 国际航空的常规燃料消耗和净 CO_2 排放量分别见图 3 和图 4。根据情景的不同，技术改进可使 2050 年的燃料消耗量额外减少 157 百万吨（图 1）和 CO_2 排放量减少 497 百万吨（图 2）。运营改进小于技术可以实现的改进，即 2050 年燃料消耗量还可额外减少 57 百万吨和 CO_2 排放量减少 183 百万吨。在当前最乐观的技术和运营情景下，预计燃料效率将以每年 1.37%的平均速率提高，而每年 2%燃油效率的目标不太可能实现。

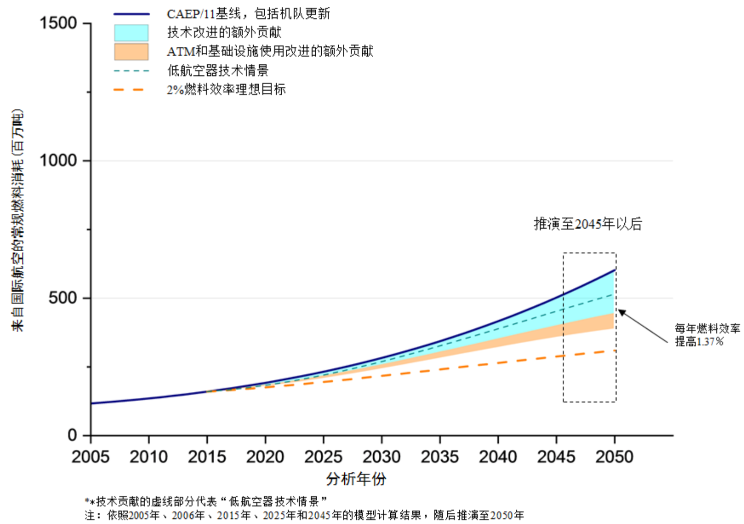


图 3.　来自国际航空的常规燃料消耗，2005 年至 2050 年

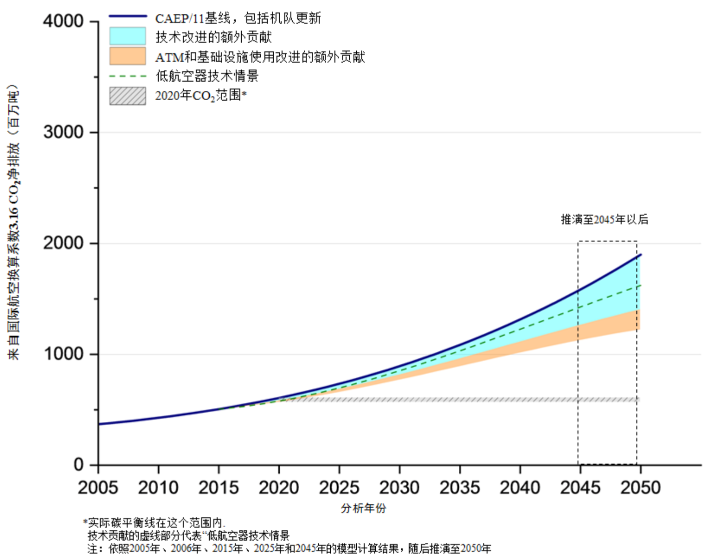
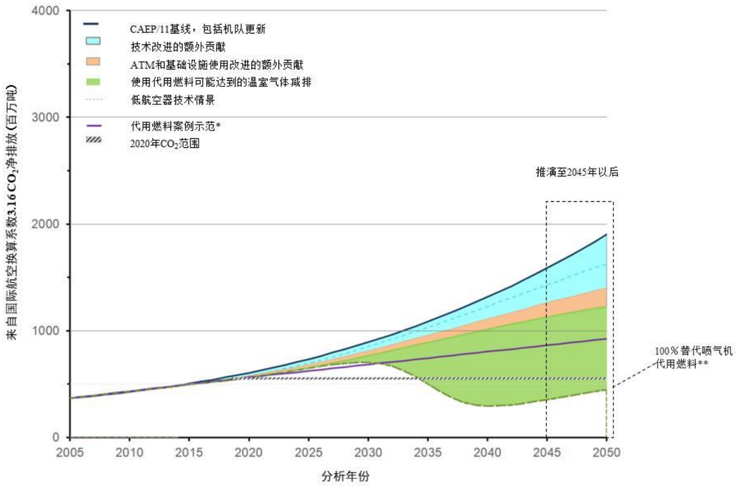


图 4.　来自国际航空换算系数 3.16 CO_2 净排放，2005 年至 2050 年

1.1.3.3　航空环境保护委员会的代用燃料工作队（AFTF）为 2020 年和 2050 年代用燃料潜在产量以及相关温室气体排放生命周期的变化进行了分析并作出了估计。2020 年，有 6 项产量估算和 2 项温室气体生命周期分析的估算（低和高），导致 12 种温室气体排放的可能情景。2020 年情景提供高达 2%的替代石油燃料和高达 1.2%的温室气体减排。2050 年，代用燃料工作队计算了 60 个不同的生产情景和 2 个温室气体排放情景，得出 120 个不同情景。某些全球条件、经济投资和政策决策都被假定为每一情景定义的一部分，并且是实现代用燃料生产和温室气体减排的相关结果的必要条件。代用燃料的数量和相关温室气体减排量是根据预计燃料需求在国际和国内使用量按比例分配（分别约为 60/40）。图 5 提供了相关温室气体排放的结果。



* 说明性案例要求提供大量的生物能源原料，其生产在极大的程度上会受到价格或其他政策机制的刺激。**100％替代喷气机代用燃料，将要求航空从石油提炼完全转换到生物燃料生产，并大规模扩大农业，这两者都需要巨大的政策支持；请注意：由于情景 9 的增长曲线升速下降，代用燃料的增长表现为曲线上升。

图 5. **来自国际航空包括代用燃料生命周期减排的 3.16 二氧化碳净排量，2005 年至 2050 年**

1.1.4 航空器噪声趋势

1.1.4.1 趋势中的噪声部分包括暴露在大约全球飞行运量 80%的 315 个机场日—夜平均声音水平（DNL）55、60 和 65 分贝以上的噪声等值线面积和人口总数。噪声趋势评估包括与第 1 工作组（WG1）就技术改进设想和与第 2 工作组（WG2）就运营改进设想进行协调。运营改进适用于受到曝露的全部人口，而不适用于等值线面积。采用了四种建模情景，用 2015 年数据为每种情景和未来三年 2025 年、2035 年和 2045 年每年的情景建模。提供了 2015 基准年和 2025 年、2035 年和 2045 年未来年份的全球总图示结果，并推算至 2050 年。CAEP/10 工作周期提供的历史数据也提供了 2010 年的数据。

1.1.4.2 图 6 提供了航空器噪声高于 55 DNL 的全球总等值线区域（即 315 个机场）的结果。这些结果包括来自所有航空器的噪声，无论其运营是国际飞行还是国内飞行。2015 年的基线值为 14 378 km^2。2050 年，全球等值线总面积在先进技术改进的情况下将下降至 14 261 km^2，在低度技术改进情况下将增加至 26 483 km^2。

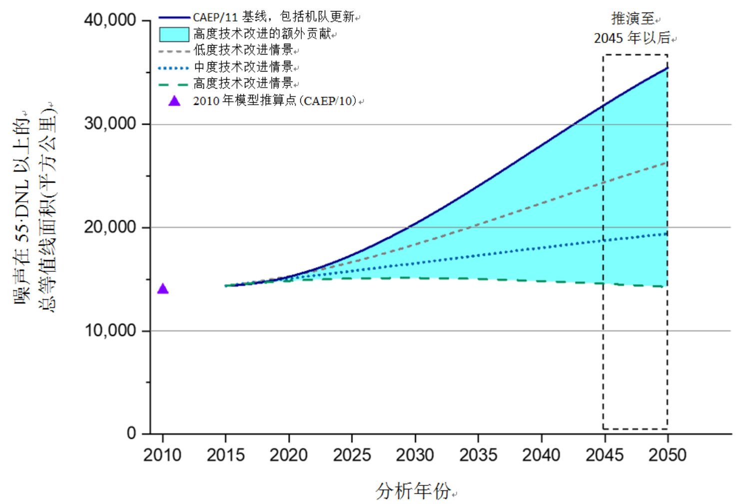


图 6　航空器噪声在 55 DNL 以上的等值线总面积

1.1.4.3　图 7 提供了暴露于航空器噪声 55 DNL 以上的全球总人口（即 315 个机场）的结果。第 2 工作组建议，运营改进适用于受到曝露的全部人口，而不适用于等值线面积。用于 CAEP/10 工作周期建模的历史数据也显示在 2010 年，由于当时使用了多个人口数据库，因此出现各种不同的人口数值。2015 年的基准值为 3 050 万人。2050 年，在先进技术和运营改进情景中，受到暴露的总人数将增至 3 420 万人，在低度技术和运行改进情景中，将增至 6 690 万人。

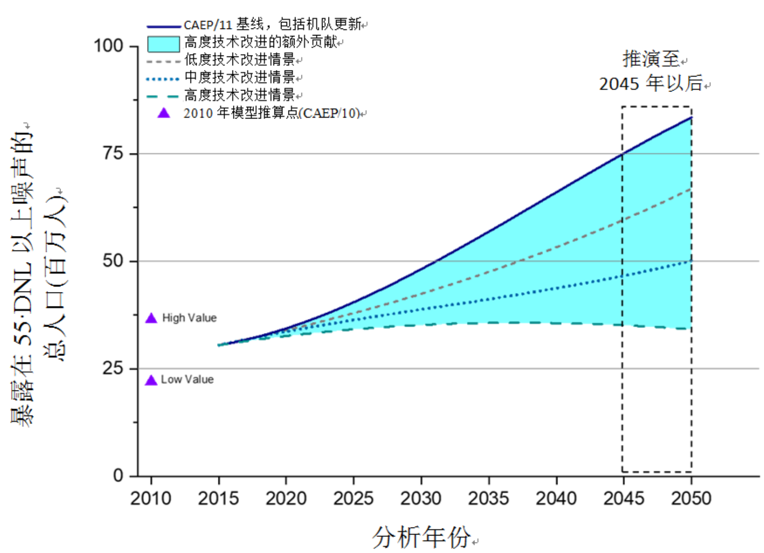


图 7. 暴露在 55 DNL 以上航空器噪声的总人口

讨论和结论

1.1.5 会议感谢建模和数据库小组小组所做的大量工作和对 LAQ 建模的改进。一位成员询问建模和数据库小组如何看待分析中的各种模型得到的结果的差异，指出噪声模型显示几乎相同的结果，因为它们都采用国际民航组织 Doc 9911 号文件所载的详细方法，而 LAQ 和 GHG 建模使用了互补的不同工具。共同报告员强调指出，由于这些差异已得到充分理解，通过促进查明错误和对模型作出可能的改进，它们为这个进程带来了好处。具体而言，关于 LAQ 扩散建模，有人解释说，先前所作的模型评估显示非常不同的方法，MDG 建议在 CAEP/12 周期对其进行进一步研究。

1.1.6 关于成果的传播问题，会议注意到，作为一项惯例，在航空环境保护委员会闭幕之后并在国际民航组织环境报告公布趋势结果之前，可以开展更多关于趋势传播的工作。

1.1.7 建模和数据库小组共同报告员在回答一位成员提问时指出，分析中使用的基线以静态增长和替代数据库为基础，该数据库用于取代到 2050 年为止的机队。技术和运营改进的情景附加在这个基础上，代表了可能作为更新机队的一部分而采用的新技术。共同报告员认识到这一点最好在提交国际民航组织大会的趋势文件中加以说明，并且他将与国际民航组织秘书处合作完成这项工作。

1.1.8 一位成员指出，温室气体趋势分析所使用的各种不同 CO_2 排放情景均假设使用了传统燃料的静态技术，因此，建议航空环境保护委员会审议该领域使用改进的低碳燃料技术可能带来的好处，这能通过大量可以提供的研究报告来完成。此外，该成员表示，他的国家愿意以通过提供这方面的信息和专门知识的方式参与今后的工作。该成员还表示，航空环境保护委员会需要让至今尚未参与这项工作的传统燃料行业的利害攸关方参加到这项过程中。会议指出，这将在未来与更新趋势假设相关的工作中加以考虑。会议还指出，趋势更新在很大程度上取决于航空环境保护委员会成员国和观察员提供的信息，欢迎有关新技术的数据将在下一次趋势评估中加以审查。

1.1.9 关于一位成员提出的关于 CAEP/10 和 CAEP/11 基线之间的差异问题，建模和数据库小组共同报告员指出，CAEP/11 趋势使用了新的预测数值，这使所有结果的趋势都趋下降，因为预测的需求减少和新技术进入机队。他们强调，这两个因素都有助于使趋势下降，但表示很难单独量化每个因素的贡献。

1.1.10 关于噪声趋势问题，一位成员认为，来自独立专家综合审查（IEIR）、以往噪声缓解办法、噪声骚扰研究、噪声计量和非声学要素的信息也应在理事会讨论噪声问题时提交理事会。会议获悉，尤其在骚扰和干扰睡眠方面，国际民航组织拟定的环境目标是减少受噪声影响的人数，但目前的趋势却是提供曝露于噪声的人数。在回答关于扩大骚扰的问题时，建模和数据库小组的一位共同报告员强调，人口建模的基础是静态的人口普查数据；这也就是说，建模不考虑随着时间的推移而可能增长的人口。

1.1.11 建模和数据库小组共同报告员强调指出，建模和数据库小组、预测和经济分析支持小组（FESG）和影响与科学小组（ISG）评估了未来航空环境保护委员会的评估可能用于包括噪声、LAQ 和 GHG 影响（包括货币化）在内的几种工具，这种分析可能会对航空环境保护委员会界定未来审议这些主题的正确方法有用。

1.1.12 航空环境保护委员会秘书欢迎有关分析趋势的工作，同时强调指出，这些趋势对本组织工作以及对大会制定政策至为重要，因此需要一个改善信息内容的进程。此外，她强调指出，由于这项工作至为重要，应在参与落实这项任务的所有工作组的未来工作方案中反映更多实质性的努力。

1.1.13 一位成员欢迎进一步开展适当传达趋势分析的结果，但指出这种沟通应尽可能简单并保持这些结果支持的高级别信息。

1.1.14 会议同意，分析趋势的信息应进一步加以完善，包括在大会第 40 届会议之前得到的任何新信息。分析的结果将伴随航空环境保护委员会有关趋势提出的建议，以此作为国际民航组织就噪声和排放作出决定的基础。这种信息应对分析结果作出适当的定性和定量解释，并根据需要，提供明确的说明和假设。会议还同意在 CAEP/12 进行趋势评估的未来工作中，审议可能需要加以审查的其他假设。

1.1.15 独立专家对发动机和航空器综合技术目标的评估和审查

1.1.15.1 独立专家（IE）小组共同主席概述了独立专家对发动机和航空器综合技术目标进行评估和审查（IEIR）的结果。使用设计空域建模对燃料燃烧与噪声之间的相互依存关系进行了评估，但是无法利用这种建模来审议各种排放的相互依存关系。尽管如此，此次审查比以往各次审查更加复杂，其中对噪声、排放和燃料燃烧分别进行了单独审议。

1.1.15.2 燃料燃烧和噪声的目标在结合优化过程之后合并进行。对于单通道航空器而言，独立专家认为，2037 年将可使用全新的机身。以 CO2 审定合格度量系统表示燃油燃烧目标作为相对于 CAEP/10 新型监管水平的百分比差距是：

EIS 日期	**BJ**	**RJ**	**SA**	**TA**
2027	-15	-16	-14	-12
2037	-23	-26	-24	-21

1.1.15.3　在第 14 章噪声限值以下以累计的有效感觉噪声分贝（EPNdB）表示的补充噪声目标是：

EIS 日期	**BJ**	**RJ**	**SA**	**TA**
2027	10.0	14.5	15.5	19.5
2037	15.0	17.0	24.0	26.5

1.1.15.4　根据所提供的证据，独立专家建议新的 2027 年中期着陆和起飞 NOx 目标，应设在航空环境保护委员会第八次会议之下 54%，处于 OPR=30，涵盖 OPR 全范围，使用下列公式：

$$Dp/F00 = 5.75 + 0.577*OPR.$$

讨论和结论

1.1.16　会议对独立专家综合审查（IEIR）专家组的努力、奉献精神和辛勤工作表示感谢。

1.1.17　一位观察员支持独立专家综合审查（IEIR）报告提出的技术目标。此外，观察员强调指出，在独立专家综合审查（IEIR）过程中，人们对独立专家向单通道技术参考航空器分配大量（7%）额外空气动力学效率表示担忧。该观察员注意到单通道和双通道航空器之间可实现的 L/D 的根本差异，并且表示不清楚独立专家综合审查（IEIR）报告中使用何种类别的技术来解释 2037 年单通道航空器大量空气动力学效率的增加。在同意独立专家综合审查（IEIR）报告的同时，该观察员建议，相较于现有的单通道技术参考航空器，独立专家可以假设空气动力学效率小幅上升（不超过 2%），以说明“净型”单通道航空器（满足国际民航组织现有的 Code-D 机场运营限制）。

1.1.18　一位观察员对独立专家所做的工作以及在审查过程中纳入公务喷气机参考数值表示赞赏，并对独立专家综合审查（IEIR）报告提供的结果表示欢迎。

1.1.19　一位成员和一位观察员指出，该报告提出了将会影响航空环境保护委员会未来工作的重要问题，因此认为国际民航组织应公开提供该报告，并最好免费提供。国际民航组织秘书处指出，该报告将在航空环境保护委员会和国际民航组织理事会批准后尽快作为国际民航组织出版物出版。

1.1.20　一位成员指出该报告提到不同环境参数之间的相互依存关系，因此询问所考虑的一些技术是否存在 nvPM、NOx 和燃料燃烧之间的相互依存关系。独立专家共同主席指出，独立专家组无法得到 nvPM 的测量数值，这妨碍了对这些相互依存的关系作出适当评估。独立专家共同主席确认在 NOx 和 nvPM 之间必须作出取舍，并表示有证据表明两种燃烧器技术可能会使 NOx 和 nvPM 数值偏低，而其他技术则不会使其偏低。

1.1.21　一位成员注意到，基于独立专家报告的独立性和工作的技术质量，该报告对航空环境保护委员会的审议工作至为重要。该成员支持未来继续进行独立专家审查，并指出航空环境保护委员会应在独立专家审查进程可能作出改进的情况下，适当考虑独立专家的建议。

1.1.22 **建议**

1.1.22.1 鉴于前述讨论，会议拟定了以下建议：

建议 2/1 — 核准全球环境趋势评估

国际民航组织/航空环境保护委员会的全球环境趋势应作为国际民航组织大会第 40 届会议就噪声和排放讨论作出决策的基础，并由航空环境保护委员会继续进行审查。

建议 2/2 — 独立专家对发动机和航空器综合技术目标的评估和审查

独立专家对发动机和航空器综合技术目标的评估和审查的最后报告应由国际民航组织尽快出版。

建议 2/3 — 接受航空环境保护委员会第十一次会议对发动机和航空器的综合噪声和排放技术目标

航空环境保护委员会第十一次会议提交的综合噪声和排放技术目标得到航空环境保护委员会核准，应为国际民航组织的噪声和排放活动提供信息。

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议程项目 2：环境模型和数据库

2.1 各工作组之间的协调

2.1.1 由于 CAEP/11 工作方案所需的资源庞大和极其复杂以及航空环境保护委员会各工作组间跨领域问题数量众多，各工作组采取了深思熟虑的行动，务使工作得到充分协调。这包括经常审查需要加以协调的活动以及向指导小组每次会议共同报告这些活动。

讨论和结论

2.1.2 会议感谢各位建模和数据库小组共同报告员对整个 CAEP/11 工作方案进行有效和必要的协调。会议同意在未来工作中讨论与制定超音速的标准和建议措施有关的协调问题以及更新对国际民航组织环境趋势评估的输入信息假设。

2.2 建模和数据库小组进度报告

2.2.1 建模和数据库小组共同报告员概述了 CAEP/11 期间的建模和数据库小组活动。对国际民航组织非挥发性颗粒物质（nvPM）的质量和数量的可能排放标准的环境效益和相互依存关系的政策选择分析有关的工作在议程项目 3 下作了说明。总结用于进行 nvPM 分析的模型和数据库的相关工作在议程项目 3 下作了说明。此外，如本报告议程项目 1 所述，建模和数据库小组更新了对噪声、氮氧化物（NOx）、微粒物质（PM）、燃料燃烧和二氧化碳（CO_2）的趋势评估。

2.2.2 在为制定和维护国际民航组织国际航空碳抵消和减排计划（CORSIA）的二氧化碳估算和报告工具（CERT）设立了 CORSIA CERT 小组（CCG）之后，建模和数据库小组审查和评估了作为 CERT 基础的二氧化碳估算模型（CEM），指出 CERT 的 2018 年版本符合这项用途。

2.2.3 建模和数据库小组一直继续与第 2 工作组合作分析航空系统组块升级（ASBU）组块 1 的效益。在本报告议程项目 5 下介绍了这项任务的结果。

2.2.4 建模和数据库小组对航空环境保护委员会用于分析的模型和数据库提供了维护。对在航空环境保护委员会批准的工具中的 nvPM 计算模块作出了更新，并且为 nvPM 标准分析开发了使用国际民航组织模式内时间计算着陆和起飞 nvPM 的建模和数据库小组共识工具。更新了航空环境保护委员会批准的温室气体模型（航空环境设计工具、航空器噪声和排放建模综合平台（IMPACT）、未来民航方案软件工具），以便包括非挥发性微粒物质的最新巡航算法。此外，还完成了对机场数据库、坎贝尔希尔（Campbell Hill）机队数据库和共同运行数据库（COD）的更新。开发了 2012 年基线共同运行数据库，并由预测和经济分析支持小组（FESG）用来开发非挥发性微粒物质（nvPM）严格度评估的相关预测。还开发了 2015 年基线共同运行数据库并与一个更新后的相关预测用于国际民航组织环境趋势评估。

2.2.5 建模和数据库小组和预测和经济分析支持小组与国际民航组织航空数据和分析专家组（ADAP）进行协调，通过提供 2012 年和 2015 年共同运行数据库的方式，为国际民航组织运量需求预测作好准备。

2.2.6 建模和数据库小组在预测和经济分析支持小组协调下，对机队历史数据、环境标准和其他潜在的机队影响（例如，燃料价格变化、全球经济活动）进行审查，以便结合环境标准更好地理解全球机队的趋势演变。它认为，环境标准能反映市场力量，也能影响市场力量。通过防止恢复采用老旧技术的办法，环境标准也有助于推动积极的环境趋势。

2.2.7 建模和数据库小组和预测和经济分析支持小组还审查了从以前各次分析学得的教训，以期改善进行未来各次分析的进程。此项任务包括查明分析假设、数据库和工具中的不足之处。

2.2.8 建模和数据库小组与预测和经济分析支持小组及影响与科学小组一道审查了成本效益分析（CBA）的现有定义、确定工具和方法的结果以及载列这些工具和方法的初步综合文件。它还进行了航空环境保护委员会使用成本效益分析的利弊的初步讨论。

讨论和结论

2.2.9 会议祝贺建模和数据库小组所做的大量优质工作。会议同意，评估国际民航组织 CO_2 标准对国际民航组织全球理想目标的贡献的范围界定工作应延长到 CAEP/12 周期继续进行，同时认为建模和数据库小组已完成它在 CAEP/11 工作方案中的所有其他任务。

2.3 预测和经济分析支持小组的报告

2.3.1 预测和经济分析支持小组概述了它在 CAEP/11 期间进行的活动。此外，它还完成了界定、制定和商定其他经济成本要素的工作。它还开发、测试和批准了 CAEP/11 版本的预测和经济分析支持小组成本模型。所有这些发展都被用于 nvPM 标准分析。

2.3.2 经航空数据和分析专家组（ADAP）进行最后审查和批准后，国际民航组织对 2015 年基准年作出的最新运量长期预测（LTF）在 2018 年 3 月底交付给预测和经济分析支持组。预测和经济分析支持组利用这项长期预测作出了航空环境保护委员会新的客机和货机机队预测。预测和经济分析支持小组还利用国际公务航空理事会（IBAC）提供的 2015 年预测编制了公务喷气机预测报告。

讨论和结论

2.3.3 会议感谢预测和经济分析支持小组（FESG）进行的工作，特别是在支持 nvPM 质量和数量标准相关分析方面作出的重大努力，及其与航空数据和分析专家组（ADAP）进行的协调。

2.3.4 预测和经济分析支持小组报告员在回答主席提出的问题时，确认航空环境保护委员会可以从 CAEP/12 周期期间工作作出的最新预测受益。应在 2020 年中期之前提供这样的最新预报，以便 CAEP/12 的趋势评估和最终的严格性分析对其加以审议。有人指出，最终将超音速纳入预测可能会影响这一时间表，因此，应与国际民航组织秘书处进行适当协调。一名成员强调，应认真看待与航空数据和分析专家组（ADAP）的协调并且这份时间表已被适当订定。

2.3.5 预测和经济分析支持小组报告员在回答一名成员提出的问题时指出，航空数据和分析专家组（ADAP）所作的客机和货机预测已作为国际民航组织的正式长期预测公布在国际民航组织网站，这项预测能免费查阅。他还指出，只要得到航空环境保护委员会的批准，原则上也能公布航空环境保护委员会的客机和货机机队预测报告。

2.3.6 会议批准基于 2015 年的 CAEP/11 机队预测报告，同意预测和经济分析支持小组已根据 CAEP/11 工作方案完成了它的任务。

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议程项目 3：航空器发动机排放

3.1 第 3 工作组的报告

3.1.1 第 3 工作组共同报告员概述了第 3 工作组在 CAEP/11 周期期间进行的工作。大多数工作项目由三个任务组（微粒物质（PMTG）；审定合格（CTG）；和技术和目标（TGTG））处理。就非挥发性微粒物质（nvPM）质量和数量的标准和建议措施以及相关附件 16 第 II 卷及《环境技术手册》第 II 卷修订案文进行的工作都载于本议程项目下的另一份报告。

3.1.2 会议感谢第 3 工作组在航空环境保护委员会这个会议周期期间作出的奉献、努力和优质工作。

3.2 制定微粒物质标准

3.2.1 在介绍第 3 工作组和建模和数据库小组关于 nvPM 严格性评估的工作之前，一位成员提交了一份信息，其中概述了在产发动机 nvPM 质量监管限制界线转换为符合俄罗斯发动机 PS-90A 的建议，这种发动机预计将在 2023 年后投产。该成员指出，由于时间安排的问题，这些发动机的 nvPM 审定合格数值的测量工作是在 CAEP/11 第 3 工作组最后一次会议之后进行的，因此，这些数据都提交给了 CAEP/11 会议，以便在 nvPM 标准设定进程期间加以审议。

3.2.2 相对于第 3 工作组提议的在产监管限制，会议注意到 PS-90A 发动机的 nvPM 质量度量数值，同意将在产发动机的拟议 nvPM 质量监管限制界线转换为适合俄罗斯 PS-90A 发动机的数值。

3.2.3 第 3 工作组共同报告员报告已经完成了与 nvPM 排放有关的 CAEP/11 任务，包括拟议的着陆和起飞（LTO）nvPM 质量和数量的标准和建议措施以及相关指导材料。

3.2.4 第 3 工作组共同报告员指出在 CAEP/12 周期需要进行更多工作，以确定对环境条件的修正。从燃烧室喷口测试和多个发动机测试得到的更多新数据可用于验证和改进计算巡航 nvPM 的方法。第 3 工作组共同报告员强调指出，还需要开展更多工作来解决测量系统丧失 nvPM 的问题，因此，建议将上述工作项目纳入 CAEP/12 的工作方案。

3.2.5 第 3 工作组共同报告员建议从 2023 年 1 月 1 日开始停止适用推力>26.7 kN 的发动机的发烟指数（SN）标准，因为商定的 CAEP/10 限制界线将给出发烟指数标准提供的能见度限度。

3.2.6 建模和数据库小组共同报告员概述了在 CAEP/11 工作方案下开展的 nvPM 严格度分析工作，包括注意事项、限制和信息背景；关键工具、方法、数据和假设的摘要；环境成本和成本效益。

3.2.7　会议接受了提出的结果，并认识到与建模、公务喷气机市场的不确定性和 nvPM 测量数值不确定性相关的注意事项。

3.2.8　第 3 工作组共同报告员提供了支持一些国际民航组织成员国公共规则制定过程的材料，并协助制定各国的 nvPM 监管影响评估（RIA），以实施拟议的 CAEP/11 的 nvPM LTO 质量和数量排放标准和建议措施。此外，由于第 3 工作组建议从 2023 年 1 月 1 日开始停止适用推力>26.7 kN 的发动机的发烟指数（SN）标准，这项材料提供了用于制定该建议的背景技术信息。

3.2.9　一位成员认识到应支持国际民航组织成员国制定公共规则的程序以及协助各国制定 nvPM 监管影响评估（RIA）以便实施拟议的 CAEP/11 nvPM LTO 质量和数量排放标准。会议同意根据 CAEP/11 通过的决定更新监管影响评估，并将其纳入本报告关于这个议程项目的附录 C。

3.2.10　若干成员和观察员支持为动力>26.7kN 的涡轮风扇和涡轮喷气发动机设定新型航空器发动机基于 LTO 的 nvPM 的质量和数量标准和建议措施，但也承认与 nvPM 质量和数量排放控制相关的特定技术问题以及不同的制造商处于生产新型发动机设计的潜在技术解决方案的开发周期的不同阶段。成员和观察员在审议新技术 nvPM 的标准和建议措施的制定时，仅支持严格度的选项 1-3。

3.2.11　关于若干成员和观察员的发言，一位成员询问了有关提出适用日期提案的理由以及这些成员和观察员认为适当的严格度选项的补充信息。成员和观察员指出，这项决定应由数据驱动，从这个角度来看，新标准应具有足够的挑战性，但对利害攸关方来说并不是极端的。

3.2.12　会议确认与 nvPM 质量和数量排放控制相关的具体技术问题，但注意到不同制造商投产的发动机并不符合新技术的严格度选项。会议进一步认识到，不同的制造商正处于为新技术设计开发潜在技术解决方案周期的不同阶段。

3.2.13　一位成员支持就 nvPM 质量和数量标准开展的工作，但认为严格度选项 6、9、10-12 不应被视为新的标准。为确保技术可行性，该成员还对在选取严格度时小型发动机的扩展挑战需要考虑到小型发动机的特定问题表示关心。该成员提议，为新的 nvPM 质量和数量标准选取严格度水平应考虑到相互依存性，并且对整个发动机额定推力范围都应具有技术可行性、经济合理性和环境效益。会议确认该成员对小型发动机的扩展挑战表示的担忧。

3.2.14　一位成员建议，对于新型发动机，应依照航空环境保护委员会的职权范围，根据分析的结果选择限制界线。该成员支持适用日期为 2023 年 1 月 1 日的 nvPM 质量和数量的反倒退在产限制界线。该成员指出，质量的最佳严格度为 3 和 4，数量的严格度为 1 和 2。该成员支持结束额定推力> 26.7kN 的发动机适用发烟指数（SN）的标准和建议措施，以反映新的在产 nvPM 排放标准。

3.2.15 一位观察员指出，严格度 4 及其以上的选项不具有成本效益，它很可能对业界导致 50 亿至 100 亿美元的额外成本。

3.2.16 一位观察员支持通过在产和新型航空器发动机着陆和起飞的 nvPM 质量和数量标准。该观察员支持适用日期为 2023 年 1 月 1 日的在产发动机 nvPM 质量和数量拟议限制界线，并支持从 2023 年 1 月 1 日开始停止适用目前的发烟指数标准和建议措施。

3.2.17 一位成员和一位观察员强调，拟议的新 nvPM 排放标准和建议措施不应被用来作为限制民用航空增长的基础，例如施加运营限制或征收排放费用。该观察员还指出，用于新技术航空器最具有挑战性的严格度选项 10 至 12 不符合技术可行性的要求。

3.2.18 另一位观察员表示反对并指出，虽然该观察员同意制定标准和建议措施的目的原则上不是为了施加运营限制或征收费用，但该观察员认为，依照国际民航组织 Doc 9082 号文件确定的政策，特别是有关第 II 节第 9 段的政策，为使机场能够继续运营和满足航空运输的需求，需要消除机场的各种限制，这就有可能需要收费和实施运行限制。

3.2.19 两位观察员就 nvPM 质量和数量的严格度问题表示了看法，强调对于严格度选项 10 至 12 的分析结果而言，市场力量压倒了技术上的因应办法，产生了不可靠的结果。观察员对 NI3 的技术可行性表示担忧，因此，选择超出严格度选项 3 的限制界线将对制造商构成高风险。

3.2.20 在两位观察员提出看法后，一位成员询问为什么其他严格度选项被认为在技术上不可行或在经济上合理，而它们都已被第 3 工作组认为是严格度分析的一部分。观察员表明，鉴于分析工作的可变性和不确定性，他们最初要求在第 3 工作组审议期间排除几个严格度的选项，并同时指出制造商需要时间从技术角度来达到更高的严格度选项。 第 3 工作组共同报告员指出，为了保持可变性，分析界线增加了额外的不确定性。观察员指出，不应孤立地审查成本效益的结果 - 还需考虑累积成本和与其他排放和燃料燃烧/二氧化碳之间的取舍，这将是业界的挑战。

3.2.21 观察员承认并赞赏所有利害攸关方为支持 CAEP/11 的一项决定所完成的工作，支持制定国际民航组织的 nvPM 标准和第 3 工作组提议的在产航空器适用日期为 2023 年 1 月 1 日的反倒退限制界线。观察员建议应该为 CAEP/11 的新机型 nvPM 标准选择适用日期为 2023 年 1 月 1 日的严格度选项 12。

讨论和结论

3.2.22 一些成员和观察员强调指出，他们支持批准基于着陆和起飞的 nvPM 质量和数量标准和建议措施及相关指导材料。

3.2.23　若干成员和一位观察员指出，根据以往有关 NOx 标准的经验，业界需要一段合理的时间才能达到新的要求。一位成员和一位观察员承认，即使是最小的严格度选项（SO）也会产生积极的影响，并同时给予业界适应的时间。一位成员支持严格度选项 1 至 9，认为最初接受较低的选项是合理的，并有可能在以后改用较高的选项。

3.2.24　依照第 3 工作组的建议，会议同意将 2023 年 1 月 1 日作为停止适用额定推力> 26.7kN 的发动机的发烟指数的标准和建议措施的日期。会议还同意第 3 工作组提出的反倒退在产 nvPM 排放标准，其中包括了最近提交的测量数据。

3.2.25　一位观察员指出，纳入俄罗斯联邦提供的最新数据的过程以及航空环境保护委员会 2017 年指导小组会议随后核可修订在产限制界线的做法与以往用于分析所有其他提交的 nvPM 数据的程序不一致。有人说明指出，在向航空环境保护委员会提交数据后，第 3 工作组与航空环境保护委员会成员进行了协商，分析并同意对拟议的在产限制界线作出修订。这样做的目的是为了保持航空环境保护委员会的一致性和透明度，会议注意到，虽然这种做法很不寻常，但由于时间限制，对该过程已作出调整。

3.2.26　一位观察员敦促航空环境保护委员会审慎评估新型发动机的严格度选项，对燃料效率和氮氧化物排放的潜在综合评定表示担心，认为不应损害机队选择的适应性和灵活性。在设定 nvPM 质量和数量标准时，一些观察员还对 NOx、CO 和 HC 以及 CO2 的综合评定表示担忧，并注意到在设定 nvPM 数量标准时，缺乏环境条件修正值和 nvPM 数量测量设备的差异。

3.2.27　会议同意在选择新型 nvPM 标准和建议措施的严格度选项时需要谨慎行事，并进一步同意，新型 nvPM 标准和建议措施应以一种严格度水平为基础，其中考虑到相互依存性、技术上可行性、经济上合理性并在整个发动机额定推力范围内对环境有利。会议还同意在评估将严格性选项作为 nvPM 质量和数量标准设定进程的一部分时，应考虑 NOx、CO 和 HC 以及 CO2 综合评定的风险、缺乏环境条件修正值和 nvPM 数量测量设备的差异。

3.2.28　在讨论了新的 nvPM 标准和建议措施可能用于运营限制之后，一位观察员提议，航空环境保护委员会应重申国际民航组织的环境标准无意引进运营限制或课税或作为进行运营限制或课税的基础的原则，而仅作为审定合格之用。一位观察员重申他们在第 1.2.18 节所述的反对意见。观察员还敦促国际民航组织务需使各项政策保持一致，并强调 CAEP/10 之前打算制定 CO2 标准的建议并非以当地空气质量排放标准为基础。观察员答复说，所说的话并不是要否定或质疑 Doc 9082 号文件中的政策，他还解释指出，承认这项原则将会对通过国际民航组织的审定合格标准给予持续支持。会议同意将在会议的晚些时候进一步讨论运营限制和收费问题。

3.2.29　会议认识到第 3 工作组在制定 nvPM 标准和建议措施方面进行的大量工作，并注意到汽车工程师学会 E-31 委员会在这项工作中所作的技术贡献。

3.3 同意新的 nvPM 质量和数量标准和建议措施

3.3.1 成员和观察员分享了他们对与新型 nvPM 质量和数量标准和建议措施相关的可接受严格度选项（SO）的观点。

3.3.2 一些成员和观察员表示，在他们提交的文件中，曾建议排除不需考虑的严格度选项和不一定是首选严格度选项。会议随后讨论并同意将严格度选项 10 至 12 排除在考虑范围之外。一位成员指出，只应审议严格度选项 2 至 9。

3.3.3 一位成员指出，希望对推力小于 50 kN 的小型发动机给予一些缓解，认为严格度选项 2 是适当的级别。

3.3.4 若干成员认为，作为最佳的 nvPM 数量严格度 2 和 nvPM 质量严格度 2 至 3，它们将产生严格度选项 3 和严格度选项 5 之间的结果，强调如果选择较低的严格度选项，那么 2023 年的早期适用性将是适当的。这样可以得到接近严格度选项 5 的结果，而成本仅略高于严格度选项 3。如果选用这些选项，那么成员均支持在 2025 年对新类型标准进行早期审查。另一位成员建议，如果选用较低的严格度选项，则航空环境保护委员会应承诺不迟于 2028 年审查 nvPM 标准和建议措施，以便大幅提高质量和数量的严格度选项。

3.3.5 若干成员指出，推力低于 150 kN 的发动机应获得一些缓解，因为依比例受到的限制会影响这些推力的发动机的低排放技术的实施。

3.3.6 若干成员要求不考虑与严格度 3 相关的严格度选项（即严格度选项 6 和严格度选项 9）。一位成员支持严格度选项 8，这仍是最严格的选择，指出对于额定推力小于 150 kN 的发动机可能会有一些降低严格度的做法。另一位成员作出表示，他认为，严格度选项 8 和严格度选项 9 不符合航空环境保护委员会的职权范围。

3.3.7 若干成员共同关切提早适用日期（即 2023 年，而非 2025 年）是否可行的问题，因为要将新的 nvPM 标准和建议措施纳入国际民航组织成员国的立法框架仍需有足够的时间。

3.3.8 一位成员进一步指出，nvPM 限制界线应设在严格度选项 3 以外的严格度选项，最好是严格度选项 5。另一位成员表示，他们希望在标准制定的进程中最好仅考虑严格度选项 1 至 5。

3.3.9 一位成员提议采用严格度选项 3，适用日期为 2025 年。

讨论和结论

3.3.10 会议讨论了新型 nvPM 质量和数量标准的可用选项，并在对所有关于严格度选项和适用日期的各种观点进行了考虑之后，会议就新型 nvPM 质量和数量标准和建议措施达成了一致。这包括 nvPM 质量和数量

的限制界线[1]，它将从 2023 年 1 月 1 日起适用于新发动机类型，但对额定推力低于 150 kN 的发动机提供一些缓解。正如早前在会议商定的那样，这些新的标准和建议措施还将列入适用日期为 2023 年 1 月 1 日的 nvPM 质量和数量在产标准。会议同意载于本议程项目附录 A 对附件 16 第 II 卷提出的修订案文。会议还同意工作组报告所载对《环境技术手册》第 II 卷提出的修订案文，以便纳入有助于落实新的 nvPM 质量和数量标准和建议措施的要素。对附件 16 第 II 卷的新 nvPM 质量和数量标准和建议措施提出的建议和《环境技术手册》第 II 卷的相关指导意见以及在 CAEP/11 商定的所有附件 16 第 II 卷其他相关案文和《环境技术手册》第 II 卷的修订案文均载于本报告第 1.5 节。

3.3.11 随同新的 nvPM 质量和数量标准的协议还有关于早期审查监管水平的协议。会议同意这将涉及 2019 至 2022 年期间所有在产发动机可用的认证和类似审定合格的 nvPM 质量和数量排放数据的订正和分析。会议还同意审查 CAEP/11 商定的新型 nvPM 质量和数量标准的边际范围和评估降低 nvPM 排放的可能技术进步。会议同意第 3 工作组向 CAEP/12 提出建议，告知更新 nvPM 发动机排放标准的必要性。如果 CAEP/12 同意，在 CAEP/13 期间将考虑进行修订 nvPM 质量和数量标准和建议措施的标准设定进程。

3.3.12 两位成员尽管同意新的 nvPM 质量和数量标准和建议措施，但对早的适用日期（2023 年）表示保留，因为这需要作出重大努力，及时更新各国的监管框架。

3.3.13 一位成员反映会议的情绪，祝贺航空环境保护委员会成员成功商定了这些新的 nvPM 质量和数量标准和建议措施。在赞扬这些新的标准和建议措施以及突破性成就时，该成员强调指出，这意味着现在已经商定了航空器环境审定合格的最后部分，结束了噪声、当地空气质量和亚音速飞机二氧化碳标准的整个循环。新的标准将导致未来几年国际航空的 nvPM 减排。

3.4 超音速发动机排放标准

3.4.1 第 3 工作组共同报告员概述了对超音速运输（SST）发动机排放的标准和建议措施开展的工作。作为这项工作的结果，第 3 工作组认为，目前拥有的技术信息尚不足以对附件 16 第 II 卷第 3 章作出改变。此外，第 3 工作组也未能就撤销目前的适用性要求达成共识。不过，第 3 工作组确实认为，第 2 章和第 4 章中目前定义的亚音速着陆和起飞（LTO）周期可被视为是未来工作的合理起点。第 3 工作组认识到，如有更多关于超音速运输发动机的排放数据，这有助于指导对标准和建议措施以及对第 3 工作组提出的《环境技术手册》第 II 卷的修订案文最近作出可能更新，以便突出表明发动机制造商可自愿收集涵盖第 2、3 和 4 章范围的排放数据，这些数据可提供给国际民航组织/航空环境保护委员会第 3 工作组，以便用于更新超音速运输发动机排放的标准和建议措施。有人着重指出，仅会收集没有加力燃烧室的超音速运输发动机的气体、nvPM 和烟排放数据。

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[1] 仅供参考：在拟议的严格度选项中，商定的限制界线等同于额定推力大于 150 kN 的发动机的 nvPM 质量严格度 2.8 和 nvPM 数量严格度 2。

3.4.2 若干成员感谢第 3 工作组，支持在更新超音速运输排放标准和建议措施方面取得的重要进展。一位成员和一位观察员询问，要使工作取得进一步进展需要哪些数据以及预期何时会收到这些数据。第 3 工作组共同报告员指出，第 3 工作组要求制造商尽早提供从成熟的超音速运输发动机项目根据实际测量结果获得的数据。一位成员表示支持第 3 工作组的报告，认为鉴于技术进步，需要为制定超音速运输排放标准和建议措施对数据修正作出进一步评估。

3.4.3 若干成员和一名观察员分享了他们对超音速运输排放标准的看法，支持第 3 工作组提出的方法，指出他们需要新超音速运输飞机类型的二氧化碳标准，建议将该项目纳入下一个航空环境保护委员会周期的工作方案。成员和观察员提议将审议中的超音速运输标准作为一揽子方案处理，并在附件 16 第 II 卷第 3 章中添加说明，指出该章内容已被视为过时。

3.4.4 一位观察员支持会员和观察员表示的意见。另一位观察员询问是否有开始收集数据的临时程序，因为有关新超音速运输飞机类型的 CO2 标准的提案需要足够的时间。该成员回答指出，需要更多时间和制造商的数据，并且目前没有批准的工作时间表。另一位观察员指出，由于缺乏数据，对新的超音速运输飞机类型的二氧化碳标准做出决定为时尚早。

3.4.5 一些成员反对将超音速运输标准和建议措施视为一揽子方案，因为这种方法不会促进标准的制定过程。

3.4.6 一位成员对由于各国立法的不一致而在附件 16 第 II 卷第 3 章中增加一个说明的建议表示关切。若干成员支持这一观点，并表达了他们的担忧，认为增加一个说明既不会使航空当局明白情况，也不会产生任何监管效果。

3.4.7 会议认识到新的超音速运输飞机发动机项目尚未足够成熟，因此无法在 CAEP/11 提供拟定修订附件 16 第 II 卷第 3 章所需的数据。但是，会议注意到，CAEP/12 需要继续努力更新附件 16 第 II 卷中关于超音速运输发动机的排放要求。

3.4.8 一位成员表示他对超音速发动机排放问题的看法，强调需要来自足够成熟的民用超音速发动机方案的技术数据以便更有信心地更新超音速发动机排放标准和建议措施。该成员还指出，在第 3 工作组努力修订预期的非加力燃烧超音速发动机的标准时，不应放弃制定现有附件 16 第 II 卷第 3 章特别是关于加力燃烧发动机适用性的工作。另一位成员支持这些关于超音速发动机排放的观点。

3.4.9 在回答有关噪声和排放标准和建议措施的制定程序之间的差异问题时，一位成员指出，与发动机排放审定合格的过程不同，目前他的国家没有适用于新型超音速航空器的噪声审定合格标准。

3.4.10 一位观察员表示了他对把超音速航空器引进全球机队的看法，认为只与亚音速航空器基线相比，这不应导致航空噪声、空气污染或二氧化碳排放总量的净增加。该观察员建议，航空环境保护委员会应以有意识和数据驱动的方式为超音速航空器和发动机制定新的标准和建议措施，并在获得足够的数据之前，应将最新的亚音速标准适用于新的超音速设计。

3.4.11 一位成员指出，环境参数“无净增加”的概念从未用于航空环境保护委员会的进程，因此，他询问如何将这个概念用于航空环境保护委员会制定其他标准的进程。观察员认识到，即使超音速航空器需要符合当前亚音速航空器的标准，但在全球范围内，环境参数仍可能净增加。除标准制定的过程外，观察员认为，国际民航组织的环境活动应力求避免这种净增加的可能性。

3.4.12 一位观察员指出，鉴于超音速和亚音速飞机之间根本性的技术差异，对亚音速和超音速发动机采用相同的标准不符合航空环境保护委员会的职权范围。该观察员支持进一步评估超音速航空器产生的噪声和排放的影响，但提醒指出，由于超音速航空器市场的特殊性，这种评估可能与航空环境保护委员会进行的传统成本效益分析不同。

3.4.13 航空环境保护委员会秘书指出，航空环境保护委员会制定标准的传统进程通常得到从实际运营的机队收集的测量数据的支持，他询问是否应根据正在开发的新型航空器的设计，如混合动力航空器和电动航空器，调整未来制定标准和建议措施的进程，以考虑到其他类型的数据。该观察员指出，航空环境保护委员会应考虑以对航空器类型或污染物无选择性的方式为这些新设计制定标准的可能方法，以便在技术可行性方面统一采用相同的原则。

讨论和结论

3.4.14 会议同意，作为 CAEP/12 工作方案的一部分，保留和修订附件 16 第 II 卷第 3 章。会议还注意到对审议现有的附件 16 第 II 卷第 3 章关于加力燃烧发动机的适用性所表示的关切。

3.4.15 为了突出表明发动机制造商可自愿收集涵盖第 2、3 和 4 章范围的排放数据，这些数据可提供给国际民航组织/航空环境保护委员会第 3 工作组，以便用于更新超音速运输发动机排放的标准和建议措施，会议同意修订《环境技术手册》第 II 卷，以便列入以下案文：*“根据国际民航组织的工作，认识到额外的超音速发动机的排放数据有助于为附件 16 第 II 卷第 III 部分第 3 章超音速发动机排放标准作出可能的更新。强调指出，发动机制造商可以依照第 2 章和第 4 章对亚音速航空器着落和起飞循环自愿进行测量和报告发动机排放。鼓励发动机制造商提供涵盖第 2、3 和 4 章范围更广的排放数据，以支持国际民航组织/航空环境保护委员会的讨论，以便更新附件 16 第 II 卷第 III 部分第 3 章的超音速发动机排放标准”*。

3.4.16 会议注意到一位观察员的立场，即将超音速航空器引进机队，如与亚音速航空器基线相比，不应导致航空噪声、空气污染或二氧化碳排放总量的净增加。

3.4.17 会议同意航空环境保护委员会应同时制定超音速运输环境标准，但不同意将超音速运输环境标准视为一个一揽子方案。

3.4.18 第 3 工作组共同报告员在回答问题时指出，第 3 工作组关于超音速发动机标准拟议展开的进一步工作是一般性的工作，因为目前尚不清楚可获得哪些数据。会议同意在议程项目 12 关于未来的工作项下进一步讨论这一问题。

3.4.19 关于澄清航空环境保护委员会的职权范围并不包含具体涉及某类航空器的问题，航空环保委员会秘书答复指出，目前虽然没有成熟的超音速项目可提供全部数据，但对载有成熟的新技术的新型航空器，可以为它们制定适当和适用的标准制定进程，同时强调航空环境保护委员会未来可能需要以灵活的方式处理高速的技术发展问题。

3.4.20 若干成员和一位观察员指出，超音速运输运行模式预计与亚音速航空器运营模式有很大不同。会议审议了将现有的亚音速标准和建议措施适用于新的超音速运输发动机类型是否合理的问题。

3.4.21 一位成员提出未来进行与二氧化碳有关的亚音速航空器标准和建议措施相关工作的建议，会议同意这将在议程项目 12 未来的工作项下审议。

3.5 对附件 16 第 II 卷和《环境技术手册》（Doc 9501 号文件）第 II 卷的拟议修订

3.5.1 第 3 工作组共同报告员介绍了附件 16 第 II 卷的拟议修订案文和国际民航组织 Doc 9501 号文件 —《环境技术手册》，第 II 卷 —《航空器发动机排放审定程序》的拟议修订案文。这些改变包括新发动机的适用日期、流量规范和条件以及在产发动机的豁免等。

3.5.2 会议感谢第 3 工作组努力使国际民航组织关于发动机排放的标准和建议措施保持最新，并批准本议程项目附录 A 所载的修正案。

3.5.3 会议还批准工作组报告所载对《环境技术手册》第 II 卷的修订案文。

3.5.4 会议提出了以下建议，以反映会议报告 1.3.10（新的 nvPM 质量和数量排放标准和建议措施）和 1.5.2（其他修订案文）对附件 16 第 II 卷的商定修订案文：

RSPP

建议 3/1 — 对附件 16 —《环境保护》，第 II 卷 —《航空器发动机的排放物》的修订

依照本议程项目的报告附录 A 的内容修订附件 16 第 II 卷。

建议 3/2 — 使用非挥发性微粒物质（nvPM）标准

认识到 nvPM 排放审定标准是对用于 nvPM 排放审定进程的航空技术进行技术比较，并非作为运营限制或排放征税之用。

3.5.5 会议还提出以下建议，以反映 3.3.10（新的 nvPM 质量和数量排放标准和建议措施）、3.4.15（超音速航空器）和 3.5.3（其他修订案文）对《环境技术手册》第 II 卷的商定修订案文：

建议 3/3 —对《环境技术手册》第 II 卷—《航空器发动机排放审定程序》的修订

修订并出版《环境技术手册》第 II 卷和嗣后航空环境保护委员会指导小组批准修订版本并在航空环境保护委员会网站免费提供。

3.6 **对附件 16 第 III 卷和《环境技术手册》（Doc 9501 号文件）第 III 卷的拟议修订**

3.6.1 第 3 工作组共同报告员介绍了附件 16 第 III 卷的拟议修订案文和国际民航组织 Doc 9501 号文件 —《环境技术手册》第 III 卷 —《飞机二氧化碳排放合格审定程序》的拟议修订案文的报告。这些改变包括定义的改进、参考条件规范、豁免签发机构的说明、和获 CO2 审定的衍生版本的适用性等。

3.6.2 会议同意本议程项目报告附录 B 内所载第 3 工作组对附件 16 第 III 卷和工作组报告所载相应的《环境技术手册》第 III 卷的拟议修订案文。

3.6.3 **建议**

3.6.3.1 鉴于前述讨论，会议拟定了以下建议：

RSPP

建议3/4 — 对附件16 —《环境保护》，第III卷 —《飞机二氧化碳排放》的修订

依照本议程项目的报告附录B的内容修订附件16第III卷。

建议3/5 — 对《环境技术手册》第III卷 —《飞机二氧化碳排放合格审定程序》的修订

修订并出版《环境技术手册》第III卷和嗣后航空环境保护委员会指导小组批准修订版本并在航空环境保护委员会网站免费提供。

3.7 **对 Doc 9889 号文件的拟议修订**

3.7.1 第 3 工作组共同报告员介绍了国际民航组织 Doc 9889 号文件《机场空气质量手册》的拟议修订案文。修订案文涉及更新与航空器微粒物质（PM）排放（质量和数量）有关的信息，包括实际样本发动机的数据和推荐的计算方法。为航空器主发动机以及为辅助动力装置（APU）提供了信息。还审查了 Doc 9889 号文件关于颗粒质量和数量考虑因素的一致性。

3.7.2 一位成员和一位观察员对第 3 工作组取得的显着成就表示赞赏，并指出该部门需尽快发布 Doc 9889 号文件的更新案文并最好免费发布。会议同意第 3 工作组对 Doc 9889 号文件提出的拟议更新案文。

3.7.3 **建议**

3.7.3.1 鉴于前述讨论，会议拟定了以下建议：

建议3/6 — 对国际民航组织Doc 9889号文件 —《机场空气质量手册》的修订

尽快发布国际民航组织Doc 9889号文件《机场空气质量手册》的最新版本。

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附录 A

对附件 16 第 II 卷的拟议修订

修订文本是这样编排的：用横线划掉的部分表示删去的文字，灰色阴影中的部分表示新增加的文字。如下所示：

1.	~~要删去的文字用横线将其划掉~~	要删去的文字
2.	新增加的文字放在灰色阴影中标出	新增加的文字
3.	~~要删去的文字用横线将其划掉~~ 其后用灰色阴影中的文字来代替	新增加文字代替原文

国际标准和建议措施拟议修订案文

《国际民用航空公约》

附件 16
《环境保护》

第 II 卷
《航空器发动机的排放物》

第 I 部分　定义和符号

第 1 章　定义

……

发烟指数　量化烟排放的无量纲数（见附录 2 中的 3）。

设计国　对负责型号设计的机构有管辖权的国家。

起飞阶段　根据发动机以额定推力工作的时间确定的运行阶段。

滑行/地面慢车　从推进式发动机最初启动到开始起飞滑跑之间以及从跑道转出到所有推进式发动机最终关车之间的滑行和慢车运行阶段。

型号合格证　缔约国颁发的对航空器型号的设计进行界定并证明该设计符合该国的相关适航要求的文件。

注 1：在一些缔约国，可以为发动机或螺旋桨类型颁发相当于型号合格证的证件。

注 2：在一些缔约国，型号合格证也可证明设计符合该国适当的航空器发动机排放要求。

未燃烧的碳氢化合物　气体样本中所含的各类和各分子量的碳氢化合物的总和，计算时将其看做处于以甲烷形式。

……

第 III 部分　排放审定

第 1 章　管理

……

1.3　每台发动机排放物审定的证明文件应至少包括下述适用于该发动机类型的信息：

a)　审定当局的名称；

b)　制造商设定的类型与型号；

c)　为符合适用的排放物审定要求所做的补充改装说明；

d)　额定推力；

e)　基准增压比；

f)　表明符合发烟指数要求的说明；

g)　表明符合气态污染物要求的说明。；

h)　表明符合微粒物质要求的说明。

1.4　各缔约国应承认由另一缔约国审定当局发放的排放物证书有效，只要发放此种证书所依据的要求其严格度不低于本附件第 II 卷的规定。

1.5　各缔约国应承认由另一缔约国负责发动机生产组织的~~审定~~主管当局发放的~~针对发动机禁产要求的发动机~~豁免有效，前提条件是采用了可接受的过程~~只要此种豁免是按照《环境技术手册》（Doc 9501 号文件）第 II 卷《航空发动机排放审定程序》规定的过程和标准发放的~~。

注：《环境技术手册》（Doc 9501 号文件）第 II 卷 —《航空器发动机排放审定程序》中提供了关于发放豁免的可接受的过程和标准的指导。

1.6　除非本附件此卷另有规定，各缔约国用以确定本附件各项标准适用范围的日期，应是向设计国提交型号合格证申请的日期，或是根据设计国审定当局规定的等效申请程序提交申请的日期。

1.7 某一类型或型号发动机型号合格证的申请在该类型或型号发动机适用的适航规章所规定的期限内有效，审定当局同意延长该期限的特殊情况除外。在超出有效期限且延期得到批准时，用以确定本附件各项标准适用范围的日期必须为颁发型号合格证或型号设计更改批准书的日期，或根据设计国规定的等效程序签发批准书的日期，减去有效期。

第 2 章　仅用于亚音速推进的涡轮喷气和涡轮风扇发动机

2.1　概述

2.1.1　适用范围

2.1.1.1　本章规定应适用于在 2.2 和 2.3 中进一步规定的仅用于亚音速推进的所有涡轮喷气和涡轮风扇发动机，审定当局或负责发动机生产组织的主管当局发放规定豁免的下述发动机除外：

a)　1965 年 1 月 1 日前颁发了第一台基本型型号合格证或办理了其他等效规定程序的特定发动机机型及此类发动机的衍生型；和

b)　超出 2.2 和 2.3 中为单一发动机制造规定的适用日期的一特定时期有限数量的发动机。

2.1.1.2　在此情况下，审定当局或负责发动机生产组织的主管当局应颁发豁免文件，发动机铭牌上应标有"豁免新"或"豁免备份"二字，发动机的永久记录上应标注豁免许可。审定当局或负责发动机生产组织的主管当局应虑及将生产的豁免发动机的数量及其对环境的影响。应按照发动机序列号报告豁免，并通过正式公开登记册公布。

建议：审定当局或负责发动机生产组织的主管当局发放此类豁免时，应考虑对此类发动机的生产规定时间限制。

2.1.1.3　本章的规定也适用于设计用途原本可由涡轮喷气和涡轮风扇发动机实现的发动机。

注：审定当局在考虑豁免时，应该虑及这类发动机的大概生产数量及其对环境的影响。审定当局在给予此类豁免时，应该考虑对作为备份生产此类安装在新航空器上或现有航空器上的发动机规定一个时限。颁发豁免的进一步指导见《环境技术手册》（Doc 9501 号文件）第 II 卷《航空发动机排放审定程序》。

2.1.1.3 本章的规定也适用于设计用途原本可由涡轮喷气和涡轮风扇发动机实现、按照综合推进动力装置进行设计并且具有某一额定推力的发动机。

注：指导材料载于《环境技术手册》（Doc 9501 号文件）第 II 卷《航空发动机排放审定程序》。

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2.1.4 基准条件

2.1.4.1 大气条件

针对发动机性能的基准大气条件应为海平面国际标准大气，但基准绝对湿度应为 0.00634 kg 水/kg 干空气。

2.1.4.2 推力设定值

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2.2 烟

2.2.1 适用范围

2.2.2 的规定应适用于：

a) 制造日期为 1983 年 1 月 1 日或之后以及 2023 年 1 月 1 日之前的发动机；和

b) 最大额定推力小于或等于 26.7kN 且其制造日期为 2023 年 1 月 1 日或之后的发动机。

2.2.2 规定发烟指数

四种着陆和起飞运行模式中任何一种模式的推力设定值下的发烟指数，当按照附录 2 的程序或审定当局同意的等效程序测量和计算并按照附录 6 中的程序转换成特征值时，不得超过用下列公式算出的值：

规定发烟指数 = 83.6 （F_{oo}）$^{-0.274}$

或一个 50 的值，取其中低者

注：等效程序的定义和使用的指导材料见《环境技术手册》（Doc 9501 号文件）第 II 卷《航空发动机排放审定程序》。

2.3 气态排放物

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2.3.2 规定等级

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e) 对于其首台单独生产型号的制造日期在 2014 年 1 月 1 日或之后且在 2022 年 12 月 31 日或 2023 年 1 月 1 日之前提交型号合格证申请的某一类型或型号的发动机：

1) 对于增压比为 30 或以下的发动机：

i) 对于最大额定推力大于 89.0 kN 的发动机：

$$D_p / F_{oo} = 7.88 + 1.4080\pi_{oo}$$

ii) 对于最大额定推力大于 26.7 kN 但不大于 89.0 kN 的发动机：

$$D_p / F_{oo} = 40.052 + 1.5681\pi_{oo} – 0.3615F_{oo} – 0.0018\pi_{oo}F_{oo}$$

2) 对于增压比大于 30 但小于 104.7 的发动机：

i) 对于最大额定推力大于 89.0 kN 的发动机：

$$D_p / F_{oo} = –9.88 + 2.0\pi_{oo}$$

ii) 对于最大额定推力大于 26.7 kN 但不大于 89.0 kN 的发动机：

$$D_p / F_{oo} = 41.9435 + 1.505\pi_{oo} – 0.5823F_{oo} + 0.005562\pi_{oo} F_{oo}$$

3) 对于增压比为 104.7 或以上的发动机：

$$D_p / F_{oo} = 32 + 1.6\pi_{oo}$$

f) 对于 2023 年 1 月 1 日或之后提交型号合格证申请的某一类型或型号的发动机：

1) 对于增压比为 30 或以下的发动机：

i) 对于最大额定推力大于 89.0 kN 的发动机：

$$D_p / F_{oo} = 7.88 + 1.4080\pi_{oo}$$

ii) 对于最大额定推力大于 26.7 kN 但不大于 89.0 kN 的发动机：

$$D_p / F_{oo} = 40.052 + 1.5681\pi_{oo} – 0.3615F_{oo} – 0.0018\pi_{oo}F_{oo}$$

2) 对于增压比大于 30 但小于 104.7 的发动机：

i) 对于最大额定推力大于 89.0 kN 的发动机：

$D_p / F_{oo} = -9.88 + 2.0\pi_{oo}$

ii) 对于最大额定推力大于 26.7 kN 但不大于 89.0 kN 的发动机：

$D_p / F_{oo} = 41.9435 + 1.505\pi_{oo} - 0.5823F_{oo} + 0.005562\pi_{oo} F_{oo}$

3) 对于增压比为 104.7 或以上的发动机：

$D_p / F_{oo} = 32 + 1.6\pi_{oo}$

注：等效程序的定义和使用的指导材料见《环境技术手册》（Doc 9501 号文件）第 II 卷《航空发动机排放审定程序》。

2.4 所需信息

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第 4 章 微粒物质排放

4.1 概述

4.1.1 适用范围

4.1.1.1 如 4.2 节中进一步规定的，本章规定应适用于~~向审定当局提交型别审定申请的~~仅用于亚音速推进的所有航空器发动机。

4.1.1.2 针对相关发动机类别的具体规定应按照第 4.2 节所述的内容加以适用，但以下情况例外：负责发动机生产组织的审定当局或主管当局在 4.2 节中针对单个发动机的生产而规定的适用日期之后的特定时间内给予有限数量的发动机以豁免。

4.1.1.3 在此情况下，负责发动机生产组织的审定当局或主管当局应颁发豁免文件，发动机铭牌上应标有“豁免”，发动机的永久记录上应标注豁免许可。负责发动机生产组织的审定当局或主管当局应考虑到将被生产的、被豁免的发动机的数量以及它们对环境的影响。应按照发动机序列号报告豁免，并通过正式公开登记册公布。

建议：负责发动机的生产组织的审定当局或主管当局在给予此类豁免时，应该考虑对此类发动机的生产规定一个时限。

注：颁发豁免的进一步指导见《环境技术手册》（Doc 9501 号文件）第 II 卷《航空发动机排放审定程序》。

4.1.2 涉及的排放物

本节的目的是控制非挥发性微粒物质（nvPM）排放。

4.1.3 计量单位

4.1.3.1 非挥发性微粒物质质量~~（$nvPM_{mass}$）~~浓度应以~~μg~~micrograms/m^3为单位计量和报告。

4.1.3.2 4.1.4.2 中界定的在基准排放着陆和起飞（LTO）循环中排放的非挥发性微粒物质质量（LTO_{mass}）应以毫克为单位计量和报告。

4.1.3.3 4.1.4.2 中界定的在基准排放着陆和起飞（LTO）循环中排放的非挥发性微粒物质数量（LTO_{num}）应以微粒数量为单位计量和报告。

4.1.4 基准条件

4.1.4.1 大气条件

对于基准标准发动机，基准大气条件应为海平面国际标准大气，但基准~~绝对~~湿度应为 0.00634 kg 水/kg 干空气。

4.1.4.2 基准排放着陆和起飞（LTO）循环

发动机应在足够的推力设定值上进行测试，以确定发动机的非挥发性微粒物质排放，从而可使用~~下述特定百分比的额定推力~~基准排放着陆和起飞循环推力设定值以及经审定当局同意的可产生最大 nvPM~~mass~~质量浓度、最大 EI_{mass} 和最大 EI_{num} 的推力来确定非挥发性微粒物质质量排放指数（EI_{mass}）和非挥发性微粒物质数量排放指数（EI_{num}）~~：~~。

为计算和报告 nvPM 排放，应使用以下推力设定值和以下每个运行模式的时间来表示基准排放着陆和起飞循环：

着陆和起飞运行模式	推力设定值 Foo 百分比	运行模式的时间 分钟
起飞	100% Foo	0.7
爬升	85% Foo	2.2
进近	30% Foo	4.0
滑行/地面慢车	7% Foo	26.0

4.1.4.3 燃料规范

测试期间使用的燃料应符合附录 4 的规范。

4.1.5 测试条件

4.1.5.1 测试时应将发动机置于测试台上。

4.1.5.2 发动机应是经审定的构型（见附录 6）的代表；不得模拟除发动机基本运行所需以外的引气和附件荷载。

4.1.5.3 当测试条件不同于 4.1.4.1 中的基准大气条件时，应根据附录 7 的程序，按基准大气条件下的发动机燃烧室进口温度对 EI_{mass} 和 EI_{num} 进行修正。

4.1.5.4 根据附录 7 的程序，针对采样系统收集部分中的稀释和热泳损失对最大 $nvPM_{mass}$ 质量浓度进行修正。以及根据附件 7 的程序，针对采样系统收集部分中的热泳损失和燃料构成对 EI_{mass} 和 EI_{num} 进行修正。

4.2 非挥发性微粒物质排放

4.2.1 适用范围

4.2.1.1 4.2.2 和 4.2.3 中进一步明确的规定应适用于某一类型或型号的额定推力大于 26.7 kN 且在 2020 年 1 月 1 日或之后生产的所有涡轮风扇和涡轮喷气发动机及其衍生产品。

4.2.1.2 本章的规定也适用于设计用途原本可由涡轮喷气和涡轮风扇发动机实现的发动机，以及设计为综合推进式动力装置并经额定推力认证的发动机。

4.2.2 规定限值

4.2.2.1 非挥发性微粒物质质量 最大浓度

对于单个的、生产日期为 2020 年 1 月 1 日或之后的发动机而言，以可以确定最大排放量的方式在足够的推力设定值下测量获得的、按照附录 7 中的程序加以计算的，并按照附录 6 中的程序或审定当局同意的等效程序转换成特征值的最大 $nvPM_{mass}$ 质量浓度 [μg/m³]，不得超过根据下列公式确定的规定限值：

$$nvPM_{mass}\text{浓度质量密度规定限值} = 10^{(3+2.9F_{oo}^{-0.274})}$$

注：因为 nvPM 质量密度与发烟指数相互关联，4.2.2.1 中的规定限值源自发烟指数规定限值。进一步的信息见《环境技术手册》（Doc 9501 号文件）第 II 卷《航空发动机排放审定程序》。

4.2.2.2 基准排放着陆和起飞循环中的 nvPM 质量与数量

当按照附录 7 中的程序测量和计算 nvPM 质量和数量排放等级并按照附录 6 中的程序或审定当局同意的等效程序转将它们换成特征值时，不得超过用下列公式算出的规定限值：

a) LTO_{mass}:

1) 单台发动机的制造日期为 2023 年 1 月 1 日或之后的某一类型或型号的发动机：

i) 最大额定推力大于 200kN 的发动机：

$LTO_{mass}/F_{oo} = 347.5$

ii) 最大额定推力大于 26.7kN 但不超过 200kN 的发动机：

$LTO_{mass}/F_{oo} = 4646.9 – 21.497F_{oo}$

2) 于 2023 年 1 月 1 日或之后提交型号合格证申请的某一类型或型号的发动机：

i) 最大额定推力大于 150kN 的发动机：

$LTO_{mass}/F_{oo} = 214.0$

ii) 最大额定推力大于 26.7kN 但不超过 150kN 的发动机：

$LTO_{mass}/F_{oo} = 1251.1 – 6.914F_{oo}$

b) LTO_{num}:

1) 单台发动机的制造日期为 2023 年 1 月 1 日或之后的某一类型或型号的发动机：

i) 最大额定推力大于 200kN 的发动机：

$LTO_{number}/F_{oo} = 4.170 \times 10^{15}$

ii) 最大额定推力大于 26.7kN 但不超过 200kN 的发动机：

$LTO_{number}/F_{oo} = 2.669 \times 10^{16} – 1.126 \times 10^{14}F_{oo}$

2) 于 2023 年 1 月 1 日或之后提交型号合格证申请的某一类型或型号的发动机：

i) 最大额定推力大于 150kN 的发动机：

$LTO_{number}/F_{oo} = 2.780 \times 10^{15}$

ii) 最大额定推力大于 26.7kN 但不超过 150kN 的发动机：

$LTO_{number}/F_{oo} = 1.490 \times 10^{16} – 8.080 \times 10^{13} F_{oo}$

4.2.3　报告要求

制造商应报告按照附录 7 中的程序或审定当局同意的任何等效程序测量和计算出的下述几个非挥发性微粒物质排放值：

~~a)　最大 $nvPM_{mass}$ 浓度的特征值（μg/m3）；~~

~~b)　着陆和起飞循环的每一推力设定值下的燃料流量（kg/s）；~~

~~c)　着陆和起飞循环的每一推力设定值下的 EI_{mass}（mg/kg 燃料）；~~

~~d)　着陆和起飞循环的每一推力设定值下的 EI_{num}（微粒/kg 燃料）；~~

~~e~~a)　最大 EI_{mass}（~~mg~~milligrams/kg 燃料）；和

~~f~~b)　最大 EI_{num}（微粒/kg 燃料）。

4.3　所需信息

注：所需的信息分为~~二~~三组：1) 用于识别发动机特性、所用燃料和数据分析方法的一般信息；~~和~~ 2) 发动机测试产生的数据；和 3) 导出信息。

4.3.1　一般信息

应为寻求排放审定的每一发动机类型提供下列信息：

a)　发动机识别信息；

b)　额定推力（千牛顿）；

c)　基准增压比；

d)　燃料规范基准；

e)　燃料氢/碳比；

f)　数据获取方法；和

~~g)　针对采样系统收集部分中的热泳损失进行修正的方法；和~~

~~h)~~g)　数据分析方法。

4.3.2 测试信息

4.3.2.1 对于每一进行审定测试的发动机，都应提供以下信息~~每一次测试都应报告下列信息~~：

a) 燃料净热值（MJ/kg）；

b) 燃料中的氢含量（质量的%）；

c) 燃料中的总芳烃含量（体积的%）；

d) 燃料中的萘类含量（体积的%）；和

e) 燃料中的硫含量（质量的百万分率~~%~~）。

4.3.2.2 对于每一进行审定测试的发动机，都应提供按照附录 7 中的程序或审定当局同意的任何等效程序测量和计算的以下信息：

a) 着陆和起飞循环的每一推力设定值下的燃料流量（kg/s）；

b) 着陆和起飞循环的每一推力设定值下的 EImass（milligram/kg 燃料）；

c) 着陆和起飞循环的每一推力设定值下的 EInum（微粒/kg 燃料）。

4.3.3 导出信息

4.3.3.1 对于每一进行审定测试的发动机，应提供下列导出信息：

a) nvPM 质量的排放率，即排放指数×燃料流量（毫克/秒）；

b) nvPM 数量的排放率，即排放指数×燃料流量（微粒/秒）；

c) 在着陆起飞循环中测得的 nvPM 质量的排放总量（毫克）；

d) 在着陆起飞循环中测得的 nvPM 数量的排放总量（微粒）；

e) LTO_{mass} / F_{oo} 值（毫克/kN）；

f) LTO_{num} / F_{oo} 值（微粒/kN）；和

g) nvPM 最大质量密度（微克/m^3）。

4.3.3.2 应为 nvPM 最大质量密度提供特征值，以及应为寻求排放审定的每一发动机类型提供 LTO_{mass}/F_{oo} and the LTO_{num}/F_{oo}。

第 IV 部分　为制定清单和模拟之目的进行非挥发性微粒物质评估

注 1：本部分的目的是提供关于如何针对除收集部分热泳损失之外的非挥发性微粒物质系统损失计算非挥发性微粒物质质量和数量修正因子。非挥发性微粒物质系统、收集部分以及热泳损失的计算在附录 7 中进行了阐述。

注 2：通过非挥发性微粒物质质量和数量系统损失修正因子可以根据附录 7 的程序获得的非挥发性微粒物质质量和数量浓度估算航空器发动机排气处的非挥发性微粒物质质量和数量浓度。

根据附录 8 中的程序或审定当局同意的等效程序，对于第 III 部分第 4 章所述的、且其单台发动机的制造日期为 2023 年 1 月 1 日或之后的某一类型或型号的发动机来说，应向审定当局报告 nvPM 质量和 nvPM 数量系统损失修正因子（$k_{SL\ mass}$和 $k_{SL\ number}$）以及针对系统损失而修正的 EI_{mass}和 EI_{number}。

~~**建议 1：**为制定清单和模拟之目的，航空器涡轮发动机制造商应该使用附录 8 所述的方法确定非挥发性微粒物质质量和非挥发性微粒物质数量系统损失修正因子（k_{SL_mass}和 k_{SL_num}），并且应该向相关当局报告这些因子。~~

建议 ~~2~~：为制定清单和模拟之目的，应该使用附录 8 所述的方法，针对系统损失对根据附录 7 的程序获得的非挥发性微粒物质质量和非挥发性微粒物质数量~~浓度~~排放进行修正。

……

附录 2　烟排放评估

……

2.　烟排放的测量

2.1　烟排放的采样探头

采样探头必须满足以下要求：

a）　与排气排放样本接触的探头材料应是不锈钢或是其他非反应性材料。

b）　如果使用多孔采样探头~~，~~：

1)　则所有采样孔应具有相等直径~~。~~；和

2)　采样探头设计应保证至少通过探头组件压力降的 80%发生在孔口处。

c）　采样位置数不得少于 12 个。

……

2.3 烟分析系统

注：这里描述的方法基于对某一滤芯在被给定质量的排气样本流沾污时造成的反射率下降进行的测量。

为获取必要的被沾污的滤芯样本所用的系统其各个部件应按图 A2-1 中以简图形式显示的方式排列。为便于读表，可以绕过体积表安装一个备选旁通管。系统的主要部件应满足下列要求：

……

e) 真空泵：此泵应具备相对于大气压力–75 kPa 的无流真空能力；其~~正常~~标准温度和压力下的全流速不得少于 ~~28~~26 L/min；

……

i) 渗漏性：子系统应满足下述测试的要求：

1） 将洁净的滤芯材料卡在芯筒内，

2） 关闭活门 A，全开活门 B，C 和 D，

3） 将真空泵运转一分钟以达到平衡状态；

4） 继续打泵并测量五分钟内通过流量表的~~体积流量~~流速。此~~体积~~流速不得超过 ~~5~~1 L/min（按~~正常~~标准温度和压力），并且在此标准达到之前不得使用系统。

……

2.5 烟测量程序

……

2.5.2 渗漏和洁净检查

只有在全部样本传输管路和活门预热并达到稳定后，才应进行测量。做系列测试前，应按如下所述检查系统是否渗漏和洁净：

a） 渗漏检查：隔离探头，堵住样本管路端头，按 2.3 h）的规定进行渗漏测试，只是活门 A 要打开并置于“旁通”位，活门 D 要关闭且渗漏极限为 ~~2~~0.4 升/min（按标准温度和压力）。恢复探头与管路的互连；

……

附录 3　用于气态排放物的仪器和测量技术

……

5.1　采样系统

5.1.1　采样探头

采样探头必须满足以下要求：

a)　与排气排放物样本接触的探头材料应是不锈钢或其他非反应性材料。

b)　如果使用多孔采样探头：；和

1)　则所有采样孔应具有相等直径。；和

2)　采样探头设计应保证至少通过探头组件压力降的 80%发生在孔口处。

c)　采样位置数不得少于 12 个。

……

6.3　运行

6.3.1　只有在全部仪器和样本传输管路预热并达到稳定，且完成了下述检查后，才能进行测量：

a)　渗漏检查：在做一系列测试前，应检查系统是否渗漏，方法是隔离探头和分析仪，连接并操作一个~~性能类似于烟测量系统所用真空泵的~~真空泵，以证实系统在~~正常~~标准温度和压力下的渗漏流速小于 0.4 L/min。此真空泵应具备相对于大气压力–75 kPa 的无流真空能力；其正常温度和压力下的全流速不得少于 26 L/min；

b)　洁净度检查：将气体采样系统与探头隔离，并将采样管端头与零气源相连接。将系统预热到做碳氢化合物测量所需的工作温度。操作样本流量泵，并把流速调到进行发动机排放物测试时所用的流速。记录碳氢化合物分析仪的读数。此读数不得超过发动机慢车排放水平的 1%或 1 ppm（二者均表示为甲烷），取其中大者。

……

附录 4 用于航空器涡轮发动机排放测试的燃料规范

除审定当局同意的偏离和必要的修正外，测试期间使用的燃料应符合本附录的规格。不得出现为抑制烟雾而使用的添加剂（如有机金属化合物）。

性质	值的许可范围
15℃时的密度 kg/m^3	780 – 820
蒸馏温度，℃	
10%沸点	155 – 201
最终沸点	235 – 285
燃烧净热值，MJ/kg	42.86 – 43.50
芳烃含量，体积 %	15 – 23
萘烃含量，体积 %	0.0 – 3.0
烟点，mm	20 – 28
氢，质量 %	13.4 – 14.3
硫，质量的百万分率 ~~%~~	小于 ~~0.~~3000
-20℃时的动力黏度，mm^2/s	2.5 – 6.5

……

附录 6 气态排放物、烟和微粒物质排放物的符合性程序

1. 概述

……

2. 符合性程序

2.1 气态排放物和发烟指数

如果实测的并经修正（按基准标准发动机和基准外界条件）的所有测试发动机各个数值的平均值在使用根据表 A6-1 所示的测试发动机数量（i）所确定的适当系数转换成某一特征值时不超过规定数值，则审定当局应发予符合性证书。

注：发烟指数或气态排放物的特征值是所有测试发动机的实测并且仅就气态排放物而言，根据基准标准发动机和基准大气条件做适当修正后的平均值，除以表 A6-1 所示的对应于测试发动机数量的系数之后得到的数值。

表 A6-1　用于确定特征值的系数

测试发动机数量（i）	一氧化碳	碳氢化合物	氮氧化物	发烟指数	非挥发性微粒物质质量浓度	着陆和起飞时非挥发性微粒物质质量	着陆和起飞时非挥发性微粒物质数量
1	0.814 7	0.649 3	0.862 7	0.776 9	0.776 9	0.719 4	0.719 4
2	0.877 7	0.768 5	0.909 4	0.852 7	0.852 7	0.814 8	0.814 8
3	0.924 6	0.857 2	0.944 1	0.909 1	0.909 1	0.885 8	0.885 8
4	0.934 7	0.876 4	0.951 6	0.921 3	0.921 3	0.901 1	0.901.1
5	0.941 6	0.889 4	0.956 7	0.929 6	0.929 6	0.911 6	0.911 6
6	0.946 7	0.899 0	0.960 5	0.935 8	0.935 8	0.919 3	0.919 3
7	0.950 6	0.906 5	0.963 4	0.940 5	0.940 5	0.925 2	0.925 2
8	0.953 8	0.912 6	0.965 8	0.944 4	0.944 4	0.930 1	0.930 1
9	0.956 5	0.917 6	0.967 7	0.947 6	0.947 6	0.934 1	0.934 1
10	0.958 7	0.921 8	0.969 4	0.950 2	0.950 2	0.937 5	0.937 5
10 台以上	$1-\frac{0.130\,59}{\sqrt{i}}$	$1--\frac{0.247\,24}{\sqrt{i}}$	$1-\frac{0.096\,78}{\sqrt{i}}$	$1-\frac{0.157\,36}{\sqrt{i}}$	$1-\frac{0.157\,36}{\sqrt{i}}$	$1-\frac{0.197\,78}{\sqrt{i}}$	$1-\frac{0.197\,78}{\sqrt{i}}$

2.2　微粒物质排放物

2.2.1　如果实测的并根据采样系统收集装置内的热泳损失进行过修正的所有接受测试发动机的最大非挥发性微粒物质质量浓度值的平均值在使用根据表 A6-1 所示的由接受测试发动机的数量（i）所确定的适当系数转换成某一特征值后不超过规定数值，则审定当局应发予符合性证书。

注：最大非挥发性微粒物质质量浓度的特征值是实测所得并根据取样系统收集装置内的热泳损失进行过适当修正的所有接受测试发动机的最大值的平均值，除以表 A6-1 所示的与接受测试发动机的数量相对应的系数后得到的数值。

2.2.2　如果实测的并根据采样系统收集装置内的热泳损失和燃料构成进行过修正的所有接受测试发动机的非挥发性微粒物质质量的平均值以及非挥发性微粒物质数量排放物的平均值在使用根据表 A6-1 所示的由接受测试发动机的数量 (i) 所确定的适当系数转换成某一特征值后不超过规定数值，则审定当局应发予符合性证书。

注：非挥发性微粒物质质量和非挥发性微粒物质数量排放物的特征值为所有接受测试、并根据采样系统收集装置内的热泳损失和燃料构成进行过适当修正的所有发动机的平均值，这些平均值由与接受测试发动机的数量相对应的系数所划分，如表 A6-1 所示。

2.3 特征值

确定发动机排放物特征值所需的系数，见表 A6-1。

3. 失败时的程序

注：在审定测试失败时，并不一定意味着该发动机型号不符合要求，但可能意味着向审定当局提供的符合性可信度不够高，即低于百分之九十。因此，应该允许制造商提供发动机型号符合性的补充证据。

……

附录 7 用于非挥发性微粒物质排放的仪器和测量技术

1. 引言

……

2.3 符号

……

EI_{mass}	针对热泳损失和燃料构成修正后的非挥发性微粒物质质量排放指数，以 mg/kg 燃料为单位
EI_{num}	针对热泳损失和燃料构成修正后的非挥发性微粒物质数量排放指数，以数量/kg 燃料为单位
F	特定运行模式下的推力
H	燃料中的氢含量（质量百分比）
[HC]	湿排气样本中碳氢化合物的平均体积比气体浓度，表示为碳
η_{VPR}（D_m）	用于 D_m 微粒的挥发性微粒去除器的微粒渗透分数
k_{fuel_M}	针对非挥发性微粒物质质量排放指数的燃料构成修正因子
k_{fuel_N}	针对非挥发性微粒物质数量排放指数的燃料构成修正因子
k_{thermo}	收集部分热泳损失修正因子

……

4. 非挥发性微粒物质采样和测量系统的总体布置

4.1 非挥发性微粒物质采样和测量系统

……

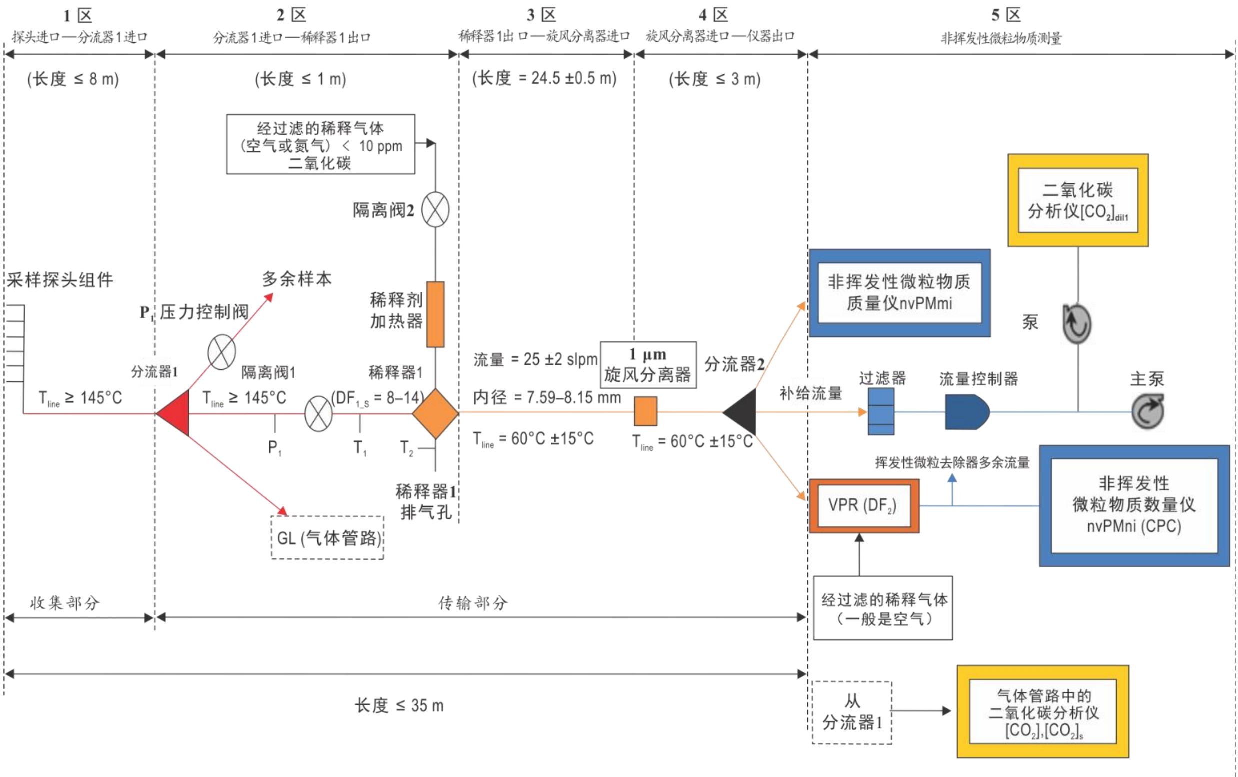

图 A7-1 非挥发性微粒物质采样和测量系统示意图

……

4.2 收集部分

4.2.1 1 区是由探头/耙状硬件和连接线组成。它应满足如下要求：

a) 采样探头材料应是不锈钢或其他非反应性耐高温材料。

b) 如果使用多孔采样探头，：

1) 则所有采样孔应具有相等直径。；和

2) 采样探头的设计应保证通过采样探头组件的压力降至少 80%发生在孔口处。

c) 采样位置数不得少于 12 个。

……

6.　计算

6.1　非挥发性微粒物质质量浓度和非挥发性微粒物质质量和数量排放指数方程式

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6.1.1　非挥发性微粒物质质量浓度

非挥发性微粒物质质量浓度（$nvPM_{mass}$）代表针对第一阶段稀释因子（DF_1）和收集部分热泳微粒损失进行修正后每单位体积发动机排气样本中的微粒质量。可通过下面的方程式计算这一浓度：

$$nvPM_{mass} = DF_1 \times nvPM_{mass\_STP} \times k_{thermo}$$

6.1.2　非挥发性微粒物质质量和数量排放指数

非挥发性微粒物质质量和数量排放指数（EI_{mass} 和 EI_{num}）代表针对各自的稀释因子~~和~~、收集部分热泳微粒损失和它们各自的燃料构成修正因子进行修正后每单位质量的燃料消耗（以千克为单位）中发动机排气微粒的质量（以毫克为单位）和数量。可通过下面的方程式计算这些指数：

$$EI_{mass} = \frac{22.4 \times nvPM_{mass\_STP} \times 10^{-3}}{\left([CO_2]_{dil1} + \frac{1}{DF_1}([CO] - [CO_2]_b + [HC])\right)(M_C + \alpha M_H)} \times k_{thermo} \times k_{fuel\_M}$$

$$EI_{num} = \frac{22.4 \times DF_2 \times nvPM_{num\_STP} \times 10^{6}}{\left([CO_2]_{dil1} + \frac{1}{DF_1}([CO] - [CO_2]_b + [HC])\right)(M_C + \alpha M_H)} \times k_{thermo} \times k_{fuel\_N}$$

$[CO_2]$、$[CO]$ 和 $[HC]$ 应按附录 3 附篇 E 所示进行计算。

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6.2　非挥发性微粒物质排放的修正因子

6.2.1　收集部分中非挥发性微粒物质热泳损失的修正

……

6.2.2　针对燃料构成的修正

针对燃料构成的修正应使用以下公式来确定：

$$k_{fuel\_M} = exp\left\{\left(1.08\frac{F}{F_{00}} - 1.31\right)(13.8 - H)\right\}$$

$$k_{fuel\_N} = exp\left\{\left(0.99\frac{F}{F_{00}} - 1.05\right)(13.8 - H)\right\}$$

……

附录 7 附篇 A　关于非挥发性微粒物质采样系统的要求和建议

……

4.2　分流器 2

分流器 2 应满足如下要求：

a)　分流器 2 本体材料应为不锈钢。

b)　分流器 2 应加热到 60℃±15℃。

c)　分流器 2 应将样本分成三个流路以便将稀释的非挥发性微粒物质样本送至：

　1)　非挥发性微粒物质质量仪；

　2)　挥发性微粒去除器；和

　3)　补给流量。

d)　相对于输入流的分流角应具有切合实际的锐度，但不得超过 35°。

e)　所有非挥发性微粒物质流路应尽可能~~直通并尽可能~~短。

……

附录 7 附篇 E　系统运行程序

1.　收集部分和气体管路渗漏检查

1.1　渗漏检查程序

在进行一系列发动机测试之前，应按如下程序检查收集部分和气体管路是否渗漏：

a)　使用隔离阀 1、P_1 压力控制阀以及可选择的切断阀（如果安装）将气体管路与非挥发性微粒物质测量部分隔离开；

b)　隔离探头和分析仪；

c)　连接并操作真空泵，以证实渗漏流速。

d)　真空泵应具备相对于大气压力–75 kPa 的无流真空能力；其~~正常~~标准温度和压力下的全流速不得小于 ~~28~~26 L/min。

1.2 渗漏检查要求

2. 收集部分和气体管路洁净度检查

只有使用完全的气体非挥发性微粒物质 EI 计算方法才可以进行这一检查。

2.1 洁净度检查程序

应按如下程序对收集部分和气体管路进行洁净度检查：

a) 使用隔离阀 1 和 P1 压力控制阀将气体管路与非挥发性微粒物质测量部分隔离开；

b) 将气体管路与探头隔离开，并将该采样管路端头与零气源相连接；

c) 将系统加热至进行碳氢化合物测量所需的工作温度；

d) 操作样本流量泵，并将流速调至进行发动机排放测试时所用的流速。

e) 记录碳氢化合物分析仪的读数。

2.2 洁净度检查要求

2.2.1 碳氢化合物读数不应超过发动机慢车排放水平的 1%或者 1 ppm（二者均表示为碳），以其中大者为准。

2.2.2 **建议：**建议在发动机测试开始和结束时以及在测试中以至少每小时一次的频率进行进气质量监控。如果认为碳氢化合物的量很大，则应该加以注意。

3. 洁净度/渗漏检查转让部分

……

附录 8 估算非挥发性微粒物质系统损失修正的程序

注 1：本附录所述的程序涉及非挥发性微粒物质（nvPM）采样和测量系统损失修正因子的确定，但不包括附录 7 数据报告中所包含的收集部分热泳损失。

注 2：非挥发性微粒物质采样和测量系统的实施需要最长达 35 m 的一条很长的采样管路，并且包含若干采样和测量系统组件，这可能会导致大量的微粒损失，其中非挥发性微粒物质质量可能损失约 50%，非挥发性微粒物质数量可能损失约 90%。微粒的损失量与尺寸相关，因此取决于发动机的运行条件、燃烧室技术，可能还有其他因素。通过本附录所述的程序可以对微粒损失进行估算。

注 3：对系统损失修正因子的估算是基于下列假设的：发动机排气出口面的非挥发性微粒物质呈对数正态分布，非挥发性微粒物质有效密度为一个常数、几何标准差为一个固定值，将非挥发性微粒物质质量浓度限制在检测极限，最小粒径的界限为 0.01μm，无凝结。

注 43：本附录中提出的方法使用了附录 7 及其附录 7 附篇所述的数据和测量结果。未在本附录中加以定义的符号和定义见附录 7 及其附篇附篇。

1. 概述

1.1 在非挥发性微粒物质采样和测量系统中，微粒会因沉积机理而损失在采样系统管壁上。这些损失有的与粒径相关，有的不相关。与粒径不相关的收集部分的热泳损失在附录 7 的 6.2.1 中进行了说明。

1.2 非挥发性微粒物质采样和测量系统的整体微粒损失（收集部分的热泳损失除外）被称为系统损失。

1.3 需要将非挥发性微粒物质的粒径分布考虑在内，因为微粒损失机理是与粒径相关的。这种与粒径相关的损失可量化为渗透出采样和测量系统的给定粒径颗粒含量。

2. 定义、缩略语和符号

2.1 定义

下列词语在本附录中使用时，具有赋予它们的如下含义：

微粒的空气动力学直径 单位密度（1g/cm^3）的等效球体达到与实际微粒相同的最终沉降速度时的直径，也称为“经典空气动力学直径”。

具备相关资质的实验室 根据不时修订的国际标准化组织标准 ISO/IEC 17025:2005 或等效标准建立、实施和维护一个与其活动范围相称的质量体系的测试和校准实验室，该实验室设计和实施一项设备校准方案，以确保其进行的校准和测量都可追溯到国际单位制（SI）。该实验室不需要通过 ISO/IEC 17025:2005 正式认证。

旋风分离器 通过旋转和重力手段将大于规定的空气动力学直径的微粒分离出去。规定的空气动力学切割粒径与穿透旋风分离器的~~特定大小的~~微粒百分比相关。

微粒的电迁移直径 在电场中达到与实际微粒完全相同的运动速度的球体的直径。

非挥发性微粒物质（nvPM） 存在于燃气涡轮发动机排气管出口平面、当加热到 350℃时不挥发的排放微粒。

微粒损失 微粒在输送通过采样或测量系统成分过程中的或因仪器性能造成的损失。~~这种~~采样和测量系统损失是由各种不同的沉积机理引起的，其中一些机理与粒径相关。

微粒质量浓度 每单位样本体积的微粒质量。

微粒质量排放指数 所用的每单位燃料质量排放的微粒质量。

微粒数量浓度 每单位样本体积的微粒数量。

微粒数量排放指数 所用的每单位燃料质量排放的微粒数量。

粒径分布 一个数值列表或数学函数，其按照粒径来表示微粒数量浓度。

渗透分数 采样系统某一组件下游微粒浓度与上游微粒浓度之间的比值。

2.2 缩略语

CPC	凝聚微粒计数器
EENEP	发动机排气管出口平面
nvPMmi	非挥发性微粒物质质量仪
nvPMni	非挥发性微粒物质数量仪

nvPM	非挥发性微粒物质（见定义）
slpm	每分钟标准升（在标准温度和压力条件下每分钟的升数）
STP	在标准温度为 0℃、压力为 101.325 kPa 下的仪器条件
VPR	挥发性微粒去除器

2.3 符号

C_c	$1+\frac{2\lambda}{D_m}\times（1.165+0.483\times e^{-\frac{0.997D_m}{2\lambda}}）$，无量纲的 Cunningham 滑动修正因子
D	$\frac{k_B\times（273.15+T_i）\times C_c}{3\times\pi\times\mu\times D_m}\times 10^7$，微粒扩散系数，$cm^2/s$
DF_1	第一阶段稀释因子
DF_2	经校准的第二阶段（挥发性微粒去除器）稀释因子
D_m	非挥发性微粒物质的电迁移微粒直径，指的是电迁移直径，但微粒直径为空气动力学直径的旋风分离器的情况除外，μmnm
D_{mg}	非挥发性微粒物质粒径分布的几何平均直径，μmnm
δ	测量的和计算的稀释修正非挥发性微粒物质质量和数量浓度之间的相对差异的平方和
EI_{mass}	针对收集部分热泳损失修正后的非挥发性微粒物质质量排放指数，以 mg/kg 燃料为单位
EI_{num}	针对收集部分热泳损失修正后的非挥发性微粒物质数量排放指数，以数量/kg 燃料为单位
ε	收敛准则（1×10^{-9}）
$f_{lgn}(D_m)$	含有几何标准差 σ_g 和几何平均直径 D_{mg} 参数的对数正态分布函数
$f_N(D_m)$	发动机排气管出口平面微粒数量对数正态分布函数
ID_{ti}	采样管路第 i 段的内径，mm
k_B	1.3806×10^{-16}，玻尔兹曼常数，$(g\cdot cm^2)/(s^2\cdot K)$

k_{SL_mass} 未进行收集部分热泳损失修正的系统损失 ~~EImass~~EI_{mass} 修正因子~~，μg/m3~~

k_{SL_num} 未进行收集部分热泳损失修正的系统损失 ~~EInum~~EI_{num} 修正因子~~，数量/cm³~~

k_{thermo} 附录 7 的 6.2.1 所述的收集部分热泳损失修正因子

λ $67.3 \sout{\times 10^{-3}} \times \left(\frac{273.15+T_i}{296.15}\right)^2 \times \left(\frac{101.325}{P_i}\right) \times \left(\frac{406.55}{T_i+383.55}\right)$，载气平均自由程，~~μm~~nm

μ 载气黏度，g/cm s

~~$nvPM_{mass\_EST}$ 未稀释的（即经稀释修正后的）仪表质量浓度估算值，μg/m³~~

~~$nvPM_{num\_EST}$ 未稀释的（即经稀释修正后的）仪表数量浓度估算值，数量/cm³~~

~~$nvPM_{mass\_EP}$ 本附录第 4 节所述的未针对收集部分热泳损失进行修正的发动机排气管出口平面的非挥发性微粒物质质量浓度估算值。~~

~~$nvPM_{num\_EP}$ 本附录第 4 节所述的未针对收集部分热泳损失进行修正的发动机排气管出口平面的非挥发性微粒物质数量浓度估算值。~~

$nvPM_{mass\_STP}$ 在标准温度和压力仪器条件下稀释的非挥发性微粒物质质量浓度，μg/m³

$nvPM_{num\_STP}$ 在标准温度和压力仪器条件下稀释的非挥发性微粒物质数量浓度，数量/cm³

η_{mass}（D_m） 未包含收集部分热泳损失的电迁移粒径 D_m 的非挥发性微粒物质质量整体采样和测量系统渗透分数

η_{num}（D_m） 未包含收集部分热泳损失的电迁移粒径 D_m 的非挥发性微粒物质数量整体采样和测量系统渗透分数

ηi（D_m） 采样和测量系统第 i 组件的电迁移粒径 D_m 的渗透分数

ηbi（D_m） 采样和测量系统第 i 组件采样管路弯折处的电迁移粒径 D_m 的渗透分数

P_i 采样管路第 i^{th} 部分的载气压力，kPa

ρ 假定的非挥发性微粒物质有效密度，g/cm³

σ_g 假定的对数正态分布几何标准差

Q_i 采样管路第 i 段的载气流，slpm

Re	$\frac{2\times\rho_{gas}\times Q_i}{3\times\pi\times\mu\times ID_{ti}}$，载气雷诺数
$R_{MN}(D_m)$	计算得出的非挥发性微粒物质质量浓度估算值与非挥发性微粒物质数量浓度估算值的比例
T_i	采样管路第 i 段的载气温度，℃

3. 非挥发性微粒物质质量和数量排放指数的修正因子

3.1 **建议：**系统损失的 EI_{mass} 修正因子是未经收集部分热泳损失修正的发动机排气管出口平面质量浓度估算值与所测得的质量浓度之间的比率，其计算公式如下：

$$k_{SL\_mass}=\frac{nvPM_{mass\_EP}}{DF_1\times nvPM_{mass\_STP}}$$

3.2 **建议：**系统损失的 EI_{num} 修正因子是未经收集部分热泳损失修正的发动机排气管出口平面数量浓度估算值与所测得的数量浓度之间的比率，其计算公式如下：

$$k_{SL\_num}=\frac{nvPM_{num\_EP}}{DF_1\times DF_2\times nvPM_{num\_STP}}$$

4. 经系统损失修正的发动机排气管出口平面质量和数量浓度的估算程序

4.1 **建议：**应使用下列程序确定发动机排气管出口平面的质量（$nvPM_{mass\_EP}$）和数量（$nvPM_{num\_EP}$）：

a) 对于所测得的 $nvPM_{num\_STP}$，先计算 $nvPM_{num\_EP}$ 的初始值= $3\times DF_1\times DF_2\times nvPM_{num\_STP}$。

b) 对呈对数正态粒径分布的几何平均直径 D_{mg} 假定一个初始值 0.02 μm。

c) 根据 a)和 b)中的 $nvPM_{num\_EP}$ 和 D_{mg} 假定值，使用下列方程式估算非挥发性微粒物质的质量（$nvPM_{mass\_EST}$）和数量（$nvPM_{num\_EST}$）浓度：

$$nvPM_{mass\_EST}=\sum_{D_m=0.01\mu m}^{1\mu m}\eta_{mass}(D_m)\times\frac{\rho\pi D_m^3}{6}\times nvPM_{num\_EP}\times f_{lgn}(D_m)\times\Delta\ln(D_m)$$

$$nvPM_{num\_EST}=\sum_{D_m=0.01\mu m}^{1\mu m}\eta_{num}(D_m)\times nvPM_{num\_EP}\times f_{lgn}(D_m)\times\Delta\ln(D_m)$$

其中

$$f_{lgn}(D_m) = \frac{1}{\sqrt{2\pi}\ \ln(\sigma_g)} \times e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}$$

$\Delta \ln(D_m) = \frac{1}{n} \times \frac{1}{\log_{10}(e)}$，是基本自然对数中粒径分档的宽度；$e$ 是欧拉常数，n 是每 10 倍粒径的粒径分档数。

d) 使用下列方程式，确定 $nvPM_{num\_STP}$、$nvPM_{mass\_STP}$ 与根据初始发动机排放管出口平面的值得出的非挥发性微粒物质数量浓度估算值（$nvPM_{num\_EST}$）和非挥发性微粒物质质量浓度估算值（$nvPM_{mass\_EST}$）之间的差值 δ：

$$\delta = \left(\frac{DF_1 \times DF_2 \times nvPM_{num\_STP} - nvPM_{num\_EST}}{DF_1 \times DF_2 \times nvPM_{num\_STP}}\right)^2 + \left(\frac{DF_1 \times nvPM_{mass\_STP} - nvPM_{mass\_EST}}{DF_1 \times nvPM_{mass\_STP}}\right)^2$$

e) 使用不同的 $nvPM_{num\_EP}$ 和 D_{mg} 重复步骤 c）至 d），直至 δ 降至 1×10^{-9} 以下。

f) 一旦 δ 降至 1×10^{-9} 以下，$nvPM_{num\_EP}$ 和 D_{mg} 的最终值即为与 δ 的这一最小值相关的值。

g) 使用从步骤 f）得出的 $nvPM_{num\_EP}$ 和 D_{mg}，通过下述公式确定 $nvPM_{mass\_EP}$：

$$\mathrm{nvPM_{mass\_EP}} = \sum_{D_m=0.01\mu m}^{1\mu m} \frac{\rho\pi \mathrm{D_m^3}}{6} \times \mathrm{nvPM_{num\_EP}} \times f_{lgn}(\mathrm{D_m}) \times \Delta \ln(\mathrm{D_m})$$

4.2 **建议：**在计算时应该使用 0.003 μm 至 1 μm 粒径范围内的共 80 种不同粒径。在这种情况下，每 10 倍粒径的粒径分档数 n 是 32（见上文关于 $\Delta\ln(D_m)$ 的定义）。上述方程式总数从 0.01 μm 为起始。

4.3 **建议：**非挥发性微粒物质有效密度应该为一个常数，对于所有粒径都等于 1 g/cm³。

4.4 **建议：**微粒数量对数正态分布的几何标准差应该等于 1.8。

注 1：图 A8-1 所示的流程图形象地描述了该程序。

注 2：如果 $nvPM_{mass\_STP}$ 小于 1 μg/m³，应将 1 μg/m³ 作为最小值用于该程序，以进行收敛计算。

注 3：可通过市售软件程序求解第 3 节所述的程序。

注 4：D_m 的单位是 μm，这与附录 7 给出的列表数值不同。

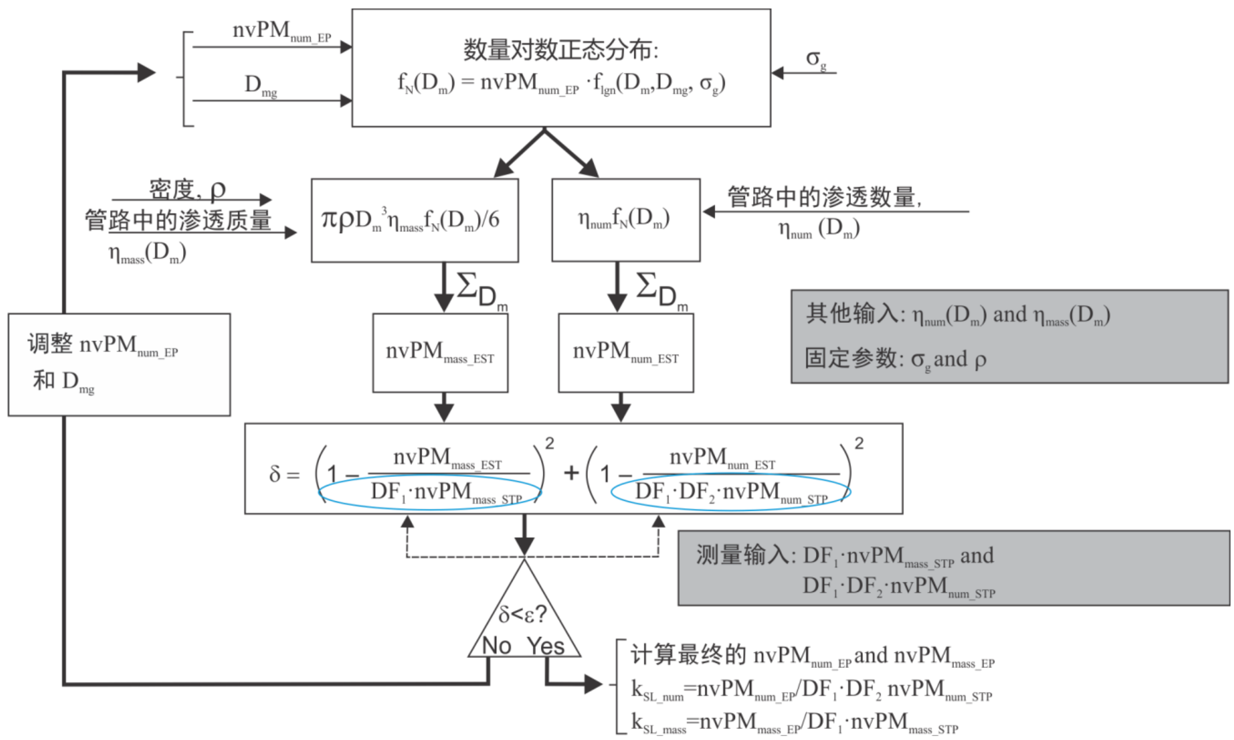

图 A8-1 计算经损失修正（收集部分热泳损失除外）的非挥发性微粒物质质量和数量的迭代法

5. 整体系统渗透分数

注 1：由于分流器 2 之后的样本流路的差异，非挥发性微粒物质质量浓度测量和非挥发性微粒物质数量浓度测量之间的微粒渗透分数是不同的。

注 2：由于粒径分布的变化，不同的发动机条件测量点之间的渗透分数有可能不同。

注 3：如果计算连续函数以预测渗透分数或者凝聚微粒计数器计数效率，则应该加以注意，确保数值不会低于零。

表 A8-1 非挥发性微粒物质采样和测量系统各部件所需的渗透分数

参数标志	说明
η_1（D_m）	1 区 — 探头进口至分流器 1
η_{b1}（D_m）	1 区 — 探头进口至分流器 1（弯折处）
η_2（D_m）	2 区 — 分流器 1 至稀释器 1 进口
η_{b2}（D_m）	2 区 — 分流器 1 至稀释器 1 进口（采样管路弯折处）
η_{dil}（D_m）	2 区 — 稀释器 1
η_3（D_m）	3 区 — 稀释器 1 出口至旋风分离器进口
η_{b3}（D_m）	3 区 — 稀释器 1 出口至旋风分离器进口（采样管路弯折处）
η_{cyc}（D_m）	旋风分离器
η_4（D_m）	4 区 — 旋风分离器出口至分流器 2
η_{b4}（D_m）	4 区 — 旋风分离器出口至分流器 2（采样管路弯折处）
η_5（D_m）	4 区 — 分流器 2 至 nvPMmi
η_{b5}（D_m）	4 区 — 分流器 2 至 nvPMmi（采样管路弯折处）
η_{th_m}	5 区 — 由于 nvPMni 进口处的热泳损失
η_6（D_m）	4 区 — 分流器 2 至挥发性微粒去除器
η_{b6}（D_m）	4 区 — 分流器 2 至挥发性微粒去除器（采样管路弯折处）
η_{vpm}（D_m）	5 区 — 挥发性微粒去除器
η_{CPC}（D_m）	5 区 — nvPMni（CPC）计数效率
η_{th_n}	5 区 — 由于 nvPMni 进口处的热泳损失

5.1 非挥发性微粒物质质量的系统渗透分数

建议：应通过将系统各组件的渗透分数结合起来，计算 0.003μm 至 1μm 范围内的 80 种不同粒径（D_m）的非挥发性微粒物质质量的整体渗透分数：

$$\eta_{mass}(D_m) = \eta_1 \times \eta_{b1} \times \eta_2 \times \eta_{b2} \times \eta_3 \times \eta_{b3} \times \eta_{cyc} \times \eta_4 \times \eta_{b4} \times \eta_5 \times \eta_{b5} \times \eta_{th\_m}$$

其中带有下标的η指表 A8-1 中所界定的非挥发性微粒物质采样和测量系统各组件的渗透分数。关于用于估算各组件渗透分数的程序，在本附录第 6 节进行了说明。

注：根据非挥发性微粒物质采样系统的精确几何结构，非挥发性微粒物质采样和测量系统中需要单独界定的组件可能会多于表 A8-1 中所述的组件数量。

5.2 非挥发性微粒物质数量的系统渗透分数

建议：应通过将系统各组件的渗透分数结合起来，计算 0.003μm 至 1μm 范围内的 80 种不同粒径（D_m）的非挥发性微粒物质数量的整体渗透分数：

$$\eta_{num}(D_m) = \eta_1 \times \eta_{b1} \times \eta_2 \times \eta_{b2} \times \eta_3 \times \eta_{b3} \times \eta_{cyc} \times \eta_4 \times \eta_{b4} \times \eta_6 \times \eta_{b6} \times \eta_{VPR} \times \eta_{CPC} \times \eta_{th\_n}$$

其中带有下标的η指表 A8-1 中所界定的非挥发性微粒物质采样和测量系统各组件的渗透分数。关于用于估算各组件渗透分数的程序，在本附录第 6 节进行了说明。

注：根据非挥发性微粒物质采样系统的精确几何结构，非挥发性微粒物质采样和测量系统中需要单独界定的组件可能会多于表 A8-1 中所述的组件数量。

6. 确定非挥发性微粒物质采样和测量系统各组件渗透分数的程序

6.1 所需数据

为计算一定粒径范围内的微粒的运输效率，需要有关流速、运输管路和外界条件的特征。表 A8-2 列出了针对管路的每个区界定的这些参数。

表 A8-2 输入参数

参数标志	说明	单位
T_i	采样管路第 i 段（收集部分除外）入口处的载气温度。假定该温度等于运输管路各区管壁的温度，且在采样管路的整个第 i 段保持恒定。	℃
P_i	采样管路第 i 段内的载气压力，假定该压力在整个第 i 区保持恒定的 101.325 kPa	kPa
Q_i	载气通过采样管路第 i 段的流速	slpm
ID_{ti}	采样管路第 i 段的内径	mm
L_i	采样管路第 i 段的长度	m
θ_{bi}	采样管路第 i 段的总弯折角度	度
$\eta_{vpm}(15)$, $\eta_{vpm}(30)$, $\eta_{vpm}(50)$, $\eta_{挥 vpm}(100)$	四种粒径的挥发性微粒去除器渗透分数	无量纲
$\eta_{CPC}(10)$, $\eta_{CPC}(15)$	两种粒径的凝聚微粒计数器计数效率	无量纲

6.2 扩散性渗透分数

6.2.1 微粒扩散附着在采样系统管壁表面会导致进入采样管路某一段或某一组件的微粒出现损失。直至仪器进口处各区内的扩散性损失的渗透分数 η_i（D_m），η_i（D_m），i=1, 2, 3, 4, 5, 6 可用下列方程式进行计算：

$$\eta_i(D_m) = e^{\frac{-0.6\times\pi\times ID_{ti}\times L_i\times V_{diff}}{Q_i}}$$

其中

L_i =采样管路第 i 段的长度，m

V_{diff} $=1.18\times Re^{0.875}\times Sc^{0.333}\times\frac{D}{ID_{ti}}$，沉积速度，cm/s

Sc $=\frac{\mu}{\rho_{gas}D}\times 10^3$，载气施密特数

m_{gas} =29.0 kg/mol，载气的分子量

P_i =载气压力，kPa（假定为 101.325 kPa），

6.2.2 **建议：**应对每一个适用的管路区段的扩散性损失计算渗透分数，计算时应使用 0.003 μm 至 1 μm 范围内的 80 种不同粒径（D_m）。

6.3 热泳

建议：对于 nvPMmi，仪器进口处的热泳渗透分数应为一个常数 η_{th_m}（D_m）= 1，对于 nvPMni，所有粒径下的渗透分数均为 η_{th_n}（D_m）= 1。

6.4 弯折处的微粒损失

6.4.1 **建议：**弯折处损失的渗透分数 η_{bi}（D_m），i=1, 2, 3, 4, 5, 6 分为 Re 大于 5000 的湍流和 Re 小于或等于 5000 的层流，其中 Re 为雷诺数。对于 Re 小于或等于 5000 的层流，应按照如下公式计算运输管路弯折导致的渗透

$$\eta_{bi} = 1 - 0.01745\times Stk\times\theta_{bi}$$

对于 Re 大于 5000 的湍流，应按照如下公式计算因运输管路弯折导致的渗透

$$\eta_{bi} = e^{-0.04927 \times Stk \times \theta_{bi}}$$

其中

Stk =$\frac{Q_t \times C_c \times \rho \times D_m^2 \times 10^{-3}}{27 \times \pi \times \mu \times ID_{ti}^3}$，无量纲斯托克斯数

θ_{bi} =采样管路第 i 段的总弯折角度，度

6.4.2 **建议：**应对采样和测量系统的每一个适当区段内的弯折损失计算渗透分数，计算时应使用 0.003μm 至 1μm 范围内的 80 种不同粒径（D_m）。

6.5 旋风分离器渗透函数

6.5.1 **建议：**应使用下列公式估算旋风分离器的渗透函数：

$$\eta_{cyc}(D_m) = 1 - \int_{x>0}^{D_m} \frac{e^{-\frac{(\ln x - \mu_{cyc})^2}{2\sigma_{cyc}^2}}}{x\sigma_{cyc}\sqrt{2\pi}} dx$$

其中

μ_{cyc} =ln（D_{50}），和

σ_{cyc} =ln（D_{16}/D_{84}）$^{0.5}$

6.5.2 **建议：**应根据旋风渗透函数计算 0.003 μm 至 1 μm 范围内的 80 种不同粒径（D_m）的渗透分数。非挥发性微粒物质采样和分析系统中的旋风分离器有如下规范：

a) 切割粒径：D_{50} = 1.0 μm ± 0.1 μm；和

b) 锐度：（D_{16}/D_{84}）$^{0.5}$ 小于或等于 1.25。

注 1：现代计算机电子表格应用程序的函数库内有内置的累积对数正态分布函数，可用来生成旋风分离器的渗透函数。

注 2：对于大多数燃气涡轮发动机的应用，D_m 将小于 0.3 μm。在这种情况下，旋风渗透函数将有效地等于 1.0。

6.6 挥发性微粒去除器渗透函数

注：可使用校准实验室提供的对四个挥发性微粒去除器校准渗透点（表 A8-3）的拟合结果为优（R^2 大于 0.95）的光滑函数，取代根据下文所述计算程序确定的函数。挥发性微粒去除器内的微粒损失是由于扩散和热泳这两个因素引起的。热泳因子 η_{VPRth} 为常数。扩散因子 η_{VPRdi} 可根据层流内扩散导致的标准微粒损失来确定。

6.6.1 **建议**：应使用下列公式估算总的挥发性微粒去除器渗透函数：

$$\eta_{VPR} = \eta_{VPRth} \times \begin{cases} 1 - 5.5 \times \psi^{\frac{2}{3}} + 3.77 \times \psi & \psi < 0.007 \\ 0.819 \times e^{-11.5\psi} + 0.0975 \times e^{-70.1\psi} + 0.0325 \times e^{-179\psi} & \psi > 0.007 \end{cases}$$

其中

Ψ = $\frac{6 \times D \times L_{VPR}}{Q_{VPR}}$，沉积参数

L_{VPR} = 挥发性微粒去除器的有效长度，m

Q_{VPR} = 挥发性微粒去除器的载气流，slpm

T_{VPR} = 挥发性微粒去除器的温度，℃

η_{VPRth} = 挥发性微粒去除器的热泳损失

6.6.2 **建议**：应通过改变挥发性微粒去除器的有效长度（L_{VPR}）和热泳损失因子（η_{VPRth}）将挥发性微粒去除器渗透函数（η_{VPR}）与所测得的四个渗透点的数据进行拟合。R^2 值应大于 0.95，以确保与所测得的渗透值的拟合程度为优。

6.6.3 **建议**：应根据挥发性微粒去除器连续函数计算 0.003 µm 至 1 µm 范围内的 80 种不同粒径（D_m）的渗透分数。

表 A8-3 挥发性微粒去除器在四种粒径情况下的最小容许渗透分数

电迁移粒径，D_m	0.015 µm	0.03 µm	0.05 µm	0.1 µm
最小渗透分数，η_{VPR}（D_m）	0.30	0.55	0.65	0.70

6.7 稀释器 1 渗透分数

6.7.1 **建议**：所有粒径下的稀释器 1 渗透分数应为一个常数 η_{dil}（D_m）= 1。

6.7.2 **建议**：应将 0.003µm 至 1µm 范围内的 80 种不同粒径（D_m）的渗透分数用于稀释器渗透函数。

6.8 凝聚微粒计数器的计数效率

6.8.1 **建议：**应使用根据下列公式用双参数 S 形函数确定出的两个凝聚微粒计数器计数效率来确定凝聚微粒计数器计数效率的连续函数：

$$\eta_{CPC} = 1 - e^{-\ln(2)\cdot\left[\frac{D_m - D_0}{D_{50} - D_0}\right]}$$

其中

$$D_0 = \frac{\alpha_{10} D_{15} - \alpha_{15} D_{10}}{\alpha_{10} - \alpha_{15}}$$

$$D_{50} = \frac{(\alpha_{15}+1) D_{10} + (\alpha_{10}+1) D_{15}}{\alpha_{15} - \alpha_{10}}$$

$$\alpha_i = \frac{\ln(1 - \eta_{CPC,i})}{\ln(2)}, i = 0.01\ \mu m \text{ 或者 } 0.015\ \mu m$$

D_{10} = 0.01 µm

D_{15} = 0.015 µm

$\eta_{CPC,10}$ = 0.01 µm 时的计数效率

$\eta_{CPC,15}$ = 0.015 µm 时的计数效率

6.8.2 **建议：**应根据凝聚微粒计数器连续函数计算 0.003 µm 至 1 µm 范围内的 80 种不同粒径（D_m）的渗透分数。

3. 所需数据

3.1 非挥发性微粒物质排放

为了计算系统损失修正因子，需要附件 7 中规定的以下浓度：

a) 非挥发性微粒物质质量浓度：$nvPM_{mass\_STP}$；

b) 非挥发性微粒物质数量浓度：$nvPM_{num\_STP}$；

3.2 其他信息

需要附录 7 附篇 D 中所列的补充信息来执行计算程序。

4. 非挥发性微粒物质系统损失修正方法和计算程序

4.1 概述

注：关于用于估算系统损失修正因子方法的概略图解见图 A8-1。

4.1.1 对系统损失修正因子的估算应基于下列假设：发动机排气出口面的非挥发性微粒物质的有效密度为一个常数、呈对数正态分布、几何标准差为一个固定值、无凝结，限制计算方法限制章节中所述的非挥发性微粒物质质量和数量浓度，以及最小粒径的界限为 10 nm。

4.1.1.1 系统损失修正方法应使用 1 g/cm^3 的微粒有效密度。

4.1.1.2 在系统损失修正方法中应使用几何标准差为 1.8 的单模式对数正态分布。

4.1.1.3 系统损失修正方法未考虑非挥发性微粒物质数量密度因凝结而变小的情况。

4.1.1.4 使用以下公式计算出的发动机排气管出口平面的非挥发性微粒物质数量密度：

$$k_{SL\_num} \times k_{thermo} \times DF_1 \times DF_2 \times nvPM_{num\_STP}$$

大于 10^8 微粒/cm^3，可能会发生凝结，且这种情况应向审定当局报告。

注 1：系统损失修正方法未考虑渗透漂移。对于符合附录 7 的非挥发性微粒物质测量系统而言，这么做被认为是无关紧要的。

注 2：关于迭代计算程序的图解见图 A8-2。

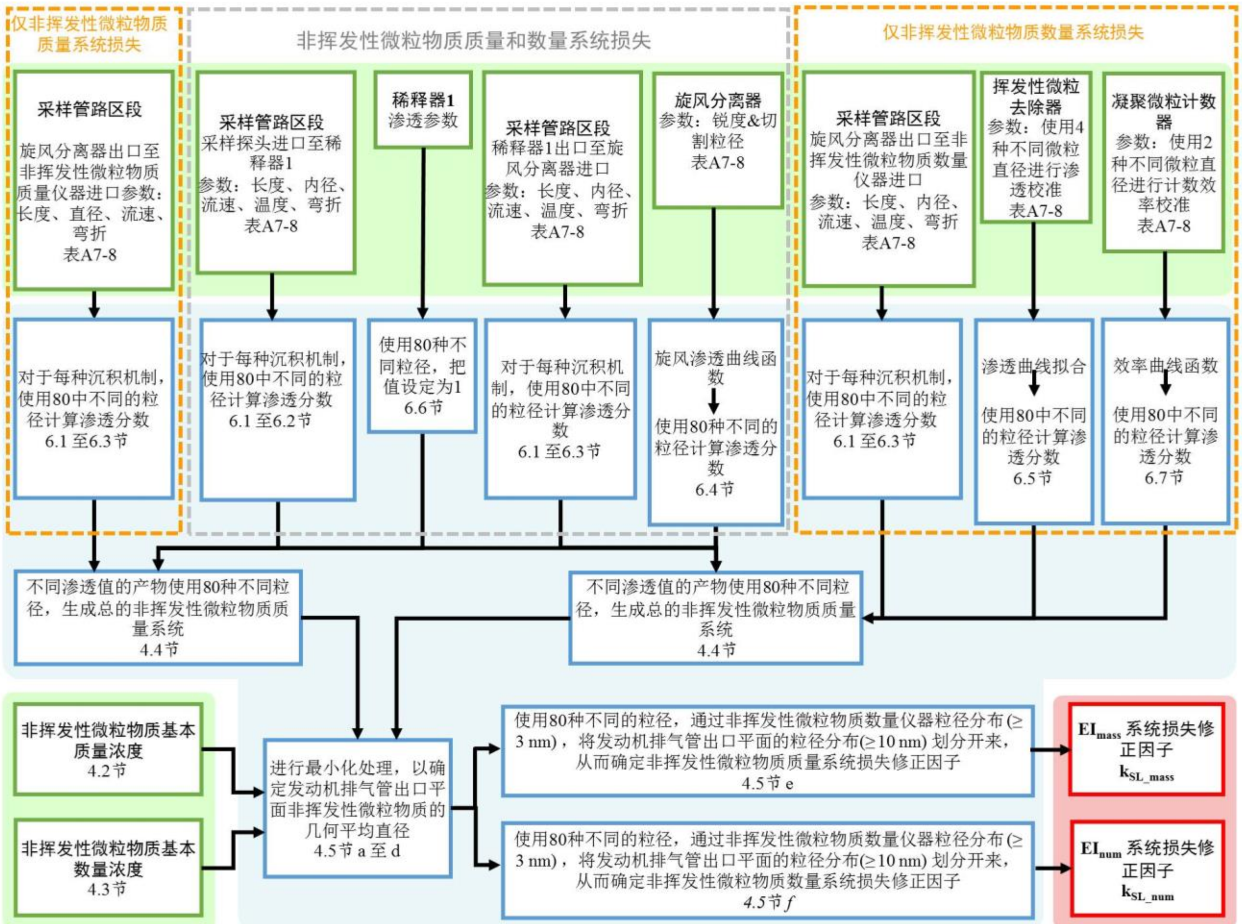

图 **A8-1** 非挥发性微粒物质系统损失修正法的流程框图。绿框部分显示了模型输入参数，蓝框部分显示了模型计算，外部的红框显示了计算输出系统损失修正因子

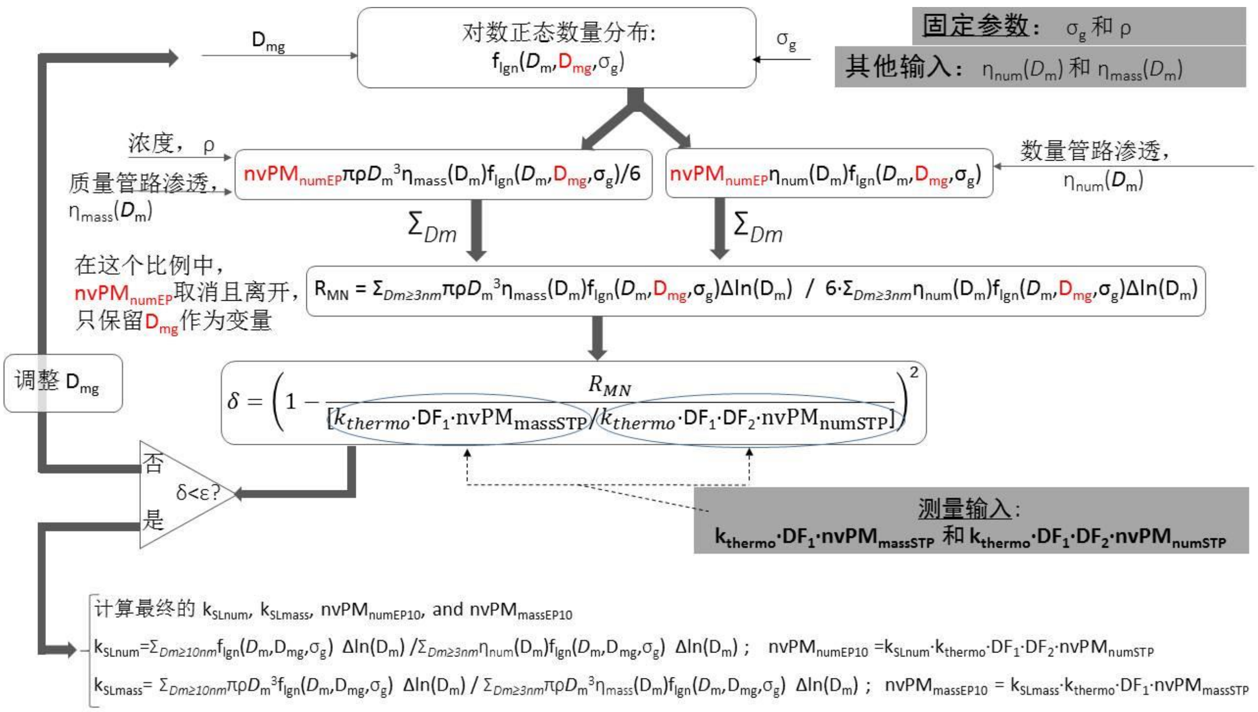

图 A8-2　确定系统损失修正因子的迭代式计算程序图解

4.2　非挥发性微粒物质基本质量浓度

使用附录 7 中规定的以下方程式来计算非挥发性微粒物质基本质量浓度（$nvPM_{mass}$）：

$$\mathbf{nvPM_{mass} = k_{thermo} \times DF_1 \times nvPM_{mass\_STP}}$$

4.3　非挥发性微粒物质基本数量浓度

非挥发性微粒物质基本数量浓度（nvPMnum）代表针对第一阶段稀释因子（DF1）、第二阶段稀释因子（DF2）和收集部分热泳微粒损失进行修正后每单位体积发动机排气样本中的微粒数量。可通过下面的方程式计算这一浓度：

$$\mathbf{nvPM_{num} = k_{thermo} \times DF_1 \times DF_2 \times nvPM_{num\_STP}}$$

4.4　非挥发性微粒物质渗透函数

4.4.1　采样系统渗透函数是单次渗透与计数效率函数的产物。表 A8-1 提供了所需的非挥发性微粒物质渗透与计数效率函数，且使用第 6 节中描述的程序来计算。

4.4.2　针对直径为 D_m 的微粒的质量仪的采样系统渗透为：

$$\eta_{mass}(D_m) = \eta_1 \times \eta_{b1} \times \eta_2 \times \eta_{b2} \times \eta_3 \times \eta_{b3} \times \ldots \times \eta_{dil} \times \eta_{cyc}$$

4.4.3　针对直径为 D_m 的微粒的数量仪的采样系统渗透为：

$$\eta_{num}(D_m) = \eta_1 \times \eta_{b1} \times \eta_2 \times \eta_{b2} \times \eta_3 \times \eta_{b3} \times \ldots \times \eta_{dil} \times \eta_{cyc} \times \eta_{VPR} \times \eta_{CPC}$$

4.4.4　与粒径不相关的非挥发性微粒物质质量和数量采样系统热泳渗透为：

$$\eta_{thermo} = \eta_{th1} \times \eta_{th2} \times \eta_{th3} \times \ldots$$

注：附录 7 的 6.2.1 中规定了收集部分的热泳损失 k_{thermo}，它不包括在这一计算中。

表 A8-1　非挥发性微粒物质采样和测量系统各部件所需的渗透分数

标志	描述非挥发性微粒物质采样和测量系统的微粒运输函数
$\eta_i(D_m)$	采样系统第 i^{th} 段的扩散性渗透分数
$\eta_{bi}(\Theta_i)$	因采样系统第 i^{th} 段中的弯折而产生的渗透分数
η_{thi}	因采样系统第 i^{th} 段中的热泳而产生的渗透分数
$\eta_{dil}(D_m)$	稀释器 1 的渗透分数
$\eta_{cyc}(D_m)$	旋转分离器的渗透分数
$\eta_{VPR}(D_m)$	挥发性微粒去除器的渗透分数
$\eta_{CPC}(D_m)$	凝聚微粒计数器计算效率

4.5　系统损失修正因子的计算

应使用迭代程序来计算针对非挥发性微粒物质质量（k_{SL_mass}）和非挥发性微粒物质数量（k_{SL_num}）的系统损失修正因子：

a)　使用下面的方程式估算几何平均直径的初始值：

$$\mathbf{D_{mg}} = \sqrt[3]{\frac{\mathbf{6 \times DF_1 \times nvPM_{mass\_STP}}}{\boldsymbol{\pi \times \rho} \times \mathbf{DF_1 \times DF_2 \times nvPM_{num\_STP}}}} \times \mathbf{10^3}$$

注：如使用为输入而规定的单位，计算得出的微粒直径的单位将是 nm。

b) 使用从步骤 a)得出的 D_{mg} 值并使用以下方程式，计算非挥发性微粒物质质量估算值与非挥发性微粒物质数量估算值之间的比例：

$$\mathbf{R_{MN}}（\mathbf{D_{mg}}）=\frac{\sum_{D_m>3nm}^{1000nm}\eta_{mass}(D_m)\times\frac{\pi\rho D_m^3}{6}\times e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}\times\Delta\ln(D_m)}{\sum_{D_m>3nm}^{1000nm}\eta_{num}(D_m)\times e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}\times\Delta\ln(D_m)}$$

其中，指数函数来自对数正态分布函数，

$$f_{lgn}(D_m)=\frac{1}{\sqrt{2\pi}\ \ln(\sigma_g)}\times e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}$$

$\Delta\ln(D_m)=\frac{1}{n}\times\frac{1}{log_{10}(e)}$，是基本自然对数中粒径分档的宽度；$e$ 是欧拉常数，n 是每 10 倍粒径的粒径分档数。

c) 使用下列方程式，确定非挥发性微粒物质质量测量值与估算值的比例与非挥发性颗粒物质数量测量值与估算值的比例之间的相对平方差值 δ：

$$\boldsymbol{\delta}=\left\{1-\frac{\mathbf{R_{MN}}(\mathbf{D_{mg}})\times 10^{-9}}{\left[(k_{thermo}\times DF_1\times nvPM_{mass\_STP})/(k_{thermo}\times DF_1\times DF_2\times nvPM_{num\_STP})\right]}\right\}^2$$

d) 重复步骤 b）至 c），直至 δ 降至 1×10^{-9} 以下。应使用与 δ 这一最小值相关的 D_{mg} 来计算系统损失修正因子。

e) 使用下列方程式计算非挥发性微粒物质质量系统损失修正因子：

$$k_{SL\_mass}=\frac{\sum_{D_m>10nm}^{1000nm}D_m^3\times e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}\times\Delta\ln(D_m)}{\sum_{D_m>3nm}^{1000nm}\eta_{mass}(D_m)\times D_m^3\times e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}\times\Delta\ln(D_m)}$$

f) 使用下列方程式计算非挥发性微粒物质数量系统损失修正因子：

$$k_{SL\_num}=\frac{\sum_{D_m>10nm}^{1000nm}e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}\times\Delta\ln(D_m)}{\sum_{D_m>3nm}^{1000nm}\eta_{num}(D_m)\times e^{-\frac{1}{2}\left\{\frac{\ln(D_m)-\ln(D_{mg})}{\ln(\sigma_g)}\right\}^2}\times\Delta\ln(D_m)}$$

g) 在这一计算中应使用 3 nm 至 1 000 nm 粒径范围内的至少 80 种不同粒径或使用将会产生审定当局同意的等效结果的最小分档数。

注 1：对于 80 种不同粒径，每 10 倍粒径的粒径分档数 n 是 32（见上文关于 $\Delta\ln(D_m)$ 的定义）。

注 2：计算系统损失修正因子总和，分子从 10 nm 开始，分母从 3 nm 开始。

注 3：可通过使用商业用途的软件程序来执行计算程序。

5. 报告和限制

注 1：附录 8 第 4 节中所述的系统损失修正因子计算方法已给出，以便就在航空器涡轮发动机非挥发性微粒物质排放中观测到的范围广泛的非挥发挥发性微粒物质和数量浓度给出可接受的结果。但是，也存在广泛的、已被确认的质量和数量浓度，在这些情况下，分析的输入内容可能缺少保真度，使用该计算方法也无法得出高质量报告。

注 2：与第 4.1.1 节中要求的计算方法所使用的假设存在的任何差异都会导致系统损失修正因子出现差异。类似地，计算方法使用的数据方面的差异将导致系统损失修正因子出现差异。数据方面的差异可能是因为粒径分布、采样系统或仪器的缘故。此外，采样和测量系统失真，如浓度低时可能从壁上脱落，可能会产生无效的系统损失修正因子。方法方面的限制归因于输入数据，而不是计算方法。

5.1 适用的质量浓度范围

注：当 nvPMmi 处的原始的非挥发性微粒物质浓度（未经修正的稀释度）低于 3 μg/m³，要谨慎使用这一方法来估算系统损失修正因子，因为浓度处于这么低的值时，非挥发性微粒物质质量浓度的确定存在不确定性。

如果 nvPMmi 原始的非挥发性微粒物质浓度低于 3 μg/m³，申请人应确认预测的发动机排气管出口平面的 D_{mg} 处于 5.3 节中的适用范围内。

建议：对于本附录中的计算或其他等效方法未得出 5.3 节中注明的合理数值（例如当使用系统损失方法计算出的发动机排气管出口平面的几何平均直径小于 7 nm 或大于 100 nm），或当系统损失方法没有收敛，可针对着陆和起飞运行模式使用替代性的估算系统损失修正因子的方法，但须得到审定当局的批准。

注：关于高质量非挥发性微粒物质浓度，目前还没有已知的限制，只要经过审核，非挥发性微粒物质质量浓度读数在使用的 nvPMmi 的范围内。

5.2 适用的数量浓度范围

如果发现在 nvPMmi 处测量的、针对稀释（DF1 和 DF2）和收集部分热泳损失而修正过的非挥发性微粒物质数量浓度低于或等于测量的周边数量浓度 [2]，申请人应确认预测的发动机排气管出口平面的 D_{mg} 处于 5.3 节中的适用范围内。

2. 见附录 7 附篇 E

建议：对于本附录中的计算或其他等效方法未得出 5.3 节中注明的合理数值（例如当使用系统损失方法计算出的发动机排气管出口平面的几何平均直径小于 7 nm 或大于 100 nm），或当系统损失方法没有收敛的情况，可针对着陆和起飞运行模式使用替代性的估算系统损失修正因子的方法，但须得到审定当局的批准。

注：对于 nvPMmi，目前还没有已知的关于非挥发性微粒物质低浓度的限制。根据凝聚微粒计数器制造商的报告，凝聚微粒计数器检测极限为 1 微粒/cm^3。关于凝聚微粒计数器处于单一技术模式的要求限制了高数量的浓度测量。如果发动机排气管出口平面的非挥发性微粒物质数量浓度高于 10^8 微粒/cm^3，可能会发生微粒凝结。在系统损失计算方法中不考虑凝结现象。

5.3 适用的几何平均直径预测值

注：航空器燃气涡轮发动机排气管出口平面的几何平均直径预测在 7 至 100 nm 的范围内。

如果系统损失的计算方法预测出发动机排气管出口平面的几何平均直径小于 7 nm 或大于 100 nm，和/或如果系统损失的计算方法预测出发动机排气管出口平面的不符合收敛准则（δ 大于 1×10^{-9}）的几何平均直径，那么，k_{SL_mass} 和 k_{SL_num} 的结果应由审定当局审查，以决定下面的建议是否适用。

建议：对于本附录中的计算或其他等效方法未得出合理数值（例如当使用系统损失方法计算出的发动机排气管出口平面的几何平均直径小于 7 nm 或大于 100 nm），或当系统损失方法没有收敛，可针对着陆和起飞运行模式使用替代性的估算系统损失修正因子的方法，但须得到审定当局的批准。

注：如果计算得出的发动机排气管出口平面的几何平均直径小于 20 nm，将导致因最小合并粒径临界值而低估的系统损失因子。当发动机排气管出口平面的 $D_{mg}\leq10$ nm 时，这种低估对 k_{SL_num} 的影响可能是很大的。

6. 确定非挥发性微粒物质采样和测量系统各组件渗透分数的程序

为计算一定粒径范围内的微粒的非挥发性微粒物质运输效率，应计算非挥发性微粒物质采样和测量系统的每个组件的渗透分数，计算时至少使用 80 种不同粒径或将产生审定当局同意的等效结果（3 nm 至 1 000 nm）的最少数量的不同粒径。

注 1：如果计算连续函数以估算渗透分数，应注意这些分数不低于零。

注 2：进行本附篇中的渗透分数的计算所需的非挥发性微粒物质的测量和采样系统参数载于附录 7 附篇 D。

6.1 区段扩散性渗透分数

使用以下方程式计算电迁移粒径为 D_m 之处的采样系统各区段的扩散性损失的渗透值 η_i（D_m）：

$$\eta_i(D_m) = e^{\frac{-\pi \times ID_{ti} \times L_i \times V_{d,diff}}{Q_i}}$$

其中

L_i = 采样管路第 i 段的长度，m

$V_{d,diff}$ = $0.0118 \times Re^{\frac{7}{8}} \times Sc^{\frac{1}{3}} \times D/ID_{ti}$，沉积速度，cm/s

Sc = $\frac{\mu}{\rho_{gas} D} \times 10^3$，载气施密特数

ID_{ti} = 采样管路第 i 段的内直径，mm

Q_i = 采样管路的第 i 段中的载气流，slpm

6.2 区段上弯折处的渗透分数

弯折处的渗透分数分为 Re 大于 5 000 的湍流和 Re 小于或等于 5 000 的层流，其中 Re 为雷诺数。对于层流（包括过渡区）而言，应按照如下公式，在电迁移粒径为 D_m 的地方，计算因区段的采样运输管路的弯折而导致的渗透：

$$\eta_{bi}(D_m) = 1 - 0.01745 \times Stk \times \theta_{bi}$$

对于湍流而言，因按照如下公式计算样因本运输管路弯折而产生的渗透：

$$\eta_{bi}（D_m）= e^{-0.04927 \times Stk \times \theta_{bi}}$$

其中

Stk = $\frac{Q_i \times C_c \times \rho \times D_m^2 \times 10^{-3}}{27 \times \pi \times \mu \times ID_{ti}^3}$，无量纲斯托克斯数

θ_{bi} = 采样管路第 i 段的总弯折角度，度

6.3 区段的热泳损失

因采样管路壁温度低于燃气温度而发生的热梯度造成了在采样管路表面沉积了另外的微粒和热泳损失。使用以下方程式计算热泳损失（收集部分中的热泳除外）：

$$\eta_{thi} = \left[\frac{T_{linei} + 273.15}{T_{gasi} + 273.15}\right]^{Pr \times K_{th}} \times \left[1 + \left(\frac{T_{gasi} + 273.15}{T_{linei} + 273.15} - 1\right) \times e^{-\frac{\pi \times ID_i \times h_{gas} \times L_i}{\rho_{gas} \times Q_i \times C_p}}\right]^{Pr \times K_{th}}$$

其中

T_{gasi} = 采样燃气温度，°C

T_{linei} = 管路壁温度，°C

h_{gas} = 载气对流热传递系数，（W/（m^2 K））

C_p = 恒压载气比热，(J/（kg K）)

Pr = 普朗特数

K_{th} $\frac{2 \times C_s \times C_c}{1 + 3 \times C_m \times K_n}\left[2 + \frac{1}{\left(k_{gas}/k_p\right) + C_t \times K_n}\right]^{-1}$，热泳系数

C_s = 1.17，滑动系数

C_m 1.14，煤烟的动量

C_t 2.18，导热系数

k_{gas} 载气的导热性，（$Wm^{-1}K^{-1}$）

K_n 2λ/D_m，克努森数

k_p 0.2 $Wm^{-1}K^{-1}$，微粒的导热性。

注：根据附录 7 的 6.2.1 段和本附篇的 1.5 段，考虑了收集部分和挥发性微粒去除器热泳损失。与附录 7 中的规范相一致的系统使用了目前不需要针对热泳损失而修正的仪器和区段，因此，ηthi 将有效地等于 1.0。

6.4 旋风分离器的渗透函数

应使用以下方程式来计算旋风分离器的渗透函数：

$$\eta_{cyc}(D_m) = 1 - \int_{x>0}^{D_m} \frac{e^{-\frac{(\ln x - \mu_{cyc})^2}{2\sigma_{cyc}^2}}}{x\sigma_{cyc}\sqrt{2\pi}} dx$$

其中

$\mu_{cyc=}$ ln(D_{50}), 和

$\sigma_{cyc}=\ln（D_{16}/D_{84}）^{0.5}$

注 1：现代计算机电子表格应用程序的函数库内有内置的累积对数正态分布函数，可用来生成旋风分离器的渗透函数。

注 2：对于大多数燃气涡轮发动机的应用，D_m 将小于 300 nm。在这种情况下，旋风渗透函数将有效地等于 1.0。

6.5 挥发性微粒去除器渗透函数

注：可使用校准实验个室提供的对四挥发性微粒去除器校准渗透点（表 A8-3）的拟合结果为优（R^2 大于 0.95）的光滑函数，取代根据下文所述计算程序确定的函数。

挥发性微粒去除器内的微粒损失是由于扩散和热泳这两个因素引起的。热泳因子 η_{VPRth} 为常数。扩散因子 η_{VPRdi} 可根据层流内扩散导致的标准微粒损失来确定。应使用以下方程式估算总的挥发性微粒去除器渗透函数：

$$\eta_{VPR} = \eta_{VPRth} \times \begin{cases} 1 - 5.5 \times \psi^{\frac{2}{3}} + 3.77 \times \psi & \psi < 0.007 \\ 0.819 \times e^{-11.5\psi} + 0.0975 \times e^{-70.1\psi} + 0.0325 \times e^{-179\psi} & \psi > 0.007 \end{cases}$$

其中

$\Psi = \frac{D \times L_{VPR} \times 100}{Q_{VPR}}$，沉积参数
L_{VPR} = 挥发性微粒去除器的有效长度，m
Q_{VPR} = 挥发性微粒去除器的载气流，slpm
T_{VPR} = 挥发性微粒去除器的温度，°C
η_{VPRth} = 挥发性微粒去除器的热泳损失

应通过改变挥发性微粒去除器的有效长度（L_{VPR}）和热泳损失因子（η_{VPRth}）将挥发性微粒去除器渗透函数（η_{VPR}）与所测得的四个渗透点的数据进行拟合。应通过将测得的挥发性微粒去除器渗透 $\eta_{VPRmeas}$ 和计算得出的渗透函数之间的平方差的相对总和 δ_{VPR} 最小化来计算这一拟合。

$$\delta_{VPR} = \sqrt{\sum_{D_m} \left(\frac{\eta_{VPRmeas}(D_m) - \eta_{VPR}(D_m)}{\eta_{VPRmeas}(D_m)} \right)^2}$$

计算显示小于 0.08 的 δ_{VPR} 值可使得与所测得的渗透值的拟合程度为优。

6.6 稀释器 1 渗透函数

所有粒径下的稀释器 1 渗透函数应为一个常数 $\eta_{dil}(D_m) = 1$。

6.7 凝聚微粒计数器的计数效率

应使用根据下列公式用双参数 S 形函数确定出的两个凝聚微粒计数器计数效率来确定凝聚微粒计数器计数效率的连续函数：

$$\eta_{CPC} = 1 - e^{-\ln(2)\cdot\left[\frac{D_m - D_0}{D_{50} - D_0}\right]}$$

其中

$$D_0 = \frac{\alpha_{10} D_{15} - \alpha_{15} D_{10}}{\alpha_{10} - \alpha_{15}}$$

$$D_{50} = \frac{(\alpha_{15}+1) D_{10} + (\alpha_{10}+1) D_{15}}{\alpha_{15} - \alpha_{10}}$$

$$\alpha_i = \frac{\ln(1 - \eta_{CPC,i})}{\ln(2)}, i = 10\ nm\ \ or\ 15\ nm$$

D_{10} = 10 nm

D_{15} = 15 nm

$\eta_{CPC,10}$ = 10 nm 时的计数效率，和

$\eta_{CPC,15}$ = 15 nm 时的计数效率

————————

附录 B

对附件 16 第 III 卷的拟议修订

修订文本是这样编排的：用横线划掉的部分表示删去的文字，灰色阴影中的部分表示新增加的文字。如下所示：

1.	~~要删去的文字用横线将其划掉~~	要删去的文字
2.	新增加的文字放在灰色阴影中标出	新增加的文字
3.	~~要删去的文字用横线将其划掉~~ 其后用灰色阴影中的文字来代替	新增加文字代替原文

国际标准和建议措施的拟议修订案文

国际民用航空公约
附件 16 —《环境保护》

第 III 卷 —《飞机二氧化碳排放》

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……

国际标准和建议措施

第 I 部分 定义和符号

第 1 章 定义

……

获得二氧化碳排放合格审定的衍生型飞机 型号设计有所改变且这些一改变导致其最大起飞质量增加或其二氧化碳排放评定度量值增加至超过下列标准的飞机：

a) 最大起飞质量为 5 700 公斤时，1.35%，线性降至；

b) 最大起飞质量为 60 000 公斤时，0.75%，线性降至；

c) 最大起飞质量为 600 000 公斤时，0.70%；和

d) 最大起飞质量超过 600 000 公斤时，为常数 0.70%。

注：在一些国家中，当审定当局认为，在设计、构型、动力或质量上对飞机进行的拟议更改非常之大，以致需要对其与适用的适航规章的符合性进行~~基本全新的~~全面审查时，该飞机~~将被认为是一种新的型号设计，而非衍生型~~要求有一个新的型号证书。

未获得二氧化碳排放合格审定的衍生型飞机　符合现有型号合格证，但未获得附件 16 第 III 卷合格审定的单机，在颁发飞机首次适航许可证之前型号设计有所改变，这一改变使其二氧化碳排放评定度量值增加超过 1.5%或被认为二氧化碳变化很大。

……

型号设计　为确定适航性而界定一个航空器、发动机或螺旋桨型号所需的一套数据和信息。

————————

第 2 章　符号

下列符号在本附件第 III 卷中使用时，具有赋予它们的如下含义和所适用的单位：

AVG	平均值
CG	重心
CO_2	二氧化碳
g_0	在海平面和大地纬度 45.5 度处的重力加速度标准值，9.80665 （m/s^2）
Hz	赫兹（每秒中的周期数）
MTOM	最大起飞质量（公斤）
OML	外模线
RGF	基准几何因子
RSS	平方和根值
SAR	单位空中航程（千米/公斤）
TAS	真空速（千米/小时）
W_f	飞机总燃油流量（公斤/小时）
~~δ~~	~~特定高度大气压力与海平面大气压力的比率~~

第 II 部分　基于燃油消耗的飞机二氧化碳排放合格审定标准

第 1 章　管理

……

1.11　缔约国必须承认另一个缔约国负责组织生产飞机的主管当局准予的有效飞机豁免，前提条件是采用了可接受的程序。（译者注：因之前英文版本的修改标注有误，中文等原译文与英文不一致。）

……

第 2 章

1.　5 700 公斤以上的亚音速喷气式飞机

2.　8 618 公斤以上的螺旋桨驱动的飞机

2.1　适用范围

注：另见第 1 章 1.4、1.5、1.6、1.7、1.8 和 1.11。

2.1.1　本章的标准须适用于下述飞机，水路两栖飞机、根据专门运行需求进行初始设计或改装并加以使用的飞机、基准几何因子（RGF）设计为零的飞机和专门为消防设计或改装和使用的飞机除外：

……

d)　2023 年 1 月 1 日或其后提交型号设计变化合格审定申请的最大审定起飞质量超过 5 700 公斤的未获得二氧化碳排放合格审定的亚音速喷气式飞机的衍生型，包括其之后获得二氧化碳排放合格审定的衍生型；

e)　2023年1月1日或其后提交型号设计变化合格审定申请的最大审定起飞质量超过8 618公斤的未获得二氧化碳排放合格审定的螺旋桨驱动的飞机的衍生型，包括其之后获得二氧化碳排放合格审定的衍生型；

……

注：根据专门运行需求进行初始设计或改装并加以使用的飞机指在审定当局看来其型号~~构型~~设计相较于附件 16 的本卷所涵盖的典型民用飞机型号具有不同的设计特点以满足具体运行需求，且可能造成很大二氧化碳排放评价度量值差异的飞机。

……

2.1.3 根据 2.1.1 规定的适用日期要求批准飞机豁免必须在合格审定当局颁发的符合性声明中注明。负责组织生产飞机的合格审定当局或主管当局可以准予豁免第 2.1.1 段规定的适用范围。在这种情况下，该当局须颁发一份豁免文件。准予豁免必须记录在永久性飞机档案中。合格审定该当局必须考虑生产的豁免飞机数量及其对环境的影响。必须使用飞机序列号报告豁免，并通过正式的公共登记册公布。

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2.5 确定飞机单位空中航程的基准条件

2.5.1 基准条件须包含批准的飞机正常运行范围内的以下条件：

a) 2.3 规定的飞机总质量；

b) 申请人选定的高度和空速综合条件；

……

2.6 试验程序

2.6.1 单位空中航程值构成二氧化碳排放评定度量值的基础，须直接根据飞行试验确定，或根据飞行试验所验证的性能模型确定。

2.6.2 试验飞机须代表申请合格审定的飞机构型型号设计。

……

附录 1 飞机二氧化碳排放评定度量值的确定

1. 5 700 公斤以上的亚音速喷气式飞机

2. 8 168 公斤以上的螺旋桨驱动的飞机

……

3. 单位空中航程合格审定试验和测量条件

3.1 概述

本节规定了进行单位空中航程合格审定试验和使用测量程序的条件。

注：~~许多~~一份审定二氧化碳排放度量值的申请可能仅涉及飞机机型设计的一个微小变化。因此，产生的二氧化碳排放度量值的变化可能往往通过一个等效程序即可准确确定，而不必进行完整的试验。

3.2 飞行试验程序

3.2.1 飞行前

飞行前的程序必须由审定当局批准，并且必须包括以下要素：

a) 飞机符合度 必须确认试验飞机符合申请进行合格审定的型号设计~~构型~~。

……

5. 根据测量数据计算基准单位空中航程

……

5.2 根据基准条件进行试验后的修正

5.2.1 历次修正须适用于测量的单位空中航程值，以根据第 II 部分第 2 章 2.5 规定的基准条件进行修正。修正须适用于以下并非在基准条件下测量的每个参数：

……

~~**质量/δ** 飞机的升力系数是质量/δ 和马赫数的函数，其中 δ 是给定高度大气压与海平面大气压之比。试验条件下的升力系数影响飞机的阻力。基准质量/δ 来源于基准质量、基准高度和国际民航组织标准大气层确定的大气压的综合结果。~~

雷诺数 雷诺数影响飞机阻力。在给定试验条件下，雷诺数是在试验高度和温度时空气的密度和粘度的函数。基准雷诺数来源于国际民航组织在基准高度~~和温度~~的标准大气的密度和粘度。

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APPENDIX C
(English only)

REGULATORY IMPACT ASSESSMENT

INFORMATION TO SUPPORT THE RULEMAKING PROCESSES OF ICAO MEMBER STATES

Table of Contents

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1. INTRODUCTION

1.1 The International Civil Aviation Organization (ICAO) is a United Nations (UN) specialized agency, established by States in 1944 to manage the administration and governance of the *Convention on International Civil Aviation* (referred to as the Chicago Convention). ICAO works with the Convention's 192 Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. Presently, there are over 10,000 such Standards and provisions contained in ICAO Annexes to the Chicago Convention. ICAO's ongoing mission is to support a global air transport network that meets or surpasses the social and economic development and broader connectivity needs of global businesses and passengers. While acknowledging the clear need to anticipate and manage the projected doubling of global air transport capacity by 2030 without unnecessary adverse impacts on system safety, efficiency, convenience or environmental performance, ICAO has established five comprehensive Strategic Objectives, namely: Safety, Air Navigation Capacity and Efficiency, Security and Facilitation, Economic Development of Air Transport, and Environmental Protection.

1.2 Improving the environmental performance of aviation is a challenge ICAO takes very seriously. In fulfilling its responsibilities, ICAO has three major environmental goals, which are to limit or reduce: 1) the number of people affected by significant aircraft noise, 2) the impact of aviation emissions on local air quality, and 3) the impact of aviation greenhouse gas emissions on the global climate. To limit or reduce the impact of aviation emissions on local air quality, ICAO takes actions on revising current and adopting new emission standards for international aviation. Following the development of a visibility based non-volatile Particulate Matter (nvPM) Standard, aircraft engine landing and take-off (LTO) nvPM mass and number emissions Standard is being adopted. The non-volatile particulate matter is defined as emitted particles that do not volatilize when heated to a temperature of 350° C. These particles are also known as "ultrafine soot" or "black carbon" particles. The new Standards regulate the mass and the number of such particles emitted during the landing and take-off cycle.

1.3 The ICAO Committee on Aviation Environmental Protection (CAEP) is a technical committee of the ICAO Council established in 1983. CAEP assists the Council in formulating new policies and adopting new SARPs related to aircraft noise and emissions, and more generally to aviation environmental impacts. CAEP undertakes specific studies, as requested by the Council. Its scope of activities encompasses noise, air quality and the Basket of Measures considered for reducing international aviation CO_2 emissions. CAEP is structured into Working Groups in order to progress tasks under the various environmental areas (noise, emissions, modelling, etc.).

1.4 Since 2013, CAEP has been developing Engine nvPM mass and number Emissions Certification Standards, following the plan approved by the ICAO Council and the request from the 38th Session of the Assembly (ResolutionA38-17[3]). These new Standards will be added to Chapter 4 (Volume II) to Annex 16 to the *Convention on International Civil Aviation*, where Annex 16, Volume I covers aircraft noise and Volume III addresses aircraft CO_2 emissions.

1.5 The nvPM mass and number Standards have been developed considering the four core CAEP tenets, which are technical feasibility, environmental effectiveness, economic reasonableness, and

[3] Doc 10022, Assembly Resolutions in Force (as of 4 October 2013), ISBN 978-92-9249-419-3, ICAO, 2014

the consideration of interdependencies (e.g. with noise and local air quality emissions). This has involved two phases of work, which have focussed on the development of a certification requirement and options for a regulatory limit line. Figure 1.1 shows a representative framework of an ICAO Environmental Standard.

Figure 1.1: The basic framework of an ICAO Environmental Standard

1.6 Phase 1 involved tasks associated with the forming of a certification requirement for the nvPM mass and number Standards, including the development of nvPM emissions evaluation metric systems (i.e. metric/correlating parameter/test points), certification procedures, measurement methodologies, applicability to new engine types, and initial inputs to the cost effectiveness assessment. Phase 2 included the following. (1) Development of the regulatory limit stringency options for in-production and new engine types; (2) considering various combinations of mass and number limits; (3) technology responses from the manufacturers when engines do not meet the nvPM mass and number stringency option combinations (SO); and, (4) the cost effectiveness analyses. The subsequent material is a summary of the nvPM mass and number Standard development work that was conducted through a period of six years (i.e., two CAEP work cycles).

2. CAVEATS, LIMITATIONS AND CONTEXT

2.1 Context: The framework for this analysis does not necessarily represent what would occur in the real world. Specifically, (a) the real world does not ensure that all products of a similar capacity get used equally regardless of price or performance; and (b) the real world does not require in production aircraft or engines to go out of production if they do not perform to a level required of newly certificated types. This analysis uses aircraft and engines that are assumed to be in production at the implementation date to assess the technical feasibility, benefits and costs of the proposed stringency option combinations. When a product no longer responds, results are influenced by the fleet evolution analysis assumptions; and coincidently the remaining fleet tends to be more fuel-efficient.

2.2 Technological Feasibility: For the purposes of the nvPM Standard setting process, CAEP relied upon representative, certificated engines to measure nvPM performance as a basis for technological feasibility and economic reasonableness. In the larger context of technology for improved engine, emissions environmental performance to be used as part of the basis for ICAO certification Standard setting, technological feasibility refers to any technology demonstrated to be safe and airworthy proven to Technical Readiness Level (TRL) 8 and available for application over a sufficient range of newly certificated aircraft.

2.3 Limitations: The information used in the analysis included a mixture of public and non-public data that is subject to change. The data was informed by assumptions unique to this analysis, which limits the applicability of the data to only this work.

2.4 The data and information provided in this document were provided to support the selection of nvPM mass and number Standards by ICAO CAEP in the context of the current ICAO Standard setting process. The in-production fleet and known products scheduled for entry into the fleet by 2023 were used for growth and replacement throughout the full analysis period (i.e., 2012-2042). The analysis did not speculate on potential future technology developments.

2.5 Fleet evolution is an element of CAEP modelling that defines the future fleet and its' deployment on routes and schedules, under different policy options and assumptions regarding the future state of the air transport system. Many of the input assumptions for this modelling are forward-looking and cannot be proven in advance. Thus, there is no certainty that any one baseline predicts what will actually happen in the future.

2.6 Assumptions of engine technology responses to regulatory levels were based on input from both manufacturers and other expert sources. These responses were meant for nvPM cost effectiveness modelling purposes, and do not imply a commitment from manufacturers to develop actual individual products.

2.7 Consequently, the environmental benefits and the costs are comparable relatively between analysis cases but cannot be represented as absolute benefits and costs. Hence, the data and information are not suitable for application to any other purpose of any kind, and any attempt at such application would be in error.

2.8 Recognizing the potential trade-offs between nvPM emissions and fuel efficiency and NOx, a range of trade-offs were modelled with the analysis submitted to CAEP. It should be noted however, regarding the proposed nvPM mass and number Standards for new engine type certificates, engines obtaining new type certificates are required to pass standards for all regulated pollutants. The anti-backsliding nvPM mass stringency proposed for in-production (InP) engines was not assessed.

2.9 Business Jets: Fleet evolution modelling for business jets (BJ) uses all types within a competition bin (CBin) equally without considering capacity, capital or operating costs, with the goal that CBins contain equivalent products in terms of costs and capabilities. However, after the analysis was run it was discovered that two BJ CBins had types with noticeably different capital costs. When some BJ types no longer respond, they were replaced by much less expensive types. This BJ CBin modelling is sufficiently influential that the combined market results are presented with and without the BJ market.

2.10 Two Paths: The analysis for the potential CAEP/11 nvPM mass and number Standards included a portion of the growth and replacement fleet modelled in two ways. Small and medium wide-bodied passenger aircraft were originally defined from the fleet forecast as CBin-9 (211 to 300 seats) and CBin-10 (301 to 400 seats). That fleet forecast-based approach was modelled as "**Path-B**" with CBin-9 and CBin-10 separated. An alternative "**Path-A**" approach modelled CBin-9/10 together. These different paths along with the equal product market share assumption resulted in a noticeable difference in the distribution of baseline operations. The original fleet forecast (Path-B) has an 82% to 18% distribution for the small and medium WB-PAX types; but 47% to 53% in the alternative (Path-A) modelling. The two paths have no noticeable consequence for the analysis until SO10 (mass5 #1) when some WB-PAX types no longer respond. Under Path-A, some small WB-PAX baseline operations are replaced by medium WB-PAX types at SO10 resulting in a noticeable capital cost increase. Results for the analysis are presented for all SO using the original fleet forecast (Path-B), as well as the alternative (Path-A) approach for SO10-12a.

3. ANNEX 16, VOLUME II AND THE ENVIRONMENTAL TECHNICAL MANUAL, VOLUME II

3.1 Overview of the nvPM Mass and Number Emissions Evaluation Metric

3.1.1 The provisions contained in the draft update to Part 3 Chapter 4 of Annex 16, Vol. II represent the SARPs for the certification of engine nvPM mass and number emissions for the standard ICAO LTO cycle: 1. The LTO nvPM mass emissions from the measured engines normalized by the given engine's rated thrust and plotted against the rated thrust; 2. The LTO nvPM number emissions from the measured engines normalized by the given engine's rated thrust and plotted against the rated thrust as follows:

3.1.1.1 nvPM Mass Metric Value:

$$\frac{LTO_{nvpm\_mass}}{F_{\infty}} = \frac{\sum_{LTO} t_m \times W_f \times EI_{nvpm\_mass}}{F_{\infty}}$$

3.1.1.2 nvPM number Metric Value:

$$\frac{LTO_{nvpm\_num}}{F_{\infty}} = \frac{\sum_{LTO} t_m \times W_f \times EI_{nvpm\_num}}{F_{\infty}}$$

Where: t_m time in mode [seconds s], W_f is the fuel flow [kg/s] and EI_{nvpm_mass} is the nvPM mass emissions index [mg/kg of fuel], EI_{nvpm_num} is nvPM number emissions index [particles/kg of fuel] and F_{∞} is the rated thrust [kN].

3.2 The Environmental Technical Manual (ETM), Volume II

3.3 An update to Part 3, Chapter 4 of the Environmental Technical Manual, Volume II (ETM, Vol. II) has also been developed to promote implementation uniformity of the technical procedures of Annex 16, Volume II by providing the following: (1) Guidance to certificating authorities, applicants and other interested parties regarding the intended meaning and stringency of the Standards in the current edition of the Annex; (2) Guidance on specific methods that are deemed acceptable in demonstrating compliance with those Standards and (3) equivalent procedures resulting in effectively the same nvPM emissions evaluation metric that may be used in lieu of the procedures specified in those Standards.

4. STRINGENCY OPTIONS

4.1 An important part of the Standard-setting process was the definition of the nvPM mass and number stringency options, which could be chosen to represent the eventual limit lines for the nvPM mass and number standards. Each stringency option for nvPM mass and number aimed to maintain the intended behaviour of the nvPM emissions metric; i.e., to equitably reward advances in engine technologies that contribute to reductions in engine nvPM emissions, and to differentiate between engines of different size and with different generations of technologies.

4.2 The development of the nvPM mass and number stringency options was based on the nvPM metric value database (nvPMVdb). The nvPMVdb contained engine test data provided directly from manufacturers and certification authorities on in-production engine types. Most of the measurements were targeted to comply with the CAEP/10 nvPM Standard (applicable from 1 January 2020), which contains the nvPM measurement system requirements, procedure and evaluation of LTO points and as such, the confidential nvPMVdb contained “certification-like” data. Overall, data from 23 engine types was used to develop the metric values and stringency options.

4.3 To correct nvPM emissions to standard day conditions, two proposed ambient conditions correction methodologies for nvPM mass and one for nvPM number were evaluated. Based on the results of the evaluation, it was concluded that additional tests may be needed and further analysis will be pursued in order to be able to propose satisfactory ambient corrections for nvPM mass and number emission indices (EIs), robust enough for inclusion into ICAO Annex 16, Volume II. For stringency options development, the nvPM emission EIs were not corrected for ambient conditions effects. The uncertainty on metric values for not correcting for ambient conditions have been taken into account, with an order of ± 10% for nvPM mass and ± 30% for nvPM number.

4.4 Application of fuel corrections was recommended and used the following functions to correct measured nvPM mass and number EIs to a fuel hydrogen content reference of 13.8% mass, hence normalising the nvPM emission values to the reference fuel for the stringency options development:

$$\boldsymbol{k_{FUEL\_M}} = exp\left\{\left(0.95\frac{F}{F_{00}} - 1.12\right)(13.8 - H)\right\}$$

$$\boldsymbol{k_{FUEL\_N}} = exp\left\{\left(0.99\frac{F}{F_{00}} - 1.05\right)(13.8 - H)\right\}$$

where $\boldsymbol{k_{FUEL\_M}}$ is the fuel correction factor for the nvPM mass emission index, $\boldsymbol{k_{FUEL\_N}}$ fuel correction factor for the nvPM number emission index, exp the exponential function, F the thrust in mode [kN], F_{00} the rated thrust [kN] and H the fuel hydrogen content measured in %mass.

4.5 In contrast to gaseous emissions not being lost in a leak-tight system, any particle measurement system will have losses for particles in the sampling system resulting in nvPM values at instrument level that will always be lower than the values at engine exit plane. The dominant particle loss mechanisms are particle size dependent and are higher for nvPM number than for nvPM mass. Relatively bigger particles penetrate better compared to smaller particles; however, larger particles contribute more to nvPM mass. For example, an engine emitting generally larger particles than a competitor engine would report higher nvPM number levels at the instrument, although it may have similar nvPM number levels at the engine exit plane.

4.6 Based on the state of science informed by data analysis, it was concluded that the metric values could not be corrected for system losses with confidence while noting that not correcting for system losses may lead to some bias between engine metric values especially for number emissions, despite the use of standardised measurement systems. This potential bias was not taken into consideration in the stringency options development for the following additional reasons. (1) The certified metric value of an engine depends on its own performance, not on the relative performance of another engine; and (2) the unintended consequence of not addressing the potential bias could be an incentive to design engines to emit even smaller particles. However, the proposed CAEP/11 Standard makes use of two metric systems, for nvPM mass and nvPM number, which work together. If particle sizes are reduced and e.g. the particle number does increase, the particle mass is reduced but the particle number will be higher. The measurement system is less responsive to the smallest particles but it does not cut them off and is still measuring them. The metric values for nvPM mass and number in the nvPMVdb show that in general, engines with a lower number emit less mass.

4.7 **nvPM Mass Stringency Options**

4.7.1 A specific nvPM mass regulatory limit for in-production (INP) engines with a proposed applicability date of 1 January 2023 was derived based on the measured data. The INP regulatory limit is designed to be an anti-backsliding Standard. Given the fact that a number of small engine technologies had relatively higher metric values, the INP regulatory limit has a decreasing metric value as thrust increases until the 200 kN kink point. For engines with rated thrusts greater than 200 kN, the data indicates no trend in metric values and therefore a constant metric value is chosen to provide the INP regulatory limit.

4.7.2 The five New Type (NT) nvPM mass stringency options are chosen with a 150 kN kink point. The 150 kN is chosen because: a) it is the best mathematical fit to the clusters of data from different technologies; and b) this allows for reduction in severity of stringency for engines of rated thrust below 89 kN without being very lenient. Above a rated thrust of 150 kN, the five stringency options have been prescribed as per cent reductions from NT-1 (0%, 16%, 44%, 72% and 82%) for which the metric value is set at 250 mg/kN. Below a rated thrust of 150 kN, these five options provide increasing margin to smaller engines due to associated technical challenges (200 per cent alleviation for NT-1 through NT-4 and 30 per cent for NT-5). Table 4.1 are the equations for the nvPM mass stringency lines are shown in Figure 4.1.

Table 4.1: nvPM Mass Stringency Equations for In-Production (INP) and New Type (NT) Engines

nvPM Mass Stringencies	Equations	Rated Output Range
INP	3343 – 15.465 F_{00}	26.7kN < F_{00} < 200 kN
	250	$F_{00} \geq$ 200 kN
NT-1	879.1 – 4.19 F_{00}	26.7kN < F_{00} < 150 kN
	250	$F_{00} \geq$ 150 kN
NT-2	738.4 – 3.52 F_{00}	26.7kN < F_{00} < 150 kN
	210	$F_{00} \geq$ 150 kN
NT-3	492.3 – 2.35 F_{00}	26.7kN < F_{00} < 150 kN
	140	$F_{00} \geq$ 150 kN
NT-4	246.1 – 1.17 F_{00}	26.7kN < F_{00} < 150 kN
	70	$F_{00} \geq$ 150 kN
NT-5	61.5 – 0.11 F_{00}	26.7kN < F_{00} < 150 kN
	45	$F_{00} \geq$ 150 kN

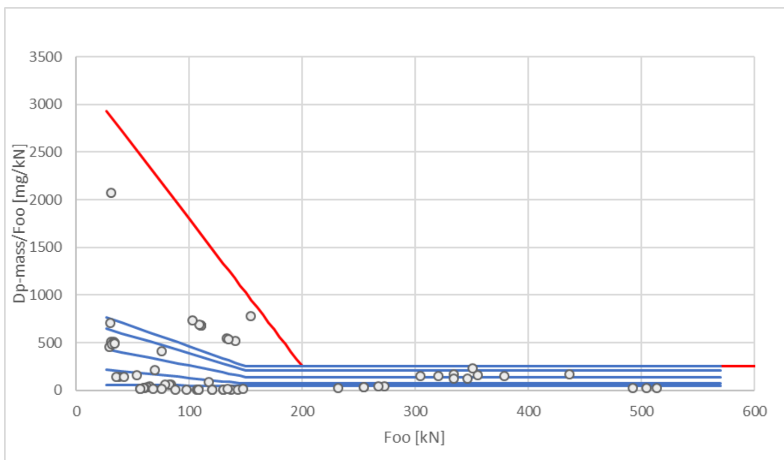


Figure 4.1: Proposed nvPM Mass Stringency Options.

The red line is the In-Production Regulatory Limit.

The blue lines represent the five proposed New Type nvPM Mass Stringency Options.

The circles are metric values obtained from the list of representative in-production engines in the nvPMVdb.

4.8 nvPM Number Stringency Options

4.8.1 One nvPM number stringency level for in-production engines with a proposed applicability date of 1 January 2023 was derived based on the cluster of data points across the thrust range. This necessitates a kink point at 200 kN. Given the trend of nvPM number metric values across the thrust range, use of one kink point is justified to represent this anti-backsliding stringency line.

4.8.2 The NT nvPM number stringency options are derived to be consistent with the mass stringency levels with a 150 kN kink point. The number of stringency options is limited to three, based on the analysis that reduction in nvPM mass does not translate to similar reductions in nvPM number metric values. Above a rated thrust of 150 kN, three stringency levels have been prescribed as per cent reductions from NT-1 (0%, 33% and 66%) for which the metric value is set at 3×1015 #/kN. The strictest stringency level for nvPM number has more margin to the best performing engines than for nvPM mass. Below a rated thrust of 150 kN, these three levels provide increasing margin to smaller engines due to associated technical challenges (200 percent alleviation for NT-1 through NT-3). The nvPM number stringency levels are shown in Figure 4.2. The equations for these lines are shown in Table 4.2.

Figure 4.2: Proposed nvPM Number Stringency Options.

The red line is the In-Production Regulatory Limit.

The blue lines represent the three proposed New Type Stringency Options.

The circles are metric values obtained from the list of representative in-production engines in the nvPMVdb.

There are two additional stringencies for nvPM mass as reducing mass emissions is better understood at this point of time.

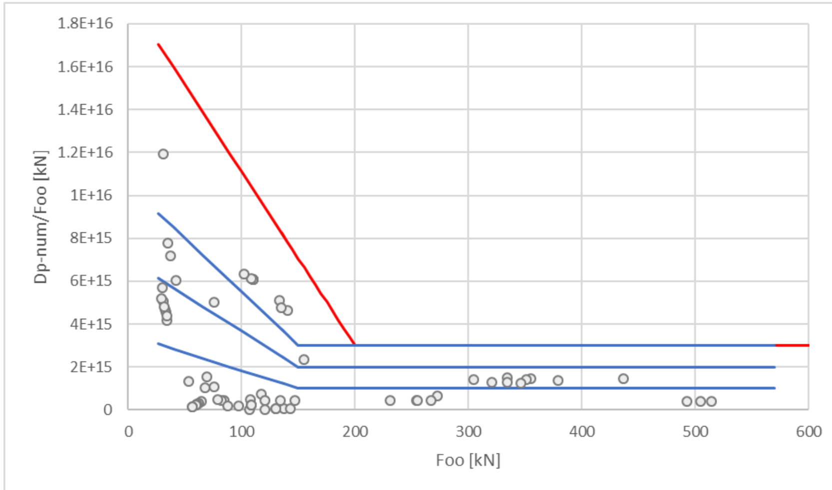


Table 4.2: nvPM Number Stringency Equations for In-Production (INP) and New Type (NT) Engines

nvPM Number Stringencies	Equations	Rated Output Range
INP	$1.92\times10^{16} - 8.1\times10^{13}\ F_{00}$	$26.7kN < F_{00} < 200$ kN
	3.0×10^{15}	$F_{00} \geq 200$ kN
NT-1	$1.05\times10^{16} - 5.0\times10^{13}\ F_{00}$	$26.7kN < F_{00} < 150$ kN
	3.0×10^{15}	$F_{00} \geq 150$ kN
NT-2	$7.03\times10^{15} - 3.36\times10^{13}\ F_{00}$	$26.7kN < F_{00} < 150$ kN
	2.0×10^{15}	$F_{00} \geq 150$ kN
NT-3	$3.52\times10^{15} - 1.68\times10^{13}\ F_{00}$	$26.7kN < F_{00} < 150$ kN
	1.0×10^{15}	$F_{00} \geq 150$ kN

4.9 **nvPM Mass and Number Stringency Option Combinations (SO)**

4.9.1 For the NT engines cost effectiveness analysis, the five nvPM mass and three nvPM number stringencies were combined to form the twelve stringency option combinations (SO) shown in Table 4.3. The colour differentiation is to indicate that the nvPM mass levels drive the responses for SO2, SO4, SO5 and SO7 to SO12, while the nvPM number levels drive the responses for SO1, SO3 and SO6.

Table 4.3: nvPM Mass and Number Stringencies Modelled for New Types

	nvPM number Stringency 1	**nvPM number Stringency 2**	**nvPM number Stringency 3**
nvPM mass Stringency 1	SO-1		
nvPM mass Stringency 2	SO-2	SO-3	
nvPM mass Stringency 3	SO-4	SO-5	SO-6
nvPM mass Stringency 4	SO-7	SO-8	SO-9
nvPM mass Stringency 5	SO-10	SO-11	SO-12

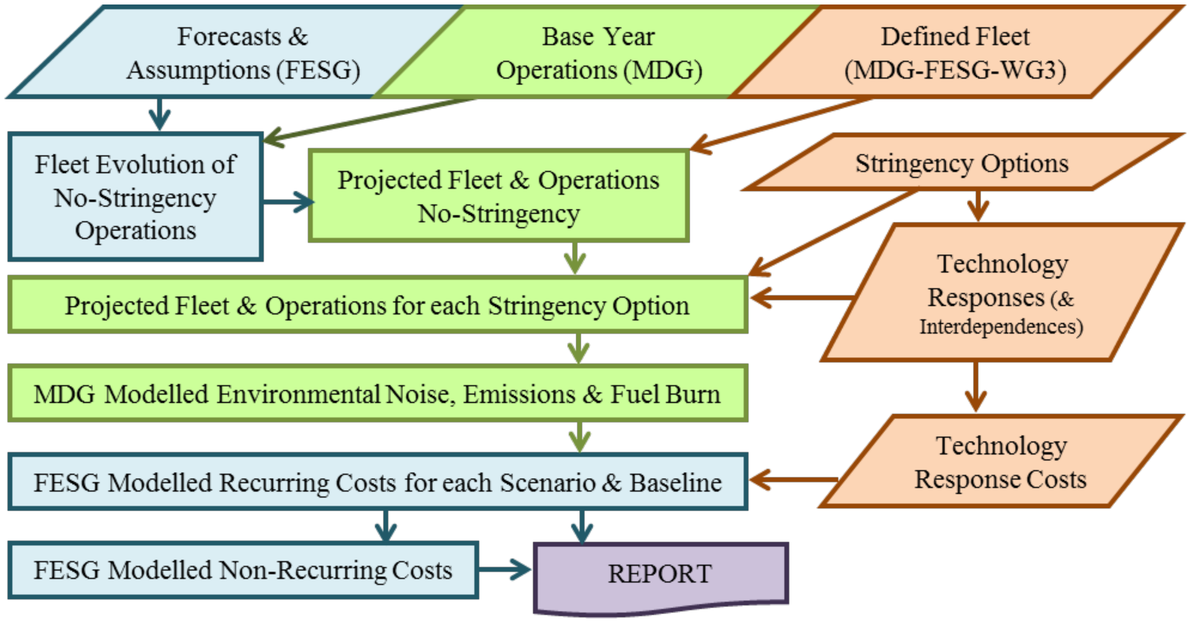
5. COST EFFECTIVENESS ANALYSIS APPROACH

5.1 In order to address the CAEP tenets of environmental effectiveness and economic reasonableness, CAEP has conducted a full cost effectiveness analysis. This involved the definition of an analysis framework and analytical tools, including fleet evolution modelling, environmental modelling, recurring costs, non-recurring costs, and costs per nvPM mass and number emissions avoided. The analysis was conducted with the aim of providing a reasonable assessment of the economic costs and environmental benefits for a potential nvPM mass and number emissions Standard in comparison with a "No ICAO action" baseline. The models that contributed to the analysis are listed in Table 5.1 and a high-level overview of the modelling process is provided in Figure 5.1.

Table 5.1: Contributing Models

	Model	Area	Sponsor
AAT	Aircraft Assignment Tool	Fleet Evolution	EUROCONTROL, EC and EASA
APMT-E	Aviation Portfolio Management Tool for Economics	Fleet Evolution & Costs	US
FCM	FESG Cost Model for nvPM	Cost-Effectiveness	FESG
FAST	Future Civil Aviation Scenario Software Tool	GHG	UK
IMPACT		GHG	EUROCONTROL
AEDT	Aviation Environmental Design Tool	GHG and Noise	US
ANCON	Aircraft Noise Contour Model	Noise	UK
STAPES	SysTem for AirPort noise Exposure Studies	Noise	EUROCONTROL, EC and EASA
MDG Landing and Take-Off cycle (LTO) Consensus Model		LTO Emissions	MDG

Figure 5.2: Analysis Process Overview



5.2 Defining the Global Fleet

5.2.1 The analysis process requires defining aeroplane and engine types that enter into the global fleet during the forecast years up to 2042, for both the baseline and each SO. This information is collated into the Growth and Replacement database (GRdb). This database documents all of the information required by the modelling community regarding each aeroplane and engine type in the analysis, both in their base configuration and as defined for each SO. The GRdb also includes references to other data sources such as the ICAO Aircraft Engine Emissions Databank and the ICAO noise certification database (NoisedB).

5.2.2 The GRdb was defined with aeroplane and engine types that are both in-production (INP) and scheduled for entry into the fleet before 2023. For products that remain to be certified, the information required for modelling (project data) were provided by manufacturers. (The analysis did not speculate on potential future technology developments.) The baseline analysis scenario included some INP types going out of production and replaced by types entering the fleet prior to the 2023-implementation year. The transition between these paired types was immediate; i.e., there was no over-lapping "ramp up/ramp down" of production between transition pairs for this analysis. Because the transitioning process ended before the 2023 stringency applicability year, it had no effect on the results.

5.2.3 Another element defined in the GRdb are competition bins (CBins), which align to the fleet forecast seat classes. There can be a one-to-one relationship between the fleet forecast seat classes and CBins (as was the case for business jets); however, CBins have also been used to separate regional jets and turboprops[4] (which are not separated in the fleet forecast). While CBins are required for the modelling process, results are primarily reported with all markets combined or at a market-specific level. Table 5.2 shows the market shares of all baseline aviation markets combined versus only those subject to the proposed CAEP/11 nvPM mass and number Standards.

[4] Turboprops are not subject to the proposed nvPM mass and number standards

Table 5.2: Comparison of All Baseline Path-B (2025-2042) **Operations vs. Those Subject to nvPM**

Market	All Operations Market Share	Operations Subject to nvPM Market Share	Operations Not Subject to nvPM Market Share
Narrow Body Passenger (NB-PAX)	55.6%	63.6%	0%
Wide Body Passenger (WB-PAX)	24.8%	28.4%	0%
Turboprops	9.2%	0.0%	73%
Business Jets (BJ)	7.6%	6.1%	18%
WB-Freighters	1.7%	1.5%	3%
NB-Freighters	1.1%	0.4%	6%
Total	100%	100%	100%

5.3 **Two Paths**

5.3.1 The analysis for the potential CAEP/11 nvPM mass and number Standards included a portion of the GRdb fleet modelled in two ways. Small and medium wide-bodied passenger aircraft were originally defined from the fleet forecast as CBin-9 (211 to 300 seats) and CBin-10 (301 to 400 seats). That fleet forecast-based approach was modelled as "**Path-B**" with CBin-9 and CBin-10 separated. An alternative "**Path-A**" approach modelled CBin-9/10 together. These different paths along with the equal product market share fleet evolution modelling assumption resulted in operations being distributed differently between the small and medium WB-PAX aircraft, as shown in Table 5.3.

Table 5.3: Operations distribution between CBin-9 and CBin-10 for Path-A and Path-B.

	Alternate Path-A BSL CBin-9/10 Combined	Path-A SO10 CBin-9/10 Combined	Forecasted Path-B BSL CBin-9 vs CBin-10 Separated	Path-B SO10 CBin-9 vs CBin-10 Separated
CBin-9 %	47%	46%	**82%**	**82%**
CBin-10 %	**53%**	**54%**	18%	18%

5.3.2 The "all-market" level results, presented later in the document, indicate whether the small and medium WB-PAX aircraft component is from Path-A or Path-B by the letter after the SO number; e.g., SO10a and SO10b. In most figures, all Path-B SO results are shown along with the Path-A SO10-12a on the right since SO10 through SO12 are where the two paths have the most notable differences in results, and because Path-B represents the original fleet forecast.

5.4 **Fleet Evolution Modelling**

5.4.1 Fleet evolution models use forecasted fleet and traffic demand as targets to project a scenario-compliant future fleet-specific schedule of operations and generate required inputs for the environmental models. The fleet evolution modelling process requires the following. (1) Base-year data, including a fleet-specific schedule of operations and the age profile for the base-year fleet. (2) The GRdb defined for the baseline (no stringency) and for each SO, and including seat/capacity assumptions for each aircraft/engine. (3) Fleet and traffic forecast targets along with compatible (4) aircraft retirement curves.

5.4.2 Depending on the "fleet choice" assumption used for particular analysis, costs can also be required for fleet evolution modelling. However, the fleet choice assumption for the CAEP/11 nvPM mass and number Standard analysis was "Equal Product Market Share" in which each available (scenario compliant) aircraft/engine within a competition bin is used equally (without considering operating costs).

5.4.3 The fleet-specific schedule of operations varies from the baseline when a GRdb entry does not respond to an SO, and is assumed to go out of production at the implementation date. The technology response nvPM Improvement (NI) levels do not impact fleet selection. Therefore, the fleet evolution modellers only needed to model four scenarios to represent the twelve SO defined for the cost-effectiveness analysis. This point is highlighted in Table 5.4; namely, a run where all engine families remain in the analysis; a run where one drops out of the analysis; a run where two drop out of the analysis; and a run where eleven drop out of the analysis.

Table 5.4: Summary of Engine Family nvPM Technology Responses

	BSL	SO1 m1n1	SO2 m2n1	SO3 m2n2	SO4 m3n1	SO5 m3n2	SO6 m3n3	SO7 m4n1	SO8 m4n2	SO9 m4n3	SO10 m5n1	SO11 m5n2	SO12 m5n3
Pass	33	31	28	26	23	22	21	18	18	18	13	13	13
NI1	0	0	1	1	1	1	0	1	1	1	0	0	0
NI2#	0	1	1	3	2	2	1	0	0	0	0	0	0
NI2M	0	0	2	1	2	2	0	2	2	2	1	1	1
NI3	0	1	1	1	5	5	9	10	10	10	8	8	8
No Response	0	0	0	1	0	1	2	2	2	2	11	11	11

5.4.4 When a growth and replacement fleet option (GRdb type) does not respond to an SO, the consequence varies by how much the remaining CBin growth and replacement options differ from the GRdb type(s) that do not respond. Apart from emissions improvements, the change from baseline stringency-results become more pronounced the more a stringency scenario fleet otherwise differs from the baseline fleet. Fuel burn and cost elements for individual GRdb types are part of the change; however, capacity differences magnify the change from the baseline because the levels of operations and deliveries change, which results in more (positive or negative) fuel burn, capital and direct operating cost changes.

5.5 nvPM Mass and Number Emissions Modelling

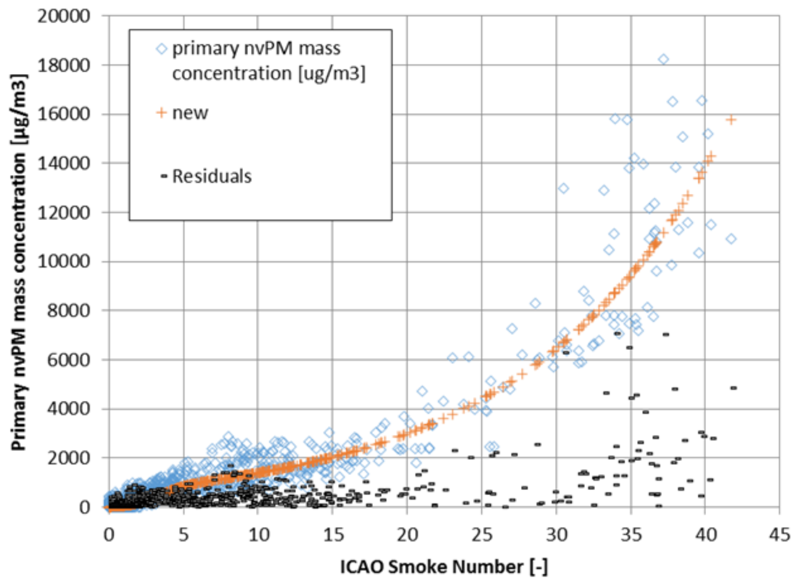
5.5.1 As much as possible, the 2012 base year and GRdb fleets were mapped to measured emission indices (EIs) from the nvPM metric value database (nvPMVdb) and provided directly from manufacturers. However, there were no measured nvPM emissions available for eleven of the thirty-three GRdb engine families represented in the analysis; so, the nvPM mass and number metric values for those engines had to be estimated. Those estimations were based on certified ICAO Smoke Numbers and correlation to nvPM derived-from-measurement comparisons between Smoke Numbers and nvPM.

5.5.2 A large set of nvPM mass concentration to Smoke Number pairs was available as more engines were tested and a correlation database (Cdb) was updated using these measurements. With this larger set of data pairs, the Cdb correlation of nvPM mass concentration to SN could be more reliably determined. An improved correlation and the corresponding equations have been derived, based on this more extensive data set. The updated correlation can be expressed as:

$$nvPM\ mass\ concentration\ [\mu g/m3] = \frac{648.4\, e^{(0.0766\, SN)}}{1 + e^{-1.098(SN-3.064)}}$$

5.5.3 This correlation was recommended for use in estimating nvPM mass concentrations when measured nvPM mass data is not available and SN data is available. In particular, this correlation was used to calculate the nvPM mass Emission Index (EI) in conjunction with the Fuel to Air Ratio (FAR) estimation procedure previously developed for the published, so called FOA3 method used before, to estimate PM LTO mass emissions from aircraft engines.

Figure 5.2: Updated smoke number to mass concentration correlation



5.5.4 The new Smoke Number to nvPM mass correlation was named SCOPE11 and provides estimations of nvPM mass EIs corresponding to measured values at instrument level of an nvPM standard measurement system required for aircraft engine nvPM emission certification. An additional step was the estimation of nvPM number EIs, which is based on the nvPM mass EIs estimated from smoke number with SCOPE11 as provided by the equation below:

$$nvPM_{EI_{number,i}} = \frac{nvPM_{EI_{mass,i}}}{\left(\frac{\pi}{6}\right) \cdot GMD_i^{\,3} \cdot \rho_i \cdot e^{(4.5\,(ln\,\sigma_i)^2)}}$$

Where $nvPM_{EI_{number,i}}$ is the nvPM number EI of LTO mode i (idle, approach, climb-out, take-off). $nvPM_{EI_{mass,i}}$ is the nvPM mass EI of LTO mode i. GMD_i is the geometric mean diameter of the particles in mode i (recommended values used in modelling provided in paragraphs below). ρ_i is the assumed particle effective density (proposed value for all modes 1 g/cm^3). σ_i is the dimensionless geometric standard deviation of an assumed one-mode lognormal distribution (proposed value for all modes 1.8).[5]

5.5.5 Two approaches were used in modelling nvPM number emissions from the mass EIs estimated from Smoke Number.

5.5.5.1 Approach 1: Use of a mode-specific set of GMDs with fixed values for the four LTO modes (GMD = 20 nm at idle and approach, 38 nm at climb-out and 41 nm at take-off thrust conditions).

5.5.5.2 Approach 2: Use a mass concentration-GMD relationship, which was given with the following formula:

$$GMD = 12.5 \cdot C^{0.15}$$

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5 Note that unit conversion factors may be needed depending on the units used in the formula

Where C is the nvPM mass concentration in μg/m^3 in the engine core, estimated using the SCOPE11 correlation and the GMD is the geometric mean diameter in nm.

5.5.6 The modellers estimated the nvPM number emissions using both approaches. While nvPM number metric values and emissions estimated using the two approaches were different, this did not adversely affect the technology response. This is because the engines for which the nvPM emissions had to be estimated using Smoke Number were driven by the mass components of the combined stringency options.

5.6 **Environmental Modelling**

5.6.1 Landing and Take-Off cycle (LTO) Modelling – Time in mode-based LTO modelling was used with the ICAO/CAEP Modelling and Database Group (MDG) LTO Consensus Model for this analysis.

5.6.2 Project Data – The information required for modelling products that remain to be certified were provided by manufacturers. Modellers applied adjustments to fuel burn and emissions for all project types entering the fleet in the future years. A separate adjustment was also applied to the NOx results when specified. These results were applied as a scalar multiplier to each operation in the LTO dataset.

5.6.3 Trajectory Assumptions – Traditionally, CAEP full-flight greenhouse gas (GHG) emissions and fuel burn modelling has involved the use of great circle trajectory for the underlying origin-destination (OD) pairs as defined in the COD. For this analysis, however, all possible aircraft/engine types were modelled flying 18 representative tracks for the maximum possible range. In addition, each aircraft/engine type was modelled flying the type-specific minimum and maximum OD pair from the 2012 Common Operations Database (COD). Operations from each analysis year were then mapped to one of these tracks and all the parameters were interpolated (except for the minimum and maximum distance in which case the values were directly used) based on the actual and representative OD distances. In addition, AEDT modellers also processed base year 2012 using the traditional modelling method and compared the results with the representative tracks approach. Distance and fuel burn were within 0.5% and all other parameters were within 1% between the two approaches.

5.6.4 Other Environmental Modelling – Trade-off response modelling is the assessment of potential environmental disbenefits that may occur when technology improvements are focused on a single pollutant. While a range from zero to “full” noise and emissions trade-offs were modelled with the analysis submitted to CAEP, engines obtaining new type certificates are required to pass standards for all regulated pollutants; so, that data is not relevant for this document.

5.7 **Cost Modelling**

5.7.1 Recurring – Direct operating costs (DOC) include fuel costs, capital costs (depreciation and finance) and other-DOCs (crew, maintenance, landing and route costs).

5.7.2 Non-Recurring – Because there are no limiting nvPM mass and number standards, there is no historic data on fleet valuation impacts on owner/operators or on how manufacturers will determine the technology response given changes in market demand associated with potential regulatory levels. Consistent with standard principles of economic analysis, all relevant recurring and non-recurring cost (NRC) items should be accounted for in the cost analysis for a potential Standard. Among these cost items, non-recurring (N-R) aircraft owner/operator (AO/O) costs may include a loss in fleet value that could be incurred by aircraft owners and operators for fleet assets that would not meet the stringency options; referred to as asset value loss (AVL). This is based on the premise that the introduction of a new Standard would reduce the market value of existing fleets that do not meet the Standard, even if the Standard does not apply to the in-service aircraft. However, it should be noted that CAEP has not definitively stated whether AVL costs should be included and therefore the results of the analysis were considered with and without AVL.

5.7.3 NRC was used to represent technology response (TR) costs. It is understood, however, that while NRC capture the fixed cost associated with developing TR to pass a standard level, they do not reflect additional production cost of implementing these responses, i.e., material, labour and other recurring costs. The analysis assumes that the cost of manufacturing remains unchanged before and after TR, whereas the additional technology contained in a TR may cost more to manufacture.

5.7.4 Further details on the NRC assumptions are provided in Section 6.

6. TECHNOLOGY RESPONSE ASSUMPTIONS

6.1 Non-Recurring Manufacturer Technology Response Cost (NRC)

6.1.1 The need for considering the inclusion of manufacturer non-recurring cost (NRC) into the analysis arises from the stringency option combinations where one or more engine-family does not meet a stringency and receives a technology response (TR) to remain in the market. NRC captures the fixed costs associated with developing the TR applied to engine-families so that they pass the standard, but not any additional production costs associated with implementing TR. Thus, NRC does not include material, labour or other recurring costs. WG3 developed the technology responses and defined the non-recurring manufacturer costs. The agreed TR framework, as applied to the GRdb engine-families, is summarized in Table 6.1. The agreed TR framework included single, low and high NRC values. Table 6.2 shows the single NRC values applied for the respective NI levels by SO in the second through fourth columns; the last three columns show the total NRC by SO for the single, low and high NRC values respectively.

Table 6.1: Summary of Engine Family nvPM Technology Responses

	Pass	NI1	NI2#	NI2M	NI3	No Response
Baseline	33	0	0	0	0	**0**
SO-1: NT SO mass1 #1	31	0	1	0	1	**0**
SO-2: NT SO mass2 #1	28	1	1	2	1	**0**
SO-3: NT SO mass2 #2	26	1	3	1	1	1
SO-4: NT SO mass3 #1	23	1	2	2	5	**0**
SO-5: NT SO mass3 #2	22	1	2	2	5	1
SO-6: NT SO mass3 #3	21	0	1	0	9	2
SO-7: NT SO mass4 #1	18	1	0	2	10	2
SO-8: NT SO mass4 #2	18	1	0	2	10	2
SO-9: NT SO mass4 #3	18	1	0	2	10	2
SO-10: NT SO mass5 #1	13	0	0	1	8	11
SO-11: NT SO mass5 #2	13	0	0	1	8	11
SO-12: NT SO mass5 #3	13	0	0	1	8	11

Table 6.2: Manufacturer Non-Recurring Costs for Engine Family Responses

Single Value NRC ($M)	$15	$250	$150	$500	Single Value	Low NRC	High NRC
	NI1	NI2#	NI2M	NI3	NRC TOTAL	TOTAL	TOTAL
SO-1: NT SO mass1 #1	$-	$250	$-	$500	$750	$450	$1,050
SO-2: NT SO mass2 #1	$30	$250	$150	$500	$930	$560	$1,350
SO-3: NT SO mass2 #2	$15	$750	$150	$500	$1,415	$955	$1,900
SO-4: NT SO mass3 #1	$15	$250	$450	$2,500	$3,215	$1,755	$4,700
SO-5: NT SO mass3 #2	$15	$500	$300	$2,500	$3,315	$1,855	$4,800
SO-6: NT SO mass3 #3	$-	$250	$-	$4,500	$4,750	$2,450	$7,050
SO-7: NT SO mass4 #1	$-	$-	$150	$5,000	$5,150	$2,600	$7,700
SO-8: NT SO mass4 #2	$-	$-	$150	$5,000	$5,150	$2,600	$7,700
SO-9: NT SO mass4 #3	$-	$-	$150	$5,000	$5,150	$2,600	$7,700
SO-10: NT SO mass5 #1	$-	$-	$150	$3,500	$3,650	$1,850	$5,450
SO-11: NT SO mass5 #2	$-	$-	$150	$3,500	$3,650	$1,850	$5,450
SO-12: NT SO mass5 #3	$-	$-	$150	$3,500	$3,650	$1,850	$5,450

6.2 Non-recurring aircraft owner/operator Asset Value Loss (AVL)

6.2.1 Consistent with prior FESG practice and standard principles of economic analysis, all relevant recurring and non-recurring cost items should be accounted for in the cost analysis of the stringency option combinations. Among these, non-recurring (N-R) owner/operator (O/O) costs may include a loss in fleet value that could be incurred by owners and operators for fleet assets that would not meet a new standard (represented in the analysis by the stringency option combinations). This Asset Value Loss (AVL) is based on the following premises. (1) The introduction of a new Standard would reduce the market value of existing fleets that do not meet the Standard, even if the standard does not apply to the in-service fleet. (2) The introduction of a new Standard would cause a loss of fleet commonality between pre-Standard assets and new compliant-fleet assets.

6.2.2 The method used in this analysis uses much of the methodology developed for the CO_2 main analysis (CO2ma) that informed the CAEP/10 Standard.[6] As with the CO2ma, fleet assets subject to AVL are all those in the growth and replacement database that do not pass the nvPM stringency option combinations and enter the fleet between the announcement and implementation dates. For example, if the Standard is announced in 2019 and implemented in 2025, AVL would be assessed for aircraft that entered the fleet in 2020, 2021, 2022, 2023 and 2024.

6.2.2.1 How to recognize AVL: It is acknowledged that accounting practices allow for asset value losses and that they are recorded as impairment charges. When there is a change in the operating environment, such as the implementation of a new regulation, negative impacts on an asset's value are recorded in financial statements as an impairment loss.

6.2.2.2 When to recognize AVL: For the purposes of the modelling, an impairment charge is being used as a proxy for the actual realized market value loss, which would be recognized when an aircraft being assessed an AVL is sold. The idea is to consider the loss an operator would incur by selling an aircraft before the end of its economic life at a lower cost than initially estimated when the aircraft was purchased. For this purpose, it is assumed that asset values as projected through depreciation schedules are sensible proxies for resale prices.

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[6] CAEP/10-IP/06 Appendix E, and to FESG-MDG in CAEP/11-FESG-MDG/6-WP/15, January 2018

6.2.2.3 It is also assumed that the impairment charge calculated at the implementation date will be equal to the loss in value when aircraft are sold when they near the end of the first third of their 25-year economic useful lives, that is, 8 years after their entry into service. This is due to the fact that, under the assumption of parallel depreciation curves, the impairment charge calculated at the Standard implementation date will be the same as the loss in market value observed when an aircraft is sold.

6.2.2.4 Estimating the AVL connected to the nvPM stringency analysis: Similar to the CAEP/8 NOx Standard analysis (NOx/8), the loss of asset value is tied to reduction in value to the engines that do not pass the Standard, whereas engines delivered from the Standard effective date will have technologies that allow them to pass the Standard. The magnitude of the value of the AVL or impairment charge for the current analysis was developed from the NOx/8 work.

6.2.2.5 One method for calculating lost value in engine fleets delivered before the stringency effective date that would not pass the Standard is to estimate the "upgrade" retrofit cost required to allow those same engines to pass the new Standard through engine improvements. For the NOx/8, the engine manufacturer experts had scaled the costs of existing emissions kits to develop cost estimates for hypothetical engine modification packages.

6.2.2.6 Table 6.3 shows the AVL values used for NOx/8 along with the values to use for the nvPM stringency analysis. The values for CAEP/8 were in 2009 US Dollars. The cost analysis for nvPM is in 2012 US Dollars. The agreed approach is to use the CAEP/8 values by Modification Status (MS) level and escalate them to 2012 US Dollars. That requires a 1.07 escalation factor.

Table 6.3 – CAEP/8 AVL

CAEP/8 Technology Response	**AVL per Engine**
MS1: Minor Changes	0
MS2: Scaled Proven Technology	$250,000
MS3: New Technology	$500,000

Table 6.4 – CAEP/11 AVL

Technology Response	**AVL per Engine**
NI1	0
NI2	$268,000
NI3	$535,000
No Response	$535,000

6.2.3 Table 6.4 presents the escalated values to use for the CAEP/11 nvPM stringency analysis. For CAEP/11, there are significantly more “no technical” responses at the higher stringency option combinations which wasn’t the case for the CAEP/8 NOX Standard analysis. Therefore, an additional impairment charge value is needed for the “no responses” in the CAEP/11 analysis. It has been agreed to use the highest technical response, NI3, value as a proxy. However, it should be acknowledged that with a “no response”, the aircraft goes out of production and the loss of asset value may be underestimated.

6.3 **Spare Engine Costs**

6.3.1 Spare engines are required by operators to cover scheduled maintenance visits and unscheduled engine removals. By exchanging a ready-to-fly spare engine for an on-wing engine that requires repair, operators can keep their aircraft flying with minimum lost time on the ground while the removed engine is sent to a maintenance provider for servicing.

6.3.2 The introduction of a new Standard would cause a loss of fleet commonality between pre-Standard assets and new compliant-fleet assets. This would incur additional owner/ operator costs to maintain spare engines for the portion of the fleet acquired before the Standard effectiveness date and a separate set of spare engines for the subsequently acquired fleet.

6.3.3 A review and survey were conducted regarding the spare engine assumptions used for the CAEP/6 and CAEP/8 NOx stringency analyses because those were based on 15-year old data that did not consider the business jet market. In addition, there were concerns that assets may be managed differently with the rise of engine leasing.[7]

6.3.4 IATA 2018 inputs were assessed against the CAEP/6 and CAEP/8 assumptions with the conclusion that the requirement for spare engines has trended lower for the commercial passenger and freighter markets than previously calculated.[8]

6.3.5 The business jet segment's investment in spare engines is somewhat similar to the commercial segment, however the business jet operators rely ever more greatly on the engine manufacturers and maintenance repair organizations (MROs) to invest in a pool of engines and make them available to the operator on a rental basis to support scheduled and unscheduled maintenance and inspections. With input from two IBAC member companies, the conclusion was to use the agreed upon commercial fleet spare engine curve to also represent the business jet market. From a global perspective, a similar relationship of spare engines required, measured in terms of percent of in-service fleet, should hold for business jet and commercial operators. The engine manufacturers and MRO providers act effectively in bringing efficiencies to the market by bringing small fleets together to act like a large fleet in terms of spare asset management.

6.3.6 An investigation was made into the relationship between aircraft and engine prices; and the linear regression that is a function of airplane price was used to estimate spare engine prices for the families that require a NI3 technical response to meet certain stringency option combinations. Average engine price was calculated for the engines grouped by aircraft retirement code and the results are presented in Table 6.5.

[7] CAEP/6-IP/13, Economic Assessment of the NOx Stringency Options, and CAEP/8-IP/14, Economic Assessment of the NOx Stringency Scenarios

[8] CAEP/11-FESG-MDG/7-WP/08

Table 6.5: Spare Engine Price Assumptions

Aircraft Retirement Code	Spare Engine Price (US2012$ Millions)
B_WB_PAX	$11.3
G_NB_FRT	$6.5
H_WB_FRT	$5.3
A_NB_PAX	$5.1
F_BJ	$3.4

6.3.7 Commonality Factor – The CAEP/8 NOx stringency analysis assumed that the requirements for extra spare engines would apply to 50% of the engines receiving a modification status level 3 (MS3) technology response. It was assumed that the other 50% of engines (receiving a MS3 technology response) could be mixed with the engines that they replaced and so did not require additional spare engines to be acquired. Lacking information to contradict the CAEP/8 assumption, the 50% commonality factor for engines receiving a NI3 response (equivalent to the CAEP/8 MS3 response) for the present analysis.

6.4 Lost Revenue Assessment

6.4.1 The cost impact for lost revenue is directly linked to engines receiving a NI3 tech response, where there is a 0% to 0.5% fuel burn penalty trade-off from technology to improve nvPM mass and number. The population of flights (operations) for which this cost impact is assessed is limited to those flights that are operated at long-range distances where the aircraft is operated at its maximum take-off mass (MTOM). For previous CAEP analyses, the percentage of an aircraft's total operations has been on the order of 0% to 2% for narrow body aircraft and 5% for wide body aircraft.

6.4.2 For the current CAEP/11 nvPM stringency analysis, forecast operations have been allocated into separate Competition Bins (CBins) that are organized by aircraft operating up to their MTOW and where the distance bands being operated on exceed the aircrafts' MTOW at full passengers; thus, the operations for these aircraft are at lower payloads to meet the long-range requirements.[9] It is this last set of CBins with long-range missions that would be impacted by an incremental fuel penalty from the NI3 tech response. An amount of payload has to be "off-loaded" so that additional fuel can be loaded to cover the incremental fuel penalty and still operate at a take-off mass that doesn't exceed the MTOM of the aircraft. Cargo is restricted first before blocking off seats to restrict revenue passengers. The reduction in payload to offset the incremental NI3 fuel penalty is approximated by a reduction in revenue belly cargo at a distance where aircraft is operated at MTOM.

6.4.3 To assess the cost impact for lost revenue the first step is to identify the aircraft models that would be impacted. For the CAEP/11 nvPM stringency analysis, the impacted aircraft are models belonging to the wide body segment that at a given level of stringency receive a NI3 tech response. The aircraft impacted for the nvPM stringency analysis are 787, A330neo, A350 and A380.

[9] Reduced capacity wide-bodied aircraft were used for operations above 999nmi in CBin-33 (85 seats); above 2499nmi in CBin-34 (100 seats) and CBin-35 (125 seats); above 3499nmi in CBin-36 (150 seats), CBin-37 (175 seats) and CBin-38 (210 seats); and above 6499nmi in CBin-39 (300 seats).

6.4.4 To simplify the analysis and to protect proprietary data, a single blended value was computed for the payload “off-loaded” at the long-range distances where the aircraft is operated at their respective MTOM.

Average cargo impact from off-loaded payload = 0.17 tonnes

6.4.5 The next step is to choose a representative cargo revenue yield. For the CAEP/8 NOx stringency analysis, cargo yields were determined from comparing IATA 2007 system average yields, yield data collected by a manufacturer from the 2008 Association of European Airlines (AEA) Star Report and data obtained from public sources used as inputs in the APMT-Economics model. The values were reasonably close. The system wide values were adjusted to the 5000 NM distance using the yield - distance adjustment curve. The cargo revenue yield value for CAEP/8 was $$0.26/RTK, in 2009 US Dollars. This cargo revenue yield was inflated to 2012 US dollars using the US Consumer Price Index (CPI) and the resulting value was $0.28/RTK.

6.4.6 The final step is to perform a set of calculations to estimate the lost revenue for each impacted aircraft for the forecast years 2032 and 2042, then interpolate the intermediate years and calculate the cumulative and present value of the lost revenue. The following equation illustrates the approach.

Lost Revenue per year =
Off-loaded payload * C-Bin Distance * Cargo Yield ($0.28 / RTK) * number of operations at MTOM

6.4.7 The lost revenue for each impacted aircraft is then aggregated to report a global cost impact for each stringency option combination.

6.5 **Other Costs**

6.5.1 In subsequent sections, the label “Other Costs” represents the lost revenue, spare engine, maintenance and incremental build costs.

7. COST EFFECTIVENESS ANALYSIS RESULTS

7.1.1 As shown in Table 5.4, the nvPM technology responses are slightly different for stringency option combinations SO1 to SO6; but they are the same for SO7 to SO9 and for SO10 to SO12. With these inputs, the cost and benefit consequences will be slightly different for the SO1 to SO6 stringency option combinations. Stringency option combinations SO7 to SO9 are defined by mass stringency 4 and number stringencies 1, 2, and 3, respectively. The same engine family technology responses were provided for SO7 to SO9 because mass stringency 4 is determined to be the driving force for these technology responses. Likewise, SO10 to SO12 are defined by mass stringency 5 and number stringencies 1, 2, and 3, respectively. The same engine family technology responses were provided for SO10 to SO12 because mass stringency 5 is determined to be the driving force for these technology responses. It is therefore understandable that there are identical cost and benefit results for SO7 to SO9, and for SO10 to SO12

7.2 The LTO nvPM mass and number emissions results are shown in Figures 7.1 and 7.2. Note that responding engines get their maximum nvPM Improvement (NI) level as soon as they respond. Thus, when an engine is defined to have an NI3 mass response to pass SO3 through SO9, the NI3 benefits are those achieved at SO9 for all NI3 responses. This response approach results in identical costs and benefits for combined SO7 to SO9, as well as combined SO10 to SO12.

Figure 7.1: LTO nvPM Mass (t) Change from Baseline, Cumulative 2025-2042

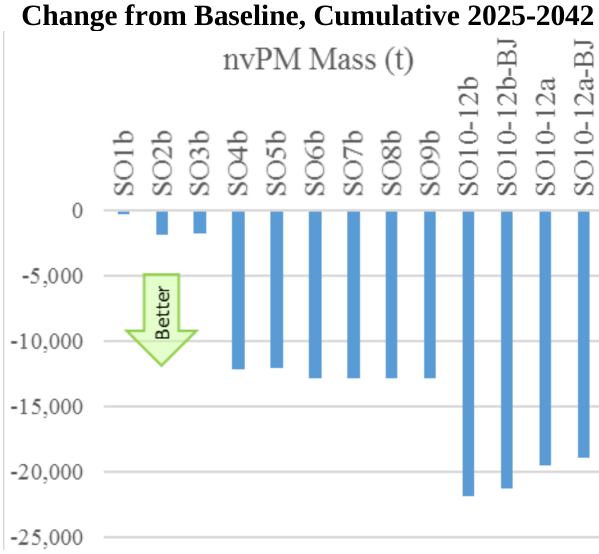
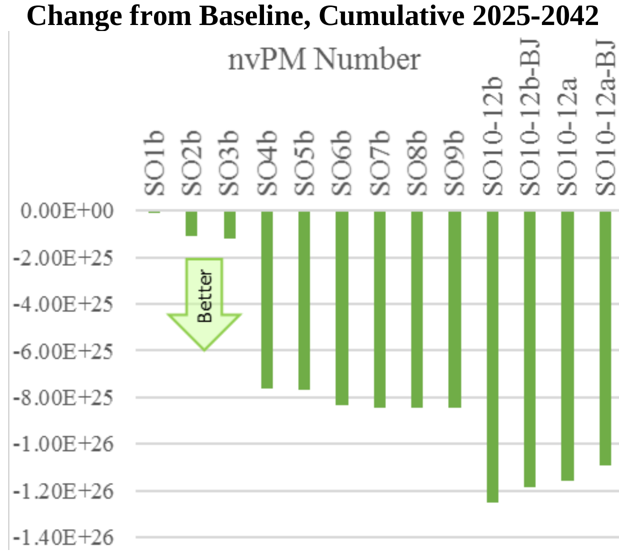


Figure 7.2: LTO nvPM Number Change from Baseline, Cumulative 2025-2042



7.3 The costs calculated included: fuel[10] costs, capital costs (depreciation and finance), other direct operating costs (crew, maintenance, landing and route costs), non-recurring aircraft owner/operator asset value loss (AVL), non-recurring manufacturer technology response cost (NRC), spare engine costs, incremental build costs, maintenance costs and lost revenue for long-range flights that are impacted by the fuel trade-off penalty. In subsequent figures, the label 'Other Costs' represents the lost revenue, spare engine, maintenance and incremental build costs.

[10] Figures reflect the full fuel-burn trade-off penalty, which applied .25% to all operations performed by NI3 responding types.

7.4 Undiscounted change in cumulative (2025-2042) costs (Billions US2012$) is presented in Figure 7.3a for all markets combined. From left to right results are first shown using the original fleet forecast (Path-B), with SO10 to SO12 shown together (SO10-12b); followed by the Path-B SO10 to SO12 combined results minus the business jet market (SO10-12b-BJ). The last two columns on the right are the alternative (Path A) approach for SO10-12a, and those minus the business jet market (SO10-12a-BJ). Figure 7.3b is also provided to zoom in on the SO1 through SO9 results.

Figure 7.3a: Change in Cumulative Costs (2025-2042, 2012$ Billions)

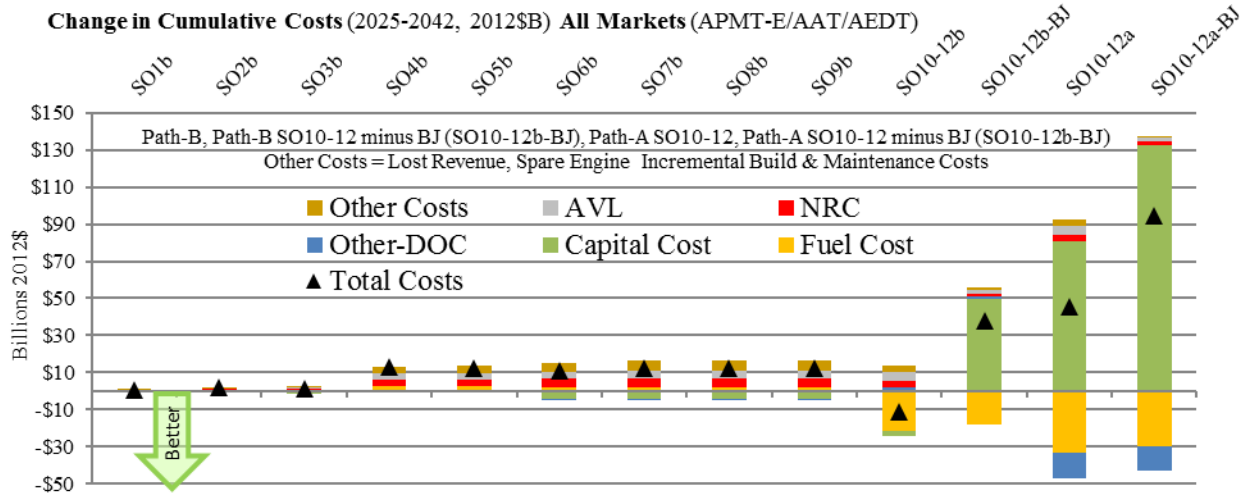
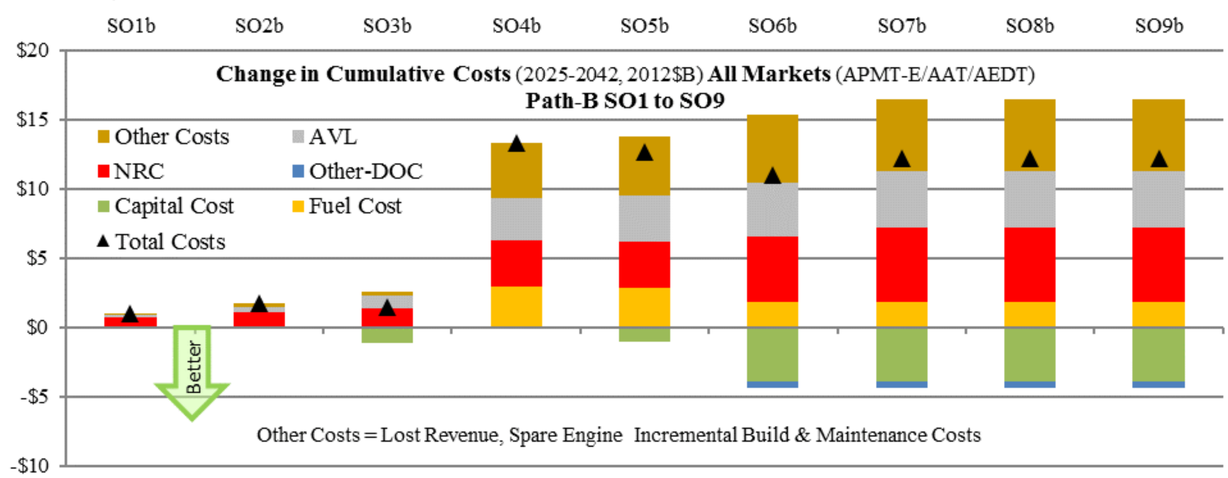


Figure 7.3b: Change in Cumulative Costs (2025-2042, 2012$ Billions) Path-B SO1 to SO9



7.5 Undiscounted change in cumulative costs per nvPM Mass avoided is presented for all markets combined in Figure 7.4. Results for nvPM Number avoided is presented Figure 7.5. The trend of the cost effectiveness ratios for both nvPM Mass and Number show the highest cost for emissions benefit at SO1, where only 7 of 119 GRdb types need to respond. The trend in total cost per emissions benefit is also relatively flat from SO2 through SO9 because the analysis framework required that responding engines meet the maximum stringency option combination defined for an nvPM Improvement (NI) level. Thus, when an engine is defined to have an NI3 mass response to pass SO3 through SO9, the NI3 benefits would be those achieved at SO9 for all NI3 responses.

Figure 7.4: Change in Cumulative Costs per nvPM Mass (Gram) Avoided

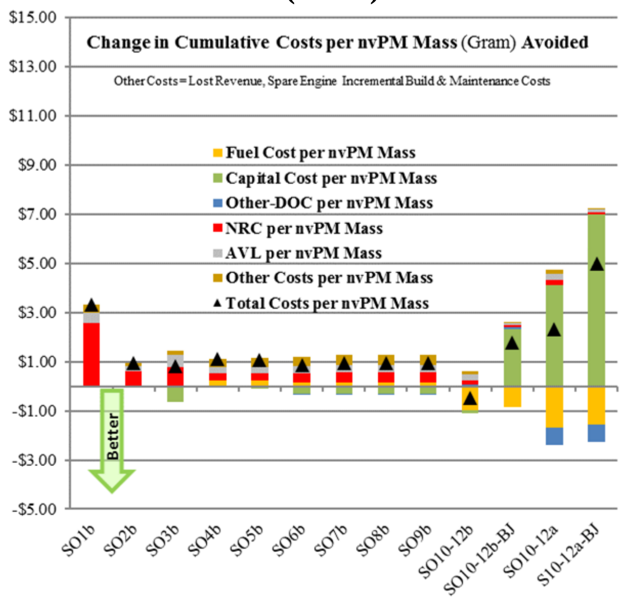


Figure 7.5: Change in Cumulative Costs per nvPM Number (10^{16}) Avoided

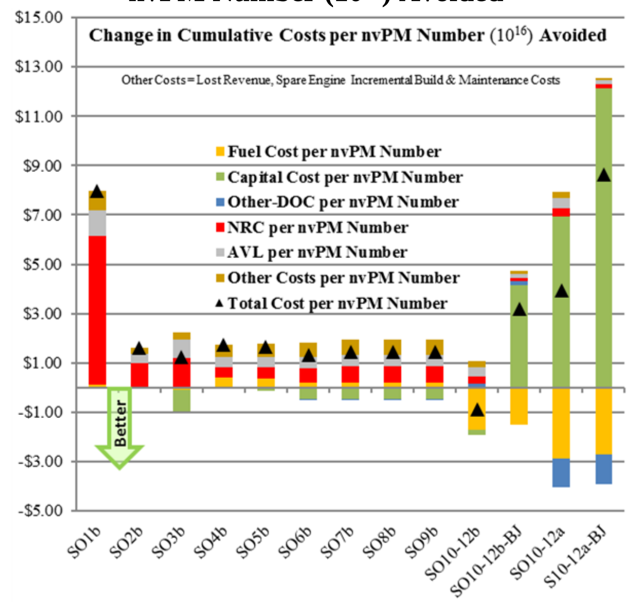
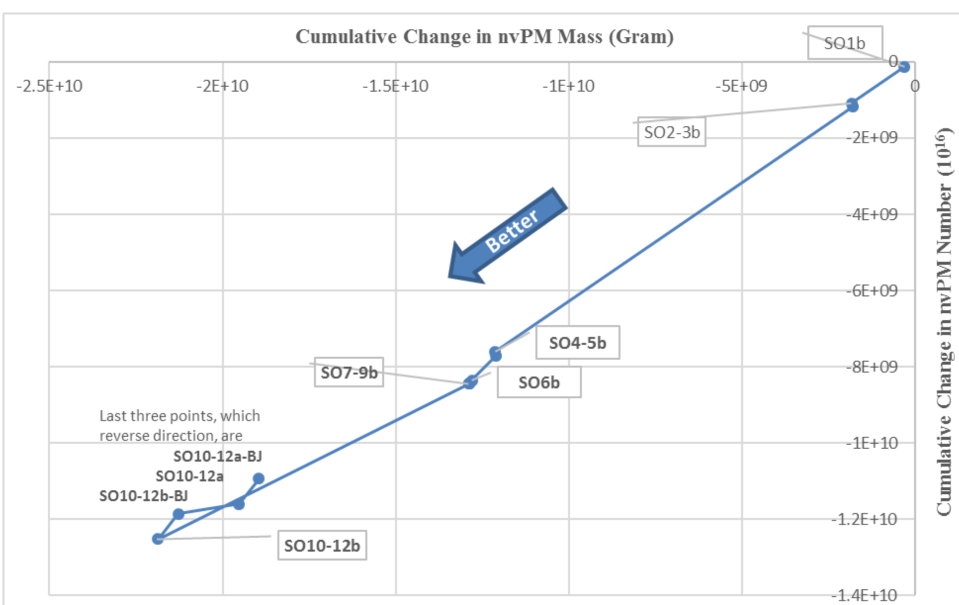


Table 8.1 **Total Costs per**	SO1b	SO2b	SO3b	SO4b	SO5b	SO6b	SO7b SO8b SO9b	SO10b SO11b SO12b	SO10/11/12b Minus BJ	SO10a SO11a SO12a	SO10/11/12a Minus BJ
nvPM Mass	$3.31	$0.96	$0.82	$1.10	$1.05	$0.86	$0.95	-$0.49	$1.79	$2.33	$4.98
nvPM Number	$7.96	$1.62	$1.25	$1.76	$1.65	$1.32	$1.44	-$0.86	$3.21	$3.93	$8.64

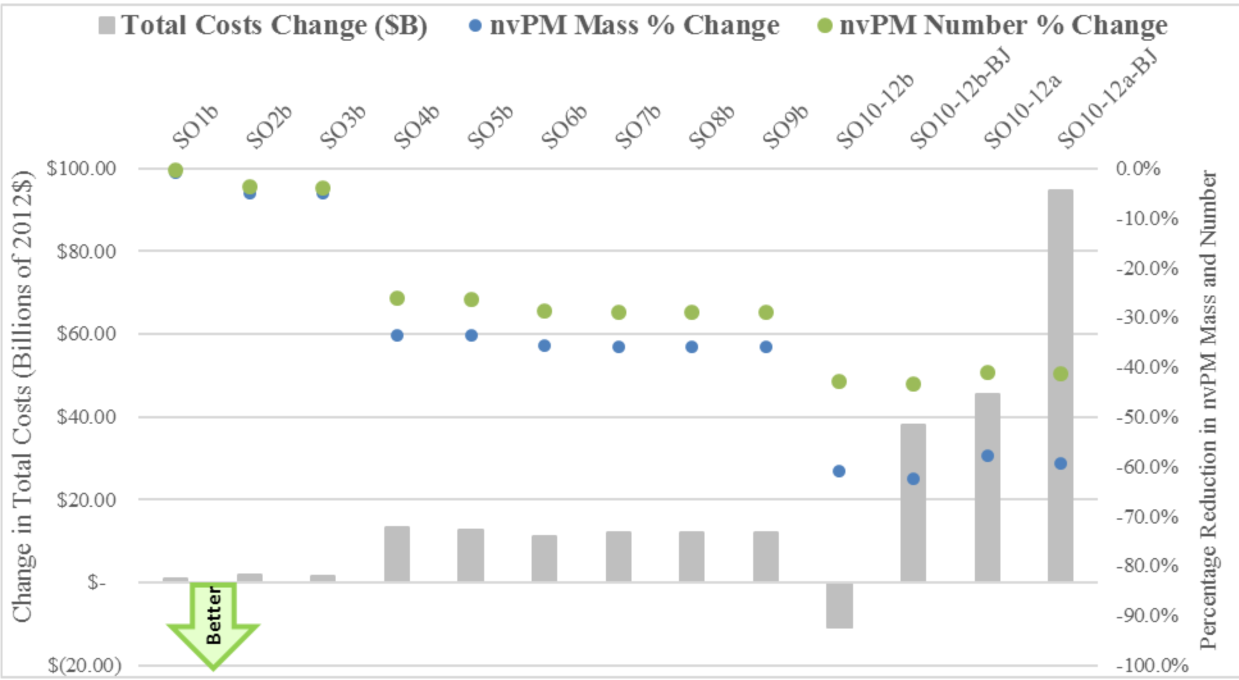
7.6 Figure 7.6 plots change in LTO nvPM mass versus nvPM number for all Path-B markets combined, with SO10 to SO12 shown together (SO10-12b); followed by the Path-B SO10 to SO12 combined results minus the business jet market (SO10-12b-BJ). The last points are the Path-A all markets combined for SO10 to SO12 (SO10-12b); and those minus the business jet market (SO10-12a-BJ).

Figure 7.6: Change in nvPM mass and number



7.7 Figure 7.7 shows the same scenarios with per cent change in nvPM mass (blue dots) and nvPM number (green dots) against change in total cumulative costs (DOC + AVL + NRC + Other) from the 2025 implementation year to 2042.

Figure 7.7: Per cent nvPM Emissions Change and Change in Total Cumulative Costs

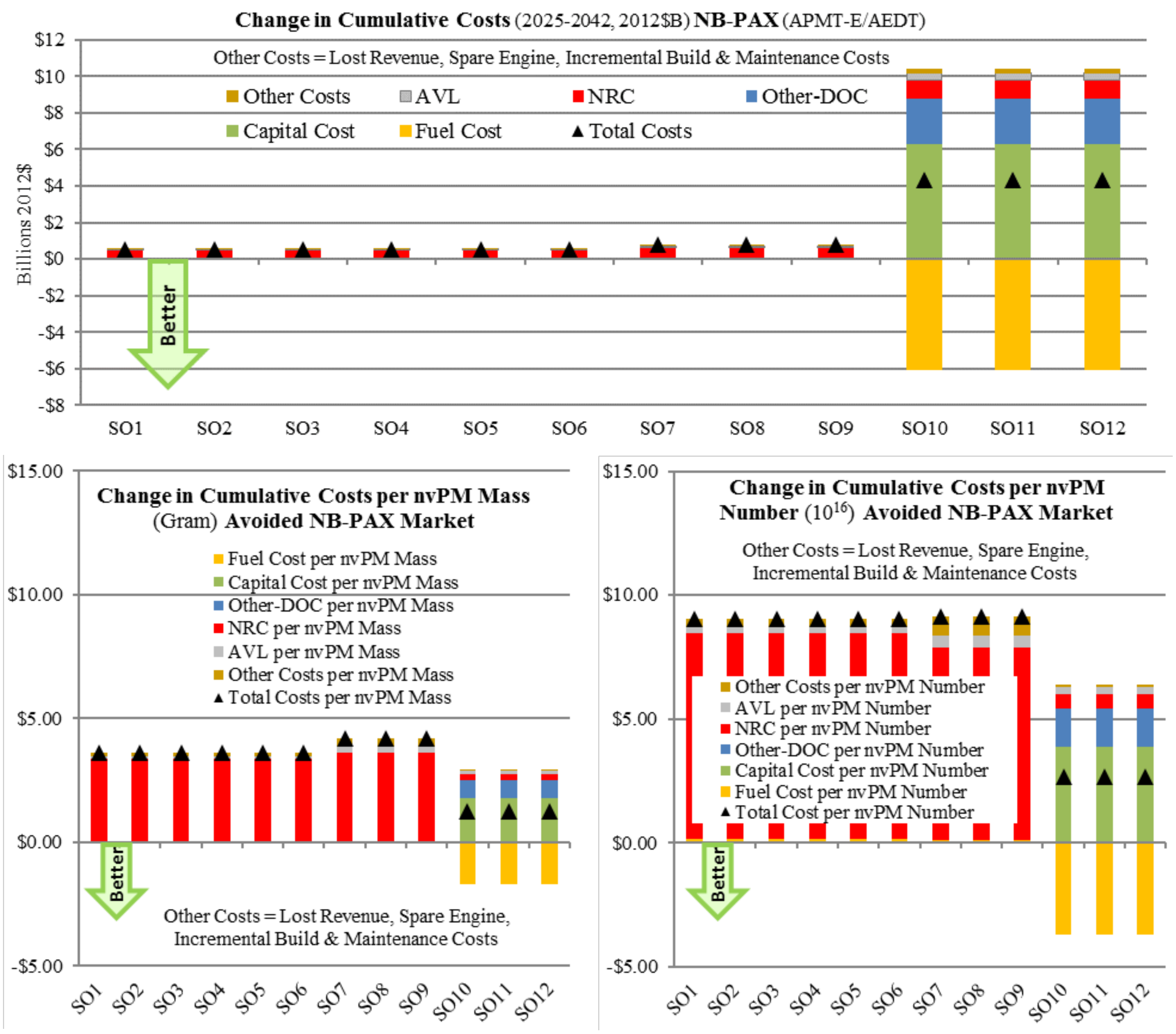


8. OTHER RESULT VIEWS

8.1 **Specific Markets:** In this section, undiscounted stringency change from the baseline results are presented for each market. Note that the scale used in the figures varies by market.

8.1.1 **Narrow Body Passenger Market**[11] (NB-PAX): All types remain available in this market through SO9; and for CBin-5 (101-125 seats) and CBin-7 (151-175 seats) all types remain available for all SO. For SO10-SO12 two engine families do not respond, which results in CBin-04 (86-100 seats) and CBin-06 (126-150 seats) capacities decreasing by 1%; operations, flight kilometres and aircraft deliveries increase to meet the forecasted demand. The other NB-PAX CBins maintain their average capacities.

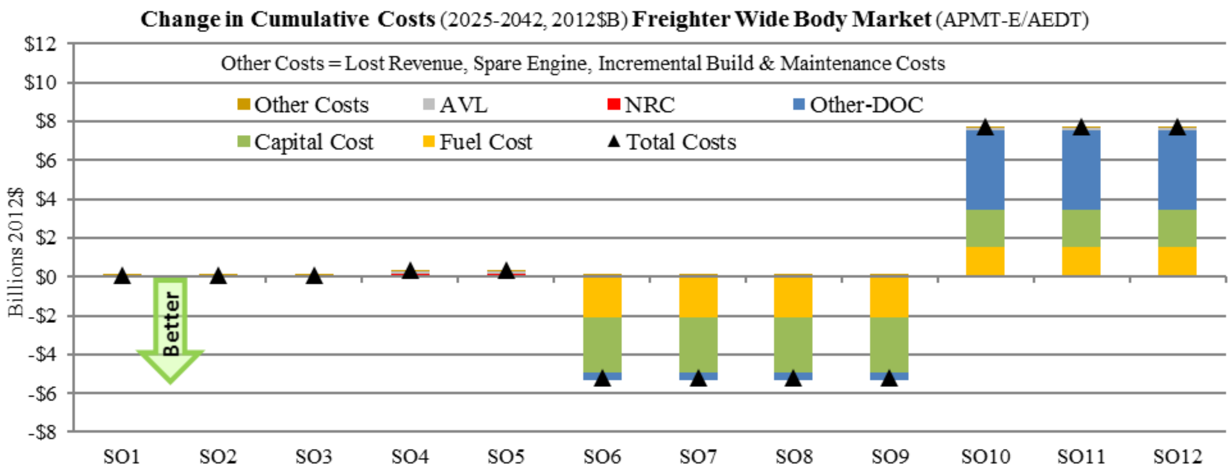
Figures 8.1a-c: Narrow Body Passenger Results



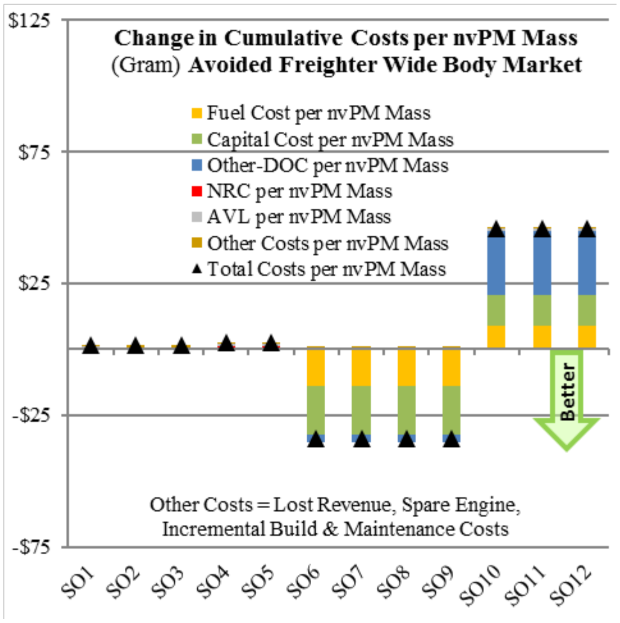
[11] For this analysis regional jets are included in the NB-PAX market.

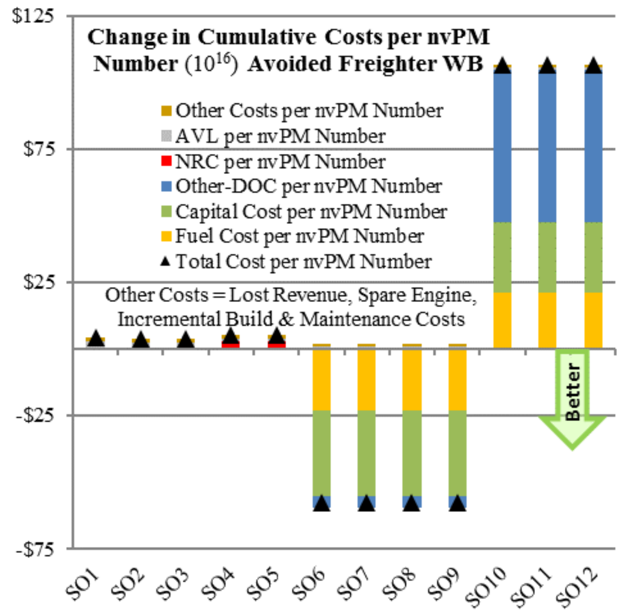
8.1.2 **Freighter Markets:** The FESG fleet forecast for narrow-bodied freighters (NB-FR) defines all demand as being for passenger-to-freighter converted aircraft, which are not subject to the Standard. Russian and Ukrainian manufacturers are of a different opinion; so there are two NB-FR entries that are included in the modelling. Both of these remain available for all SO. All wide-bodied freighter (WB-FR) types subject to the Standard either pass or respond. Medium wide-bodied freighters (CBin-19) are impacted by engine families not responding at SO6, when average capacity increases by 1%, and at SO10, when average capacity decreases by 14%. For SO6-SO9 when average capacity increases it results in a decrease in operations, flight kilometres and fleet deliveries. For SO10-SO12 when average capacity decreases it leads to an increase in operations, flight kilometres and fleet deliveries.[12]

Figures 8.2a-c: Freighter Results



[12] The two fleet evolution models use different capacity metrics; AAT uses ATKs and APMT-E seats. To improve alignment between the two models, the freighter equivalent seat counts in APMT-E were adjusted to more closely reflect the change in payload capacity observed in AAT for the stringencies. The results presented in the Compendium files now show closer operational and fleet alignment between the two models.





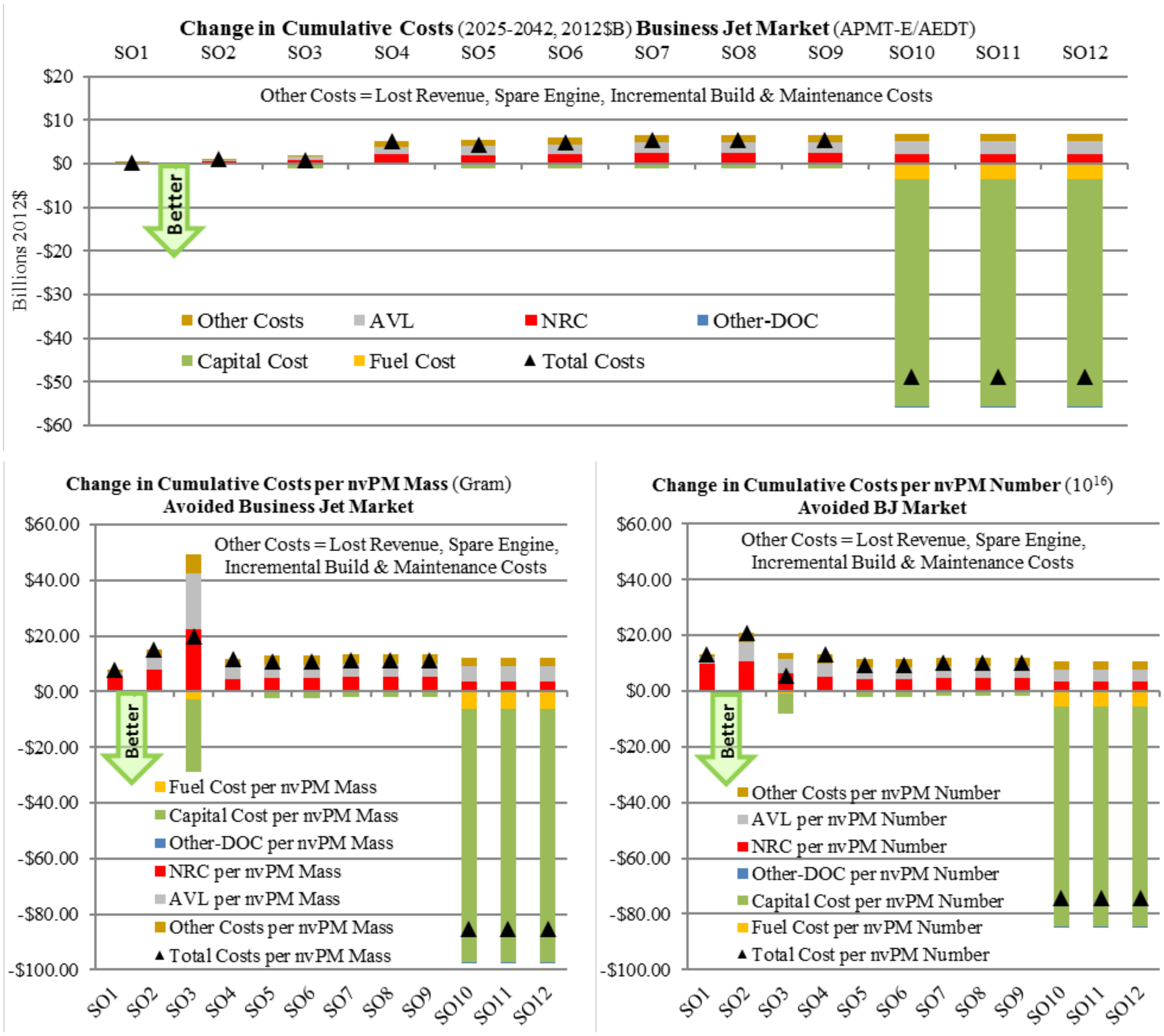
8.1.3 **Business Jet Market:** Since business jets are assumed to have equivalent capacity within a CBin, there are no capacity consequences such as operational changes or fleet deliveries. There are, however, cost consequences.

8.1.3.1 Light-medium business jets (CBins 27&28) are impacted at SO3 and SO5 and above when one engine family does not respond. Average capital cost decreases 13% in CBin-27 and 3% in CBin-28.

8.1.3.2 Large business jets (CBins 29-31) are impacted at SO10 when 3 of 6 engine families do not respond. Average capital cost decreases 1% in CBin-29, 8% in CBin-30, and 3% in CBin-31.

8.1.3.3 Corporate business jets (CBin-32) are impacted at SO10 when two engine families do not respond. Unfortunately, given the wide range of aircraft prices in this CBin, it should have been subdivided between types above (3) and below (6) the $100M price. However, because they were modelled together the average capital cost drops by 26% when two types priced above $200M do not respond.

Figures 8.3a-c: Business Jet Market Results



8.1.3.4 Concerns: Some feel that it is counterintuitive to see less-expensive BJs replacing more expensive types, which no longer respond at SO10 through SO12. There is also concern that the business jet responses are producing a disproportionate impact on the overall fleet analysis, particularly in terms of capital costs. Figure 5.3b shows the sensitivity results where the corporate business jet market goes from a $29B capital cost saving to a $4B savings when the highest priced variants are no longer available and are replaced with only a similar type priced above $200M.

8.1.4 **Passenger Wide Body Market** (WB-PAX): This market has nine engine families; and all GRdb types remain available through SO9. For CBin-11 (≥401 seats) when one engine family does not respond at SO10, the average remaining capacity is 3% lower. Two engine families are used for CBin-9 (211-300 seats), when one does not respond at SO10 average capacity increases by 1% when CBin-9 is modelled alone (Path-B). Six engine families are used for CBin-10 (301-400 seats), when three do not respond at SO10 average capacity increases by 3% when CBin-10 is modelled alone (Path-B). These capacity increases reduce fleet deliveries, operations and the associated costs.

8.1.4.1 The reason this analysis had a Path-A and Path-B was covered in Section 1.3. The details regarding the Path-A and Path-B fleet evolution modelling results was covered in Section 3.2.6. The impact for capital costs is discussed in Section 5.4.6.

8.1.4.2 Per Table 3.1, the proportion of total baseline operations forecasted for CBin-9 (211-300 seats) is 14.5% and 3.5% for CBin-10 (301-400 seats). So, the assumptions for CBin-9 and how it is modelled have more influence on the analysis than those for CBin-10. Table 8.1 lists technology responses, seats and price assumptions for the wide-bodied passenger GRdb types up to 400 seats; and it shows a smaller price range for CBin-9 versus CBin-10.[13] So, when some GRdb types are no longer available at SO10, the similarity of prices within CBin-9 means the change from the baseline is small if demand is met with only CBin-9 types (Path-B). To break from the forecast and mix CBin-9/10 (Path-A) causes the wider range of CBin-10 prices to significantly influence capital costs.

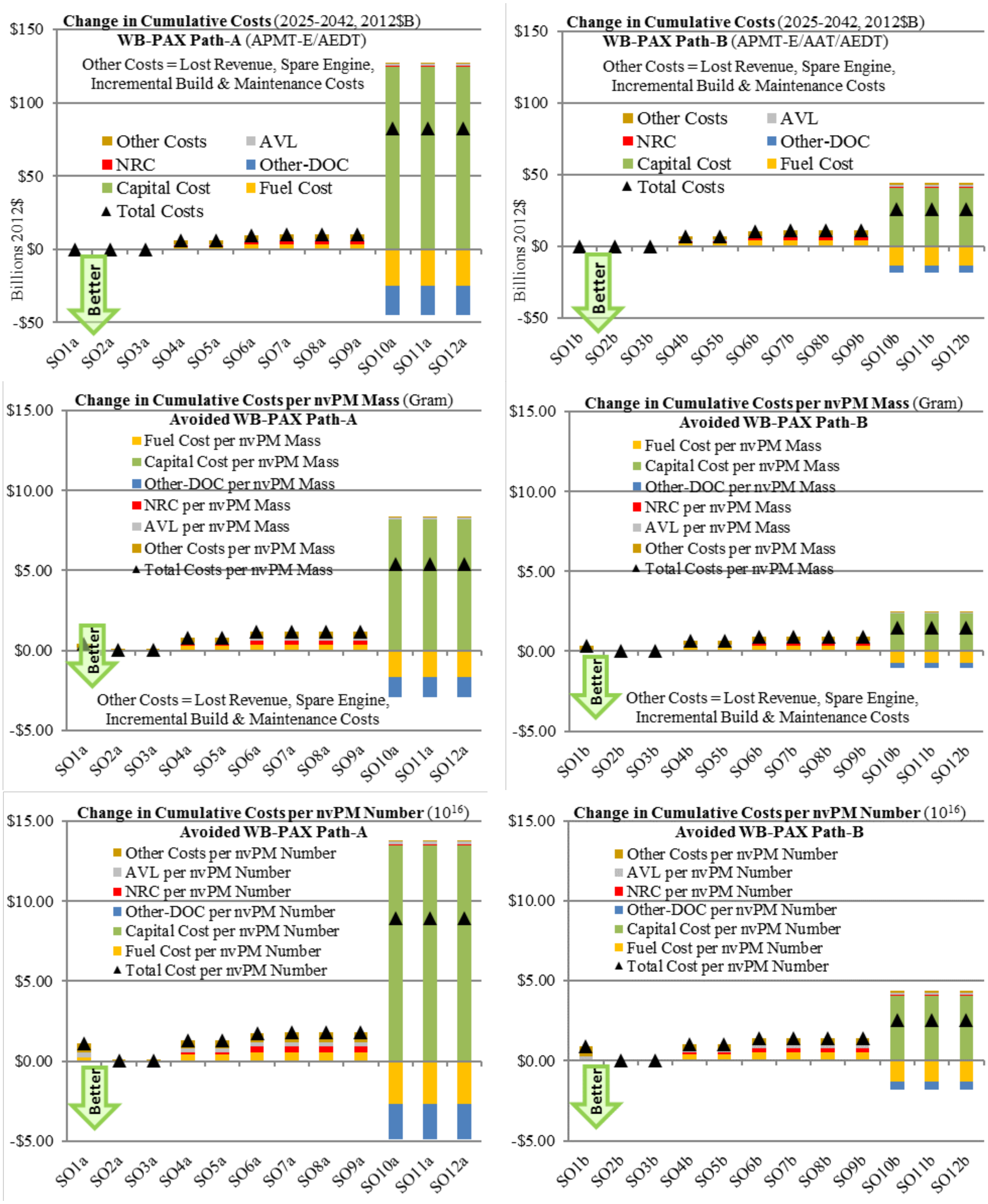
Table 8.1: GRdb wide-bodied passenger technology responses

CBin	SO-1	SO-2/3	SO-4/5	SO-6	SO7/8/9	SO10/11/12	Engine	Seats	Price
CBin-09	Pass	NI1@ SO3	NI3@ SO9	NI3@ SO9	NI3@ SO9	No Response	25	256	$119,435,310
CBin-09	Pass	NI1@ SO3	NI3@ SO9	NI3@ SO9	NI3@ SO9	No Response	25	257	$126,808,000
CBin-09	Pass	NI1@ SO3	NI3@ SO9	NI3@ SO9	NI3@ SO9	No Response	25	277	$132,388,990
CBin-09	Pass	Pass	Pass	Pass	Pass	Pass	07	256	$119,435,310
CBin-09	Pass	Pass	Pass	Pass	Pass	Pass	07	277	$132,388,990
CBin-10	NI3@ SO12	NI3@ SO12	NI3@ SO12	NI3@ SO12	NI3@ SO12	NI3@ SO12	32	350	$141,480,000
CBin-10	Pass	NI1@ SO3	NI3@ SO9	NI3@ SO9	NI3@ SO9	No Response	25	315	$132,388,990
CBin-10	Pass	NI1@ SO3	NI3@ SO9	NI3@ SO9	NI3@ SO9	No Response	25	318	$126,808,000
CBin-10	Pass	Pass	NI1@ SO5	NI3@ SO9	NI3@ SO9	No Response	22	305	$144,100,000
CBin-10	Pass	Pass	NI2M@ SO5	NI3@ SO9	NI3@ SO9	No Response	26	369	$161,392,000
CBin-10	Pass	Pass	Pass	Pass	Pass	Pass	07	315	$132,388,990
CBin-10	Pass	Pass	Pass	Pass	Pass	Pass	08	345	$201,238,972
CBin-10	Pass	Pass	Pass	Pass	Pass	Pass	08	365	$217,338,090

8.1.4.3 The undiscounted change in cumulative costs (2025-2042, 2012$B) and cost effectiveness results for the Path A and Path B WB-PAX market are shown in Figures 8.4a to 9.4f.

[13] Stringencies are clustered when there is no difference between the technology responses.

Figures 8.4a to 8.4f: Wide Body Passenger Market Results for Path-A and Path-B



8.2 Outcome of Path-A and Path-B for All-Markets

8.2.1 Table 8.2 shows the all-market[14] level cost results for Path-A and Path-B for SO4 through SO12.[15] The only difference between the paths is for the 211-400 seat wide-bodied passenger market; i.e., forecast-based Path-B and alternate Path-A for WB-PAX aircraft. For SO10 through SO12, there is an $83.4B capital cost difference between the paths, which is the primary reason total costs shift from being less than the baseline for Path-B to significantly more than the baseline for Path-A.

Table 8.2: Path-A and Path-B Change in Cumulative Costs (2025-2042, 2012$B; All Market Level)

	Path-A	Path-B	Path-A	Path-B	Path-A	Path-B	Path-A	Path-B	Path-A	Path-B
	SO4	**SO4**	**SO5**	**SO5**	**SO6**	**SO6**	**SO7/8/9**	**SO7/8/9**	**SO10/11/12**	**SO10/11/12**
Total Costs	**$11.92**	**$13.37**	**$11.25**	**$12.70**	**$10.01**	**$11.02**	**$11.17**	**$12.18**	**$45.58**	**-$10.79**
Fuel Cost	$1.97	$3.00	$1.87	$2.90	$0.97	$1.84	$0.99	$1.86	-$33.12	-$21.39
Capital Cost	$0.00	$0.00	-$1.05	-$1.05	-$3.92	-$3.92	-$3.92	-$3.92	$80.59	-$2.83
Other-DOC	$0.00	$0.00	$0.00	$0.00	-$0.40	-$0.40	-$0.40	-$0.40	-$13.48	$1.74
NRC	$3.32	$3.32	$3.32	$3.32	$4.75	$4.75	$5.32	$5.32	$3.65	$3.65
AVL	$2.84	$2.98	$3.17	$3.32	$3.74	$3.82	$4.00	$4.08	$5.06	$5.14
Other Costs	$3.80	$4.07	$3.96	$4.22	$4.86	$4.93	$5.19	$5.25	$2.89	$2.90

"Other Costs" = lost revenue, spare engine, incremental build and maintenance costs.

8.2.2 Table 8.3 shows the Path-A and Path-B change in cumulative (2025-2042) total costs (2012$B) for all markets combined, effectiveness (total costs per emissions benefit), and the difference between the paths (last three rows) by stringency option combination (SO).

Table 8.3: Path-A and Path-B Total Cost (2012$B) **Results for All Markets Combined**

2012$ Billions	**SO1**	**SO2**	**SO3**	**SO4**	**SO5**	**SO6**	**SO7/8/9**	**SO10/11/12**
Path-A Total Costs	$0.99	$1.75	$1.47	$11.92	$11.25	$10.01	$11.17	$45.58
Path-B Total Costs	$0.99	$1.75	$1.47	$13.37	$12.70	$11.02	$12.18	-$10.79
Path-A Total Costs per nvPM Mass	$3.33	$1.41	$1.21	$1.51	$1.43	$1.10	$1.22	$2.33
Path-B Total Costs per nvPM Mass	$3.31	$0.96	$0.82	$1.10	$1.05	$0.86	$0.95	-$0.49
Path-A Total Cost per nvPM Number	$7.99	$2.43	$1.81	$2.37	$2.20	$1.61	$1.78	$3.93
Path-B Total Cost per nvPM Number	$7.96	$1.62	$1.25	$1.76	$1.65	$1.32	$1.44	-$0.86
Total Costs Difference	$0.00	$0.00	$0.00	-$1.44	-$1.44	-$1.02	-$1.01	$56.36
Total Costs per nvPM Mass Difference	$0.01	$0.45	$0.39	$0.41	$0.38	$0.24	$0.28	$2.83
Total Cost per nvPM Number Difference	$0.03	$0.81	$0.56	$0.61	$0.55	$0.29	$0.33	$4.79

[14] All-markets is the sum of the freighter, business jet, and the narrow and wide body passenger markets subject to the Standard.

[15] Results for SO7 through SO9 and SO10 through SO12 are clustered because they are identical. Results for SO1 through SO3 are in the Compendium files and are within $0.004B for the two paths.

9. CAEP/11 DECISION

9.1 During the CAEP/11 meeting the new nvPM mass and number SARPs were agreed. This included limit lines for nvPM mass and number, that would be applied to in-production and new engine types from 1 January 2023, providing some alleviation for smaller engines. These limit lines were adjusted according to the one engine characteristic level factor, and can be found in the proposed amendments to Annex 16, Volume II contained in Appendix A to Agenda Item 3 of the CAEP/11 Report.

9.2 The CAEP/11 decision amends Annex 16, Volume II, Part IV to include mandatory reporting of nvPM system losses to the certificating authority. The mandatory reporting of system losses allows for proper calculation of nvPM emissions for inventory purposes, is expected to be a minor burden on the competent authority, and is not part of the pass/fail compliance determination of an engine type during the certification process.

Figure 9.1 – nvPM Mass In-Production and New Type Regulatory Limits

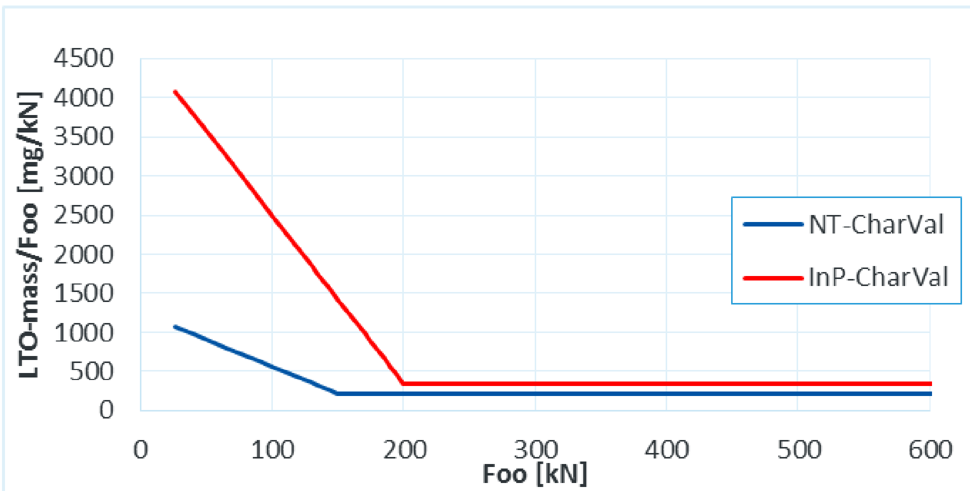
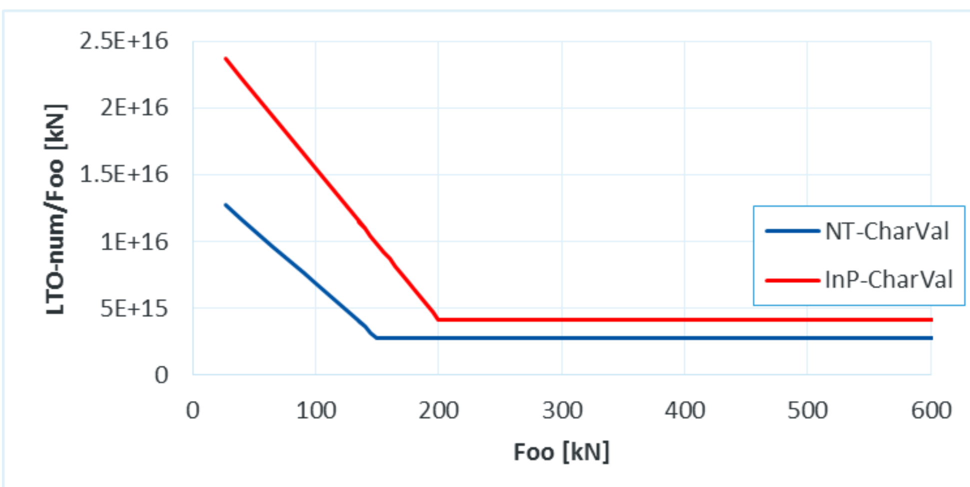


Figure 9.2 – nvPM Number In-Production and New Type Regulatory Limits



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ON THE VISIBILITY OF THE EXHAUST PLUMES OF AIRCRAFT ENGINES

1. INTRODUCTION

1.1 During CAEP/10, a mass concentration limit line was developed with the aim to "transition" towards a regulation "that is equivalent to the existing SN [Smoke Number] Standard" [CAEP10-WG3-PMTG10-WP6]. This transitional mass concentration Standard was developed by correlating SN with mass concentration, shifting this best fit line upwards by ~2 standard deviations and substituting the $SN = f(F_{00})$ limit line relationship into this. The goal of the transition was to allow for the collection of mass concentration data to create the framework for the regulation and thus it was developed to ensure all engines that pass the SN limit line would also pass the mass concentration limit line.

1.2 A corollary of this ~2 standard deviation shift is that statistically we expect approximately 97.5% of engines that lie on the CAEP/10 limit line to be above the SN limit line. A schematic portrayal of this was provided in CAEP11-WG3-PMTG08-Flimsy06. These conclusions suggest that the method used to convert the SN limit line to an equivalent mass concentration limit line does not provide the clarity required for regulatory purposes to assess whether the CAEP/10 limit prevents the visibility of smoke plumes.

1.3 Aerosol optical theory and a visibility criterion can be used to identify the mass concentration at which the smoke plume may become visible, which formed the basis for developing the SN limit line. An introduction to this theory was provided in CAEP11-WG3-PMTG09-Flimsy03, which included a preliminary method to estimate the core nozzle diameter of unmixed turbofan engines. In this paper, we improve upon and extend the analysis presented during PMTG/09 with a validated, iterative gas turbine model used to estimate the exhaust nozzle diameter, a modern update to the optics theory equations and constants, and a model for estimating the transmissivity of exhaust plumes for mixed and unmixed turbofan engines.

1.4 During CAEP/11 meeting it was agreed that 1 January 2023 would be the end date for the applicability of the SN SARPs for engines of a rated thrust > 26.7kN.

2. VISIBILITY OF THE SMOKE NUMBER LIMIT LINE FOR TURBOJETS

2.1 A derivation of the smoke number (SN) that has a transmission of 98% is covered in Munt (1979), which finds that the limit line has a transmission slightly greater than this. This means that, according to the method developed by Munt, the SN limit line conservatively prevents the visibility of an exhaust plume at the 98% transmission level.

2.2 The derivation requires three pieces of information. First, optics theory and associated absorption coefficients gives a relationship to estimate the transmission as a function of concentration and path length. The optics theory is based on a method described in Champagne (1971) and the absorption coefficient is derived analytically in Stockham and Betz (1970) for graphite rather than soot from a kerosene flame. Second, a relationship between mass concentration and smoke number is required, which is also described in Champagne (1971). Finally, a relationship between rated thrust and path length is derived based on measurements made by Munt.

2.3 These three parts can be combined together to produce an estimate of the SN with a transmission of 98% as a function of rated thrust. Munt finds this line to lie slightly above the EPA NPRM (equivalent to the SN limit line) as shown in the diagram below.

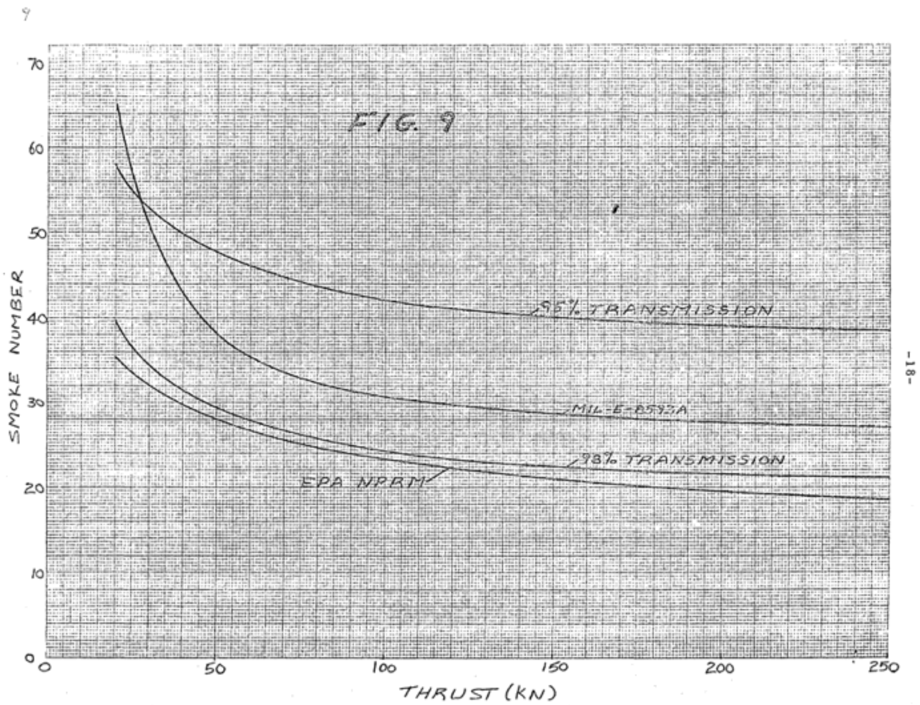

FIGURE B3: RELATIONSHIP BETWEEN SN AND RATED THRUST ADAPTED FROM MUNT (1979). THE EPA NPRM IS IDENTICAL TO THE SN LIMIT LINE, THE MIL-E-8593A IS THE CORRESPONDING MILITARY LIMIT LINE AND THE 98% AND 95% TRANSMISSION LINES ARE DERIVED BY MUNT.

2.4 The analysis by Munt can be reproduced on a mass concentration versus rated thrust basis. This is useful to help identify the mass concentration at 98% transmission according to the method developed by Munt. Unfortunately, the path length versus rated thrust relationship was not provided by Munt, so we use his data points to estimate the best fit line. The relationship is shown in Figure B4 and Eq 1 shows the coefficients and form of the equation.

$$L = 1.23 - 0.95 \cdot e^{-0.011 \cdot F_{00}} \qquad \text{Eq 1}$$

where L is the path length in meters and F_{00} is the rated thrust in kN.

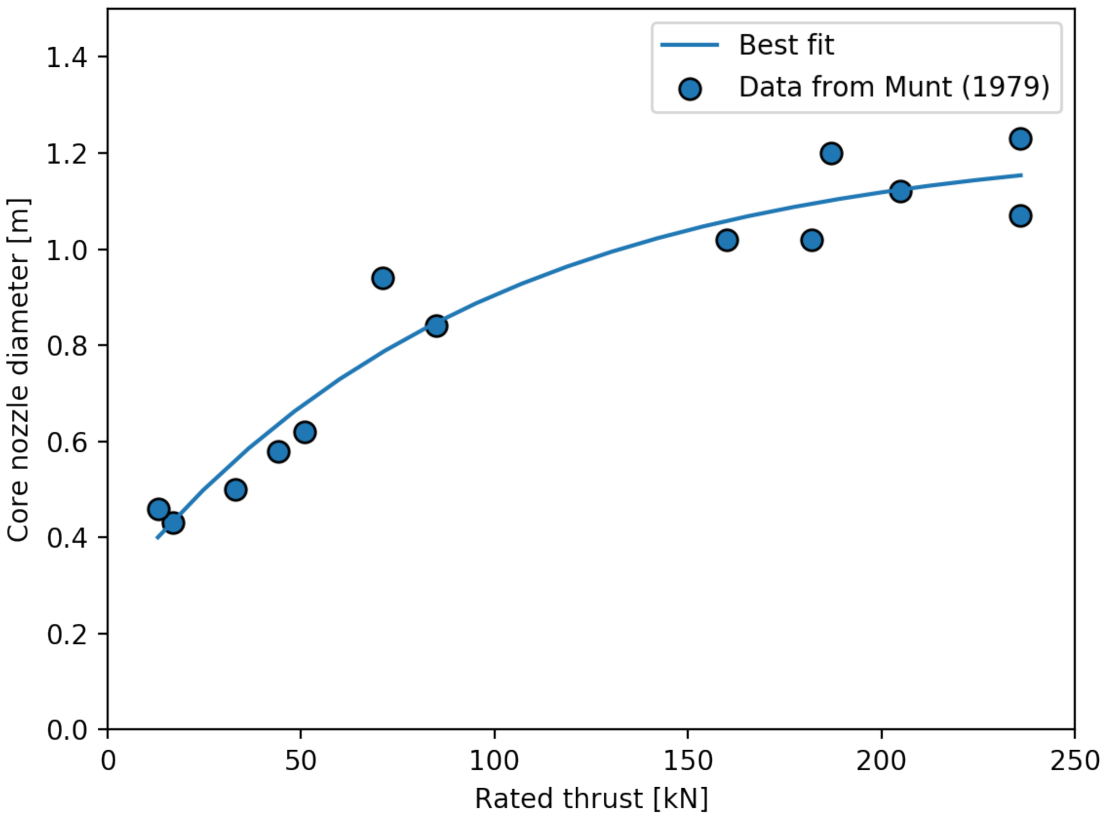

FIGURE B4: BEST FIT LINE BETWEEN RATED THRUST AND CORE NOZZLE DIAMETER USING DATA TABULATED IN MUNT (1979).

2.5 With this relationship, we can apply the optics theory from Champagne (1971) to estimate the mass concentration at a transmission of 98% and 95%, which is shown in Figure B5. These results suggest that the SN limit line in mass concentration space is at a transmission of ~98% according to this particular optics theory. It is also noticeable that the shape of the 98% transmission points differ from the SN limit line, particularly at low rated thrust. This is an artefact of the relationship between rated thrust and path length, where our best fit line is slightly higher than that derived by Munt at a rated thrust below ~50 kN.

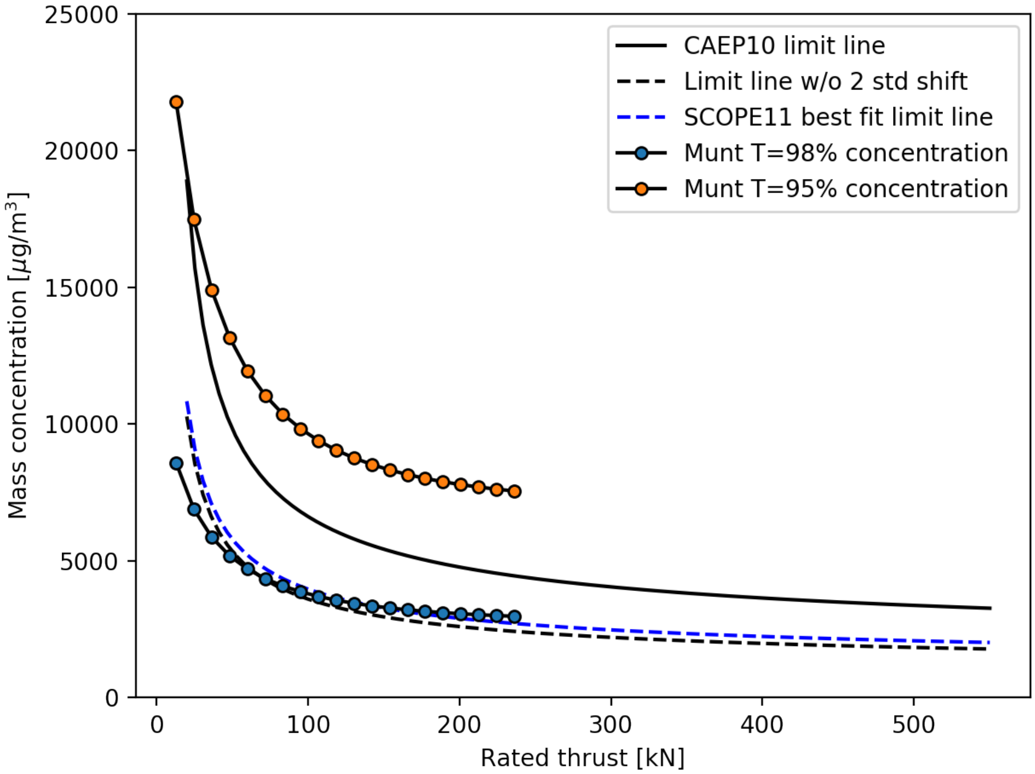

FIGURE B5: MASS CONCENTRATION AT A TRANSMISSION OF 98% (BLUE) AND 95% (ORANGE) AS A FUNCTION OF RATED THRUST DERIVED USING THE SAME METHOD AS IN MUNT (1979). THE SOLID BLACK LINE SHOWS THE CAEP/10 LIMIT LINE, THE DASHED BLACK LINE IS THE LIMIT LINE WITHOUT THE 2 STANDARD DEVIATION SHIFT IN THE SN – MASS CONCENTRATION RELATIONSHIP AND THE DASHED BLUE LINE IS THAT BUT USING THE SCOPE11 RELATIONSHIP.

3. IMPROVEMENTS TO MUNT'S ANALYSIS

3.1 There are three caveats to Munt's analysis which we address.

3.1.1 First, the optics theory that Munt used is now outdated and the modern version of it is shown in Eq 2. In addition, the absorption coefficient was based on theoretical estimates starting from the refractive index of black carbon. Recent literature finds that experimentally measured mass-normalized absorption coefficients are 7.5±1.2 m^2/g at a light wavelength of 550 nm (Bond and Bergstrom (2006)), ~50% higher than the equivalent value in Munt (1979) (~5.76 m^2/g at a wavelength of 490 nm).

$$C_{m,e} = \frac{\rho_{soot}\,\lambda \log(1/T)}{K_e\,L} \qquad \text{Eq 2}$$

3.1.2 Second, the exhaust nozzle diameters tabulated in Munt (1979) were measured from photographs and include the size of the exhaust cone. This means that the nozzle diameters represent the physical outer diameter of the core nozzle, while the area-equivalent diameter would be smaller than this.

Instead of using measured values, we have developed a simple turbojet cycle model that is able to estimate the area-equivalent nozzle diameter. The model only requires the overall pressure ratio (OPR) and rated thrust, and assumes values for the air-fuel ratio (AFR) of 55 at rated thrust and that the exhaust nozzle is choked. The full method is described in Appendix J.1 and the final equation to estimate the nozzle diameter is shown in Eq 3.

$$\mathrm{L} = \sqrt{\frac{4F_{00}}{\pi\gamma_c P_9}} \quad \text{Eq 3}$$

where F_{00} is the rated thrust in N, $\gamma_c = 1.4$ is the heat capacity ratio in the compressor and P_9 is the static pressure at the exit plane found using the method described in Appendix J.1.

3.1.3 Third, the measurement system upon which the mass concentration limit line was developed corrects all measurements to standard temperature and pressure (STP) conditions and leads to the loss of particles as the flow passes through it. This information was not available to Munt and so we correct to STP conditions by scaling the mass concentration from Eq 2 by the ratio of density at STP (1.2 kg/m^3) to the density at the exhaust of the engine. The latter density can be found using the turbojet cycle model. System losses can be accounted for using the correlation found in the SCOPE11 method that relates losses to mass concentration in reverse.

3.2 Using a subset of engines in the Engine Emissions Data Bank (EEDB), we have used the method introduced by Munt to predict the mass concentration at a transmission of 98%. The results are shown in Figure B6 in the blue circles. We then apply each of the 3 changes discussed earlier to show the effect of the changes.

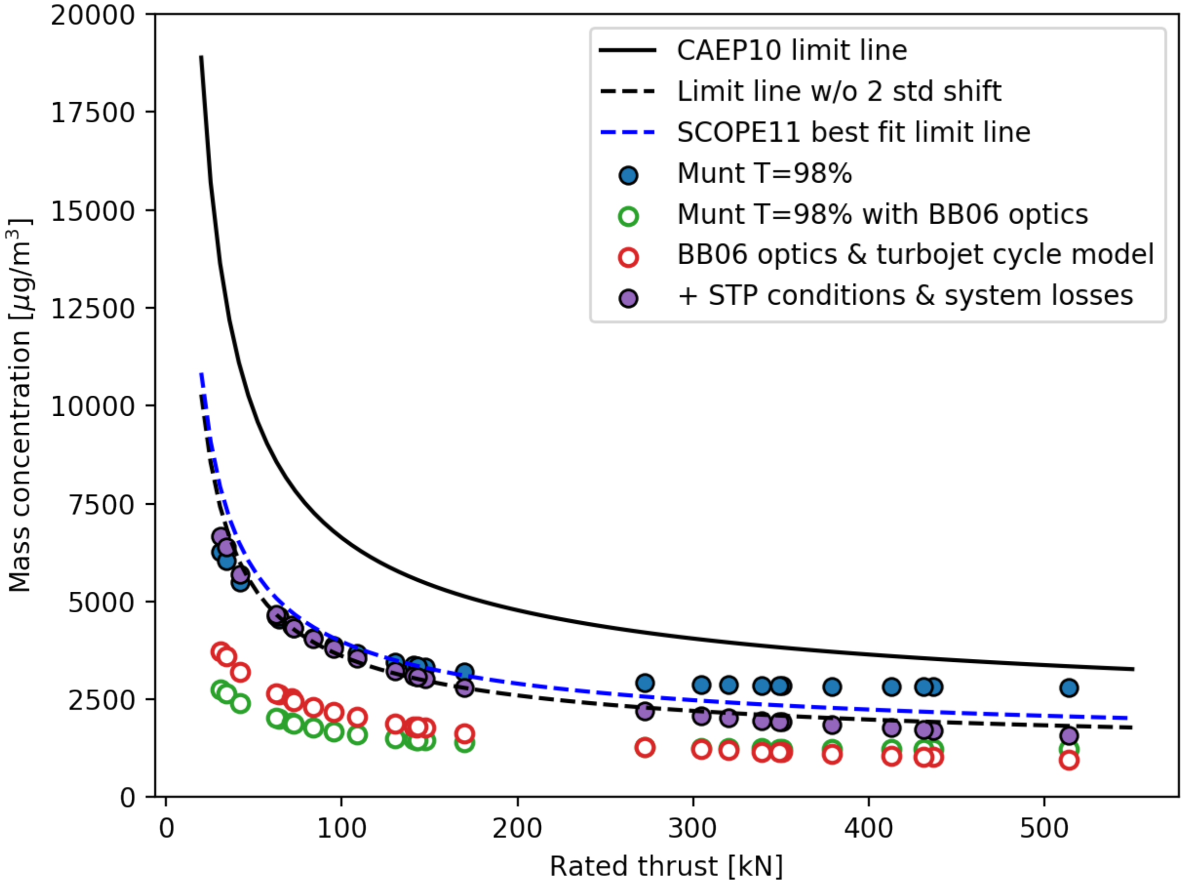

FIGURE B6: THE MASS CONCENTRATION AT 98% VISIBILITY AGAINST RATED THRUST. BLUE FILLED CIRCLES SHOW THE RESULTS USING THE METHOD IN MUNT (1979). THE GREEN OPEN CIRCLES APPLY THE UPDATED OPTICS THEORY BUT USE THE RATED THRUST TO PATH LENGTH RELATIONSHIP FROM MUNT. THE RED OPEN CIRCLES THEN USE OUR TURBOJET CYCLE MODEL TO PREDICT PATH LENGTH FOR A GIVEN RATED THRUST. FINALLY, THE PURPLE FILLED CIRCLES CORRECT THE RESULTS TO STP CONDITIONS AND INCLUDE THE EFFECT OF SYSTEM LOSSES.

3.3 The green circles use the rated thrust to path length relationship derived by Munt, but use the optics theory and coefficients from Bond and Bergstrom (2006). Relative to the blue circles, we find that the mass concentration at 98% transmission reduces by 44%. This is an expected change since the dimensionless absorption coefficient in Bond and Bergstrom (2006) is ~50% larger than that used by Munt (1979).

3.4 The red circles then include the effect of using our turbojet cycle model to predict the nozzle diameter. In this case, we find the effect on the mass concentration depends on the thrust. On average, the nozzle diameter decreases by 10% compared with Munt (1979) leading to an increase in mass concentration of 13%. At rated thrust above ~300 kN, where the Munt (1979) correlation is extrapolated, the nozzle diameter is 13% larger and the mass concentration is 11% lower.

3.5 Finally, the correction to STP conditions and including system losses has the largest effect on the mass concentration. On average, the mass concentration at 98% transmission increases by 78%. The other noticeable feature is that the purple circles more closely follow the shape of the dashed line.

3.6 The three updates to the method show that we can reproduce the SN limit line in mass concentration space, finding this to have a transmission of approximately 98% for turbojet engines. The modern optics theory reduces the allowable mass concentration and this is offset mainly by the correction to STP conditions.

4. VISIBILITY FOR UNMIXED TURBOFAN ENGINES

4.1 The previous section showed the ability to reproduce the SN limit line in mass concentration space for turbojet engines. In this case, there was a single nozzle that contained all of the emissions and it was this nozzle diameter that we were interested in. For an unmixed turbofan engine, the nozzle is split into a core and bypass stream. The emissions are all contained within the core stream and thus the relationship between the rated thrust and core nozzle diameter is now of interest. Compared to turbojet engines, this relationship is more complicated, so we must develop a new gas turbine cycle model that is capable of modelling unmixed turbofan engines. The optics theory, required correction to STP conditions and artificially including system losses, are all applied in the same way as in Section 3.

4.2 The gas turbine model we have developed extracts the rated thrust, overall pressure ratio, bypass ratio and fuel flow rate at rated thrust from the EEDB and assumes the bypass to jet velocity ratio is fixed at 0.9. The calculation method requires iterating over the fan pressure ratio to begin until we obtain the desired jet velocity ratio. The implementation is conducted in Python and leads to the rapid estimation of the conditions within the engine and thus the core nozzle diameter and exhaust density. This model is described in Appendix J.2.

4.3 To validate the results of iterative model, we have estimated the fan diameter and compared with publicly available values for a range of engines as shown in Figure B7. The engines chosen include mixed and unmixed engines, however every engine has been modelled as unmixed. Estimating fan diameter requires knowledge of the air mass flow rate through the engine, which is estimated in the iterative model, but also the hub-to-tip ratio of the fan blade. Although this value varies between engines, we assume it to be 0.33 to create Figure B7.

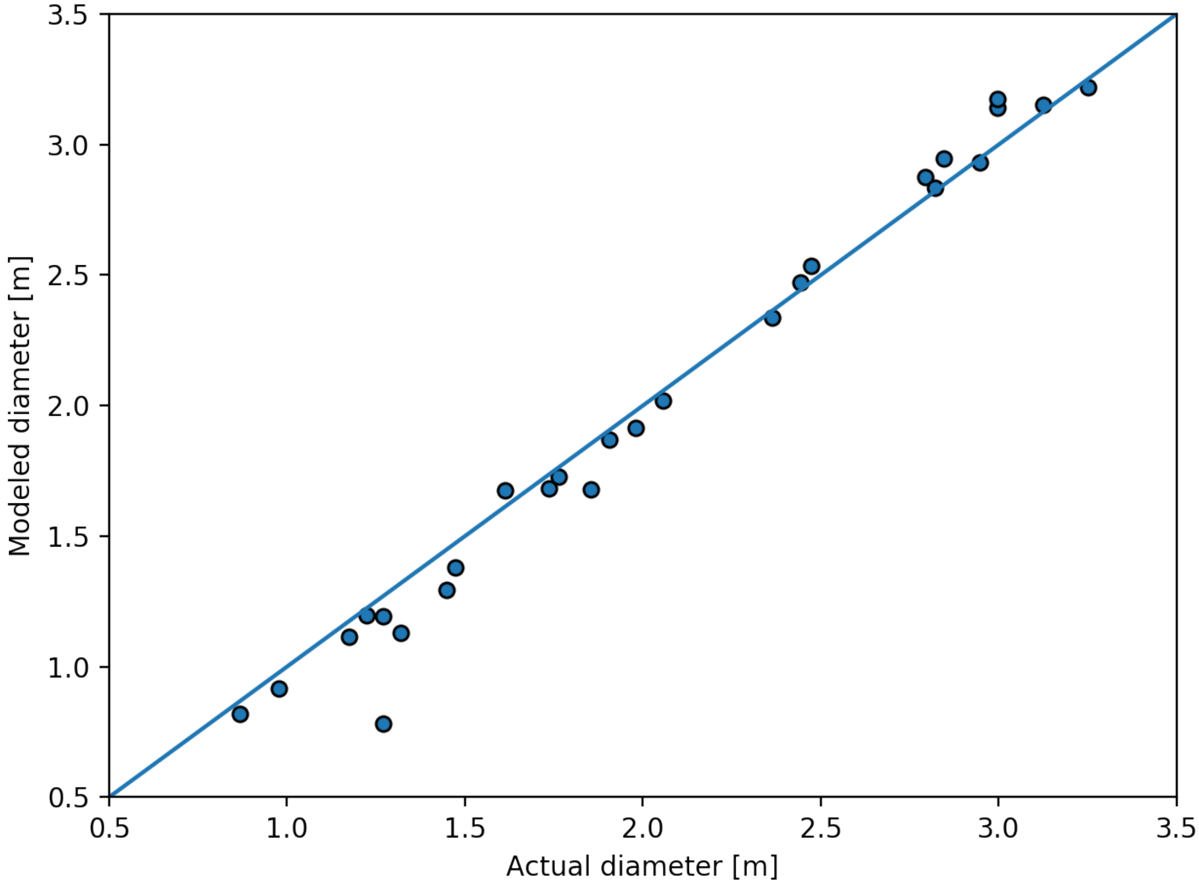

FIGURE B7: ACTUAL VERSUS MODELED FAN DIAMETER [IN]. BOTH MIXED AND UNMIXED ARE INCLUDED, BUT ALL ENGINES ARE MODELED AS UNMIXED.

4.4 We find the error in predicting fan diameter to be 3% on average. There is a skew of -1.56[16] in the residuals and we find too small a diameter at low rated thrust and too large a diameter at high rated thrust. We expect that this is driven by the variation in hub-to-tip ratio as a function of rated thrust. The largest error is 38%, however we expect this is an incorrect measured diameter that includes the size of the nacelle, rather than just the fan blade diameter.

4.5 To further validate the results, we have run simulations in GasTurb, a detailed gas turbine cycle programme, which is capable of modelling a variety of aircraft engine configurations. For unmixed engines, the OPR and BPR were fixed as per the EEDB. Three iteration variables were then set: (1) the turbine inlet temperature until the required fuel flow rate was attained; (2) the fan pressure ratio (FPR) for a fixed jet velocity ratio; and the air mass flow rate for a fixed fan diameter.

4.6 Upon convergence of the GasTurb simulations, we compared the core nozzle diameter with that found using the turbojet cycle discussed above. A comparison of the results is shown in Figure B8. The error for all engines was found to be less than 5%, except for one engine with an error of 15%.

[16] A skew between ±2 are considered acceptable to prove normally distributed residual

This particular engine was modelled as unmixed, however is actually a mixed-flow engine leading to a larger error in predicting the core nozzle diameter.

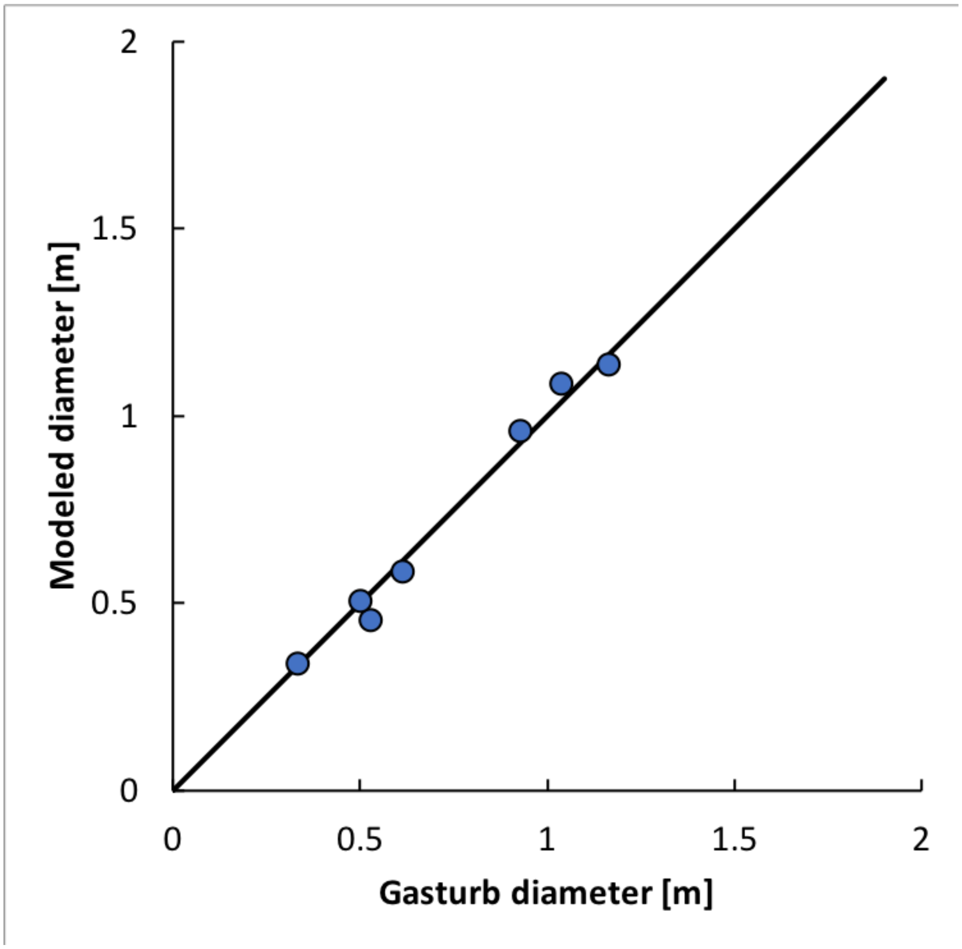

FIGURE B8: COMPARISON BETWEEN CORE NOZZLE DIAMETER FROM GASTURB AND THE MODELED, ITERATIVE GAS TURBINE CYCLE FOR UNMIXED ENGINES.

4.7 We can now apply the diameter estimated using our gas turbine cycle model with the optics theory described in Section 3 to estimate the mass concentration at 98% transmission of unmixed turbofan engines at the exit plane. These results are shown by the orange circles in Figure B9 and include the correction to STP conditions and system losses. We also include the results for turbojets (blue circles).

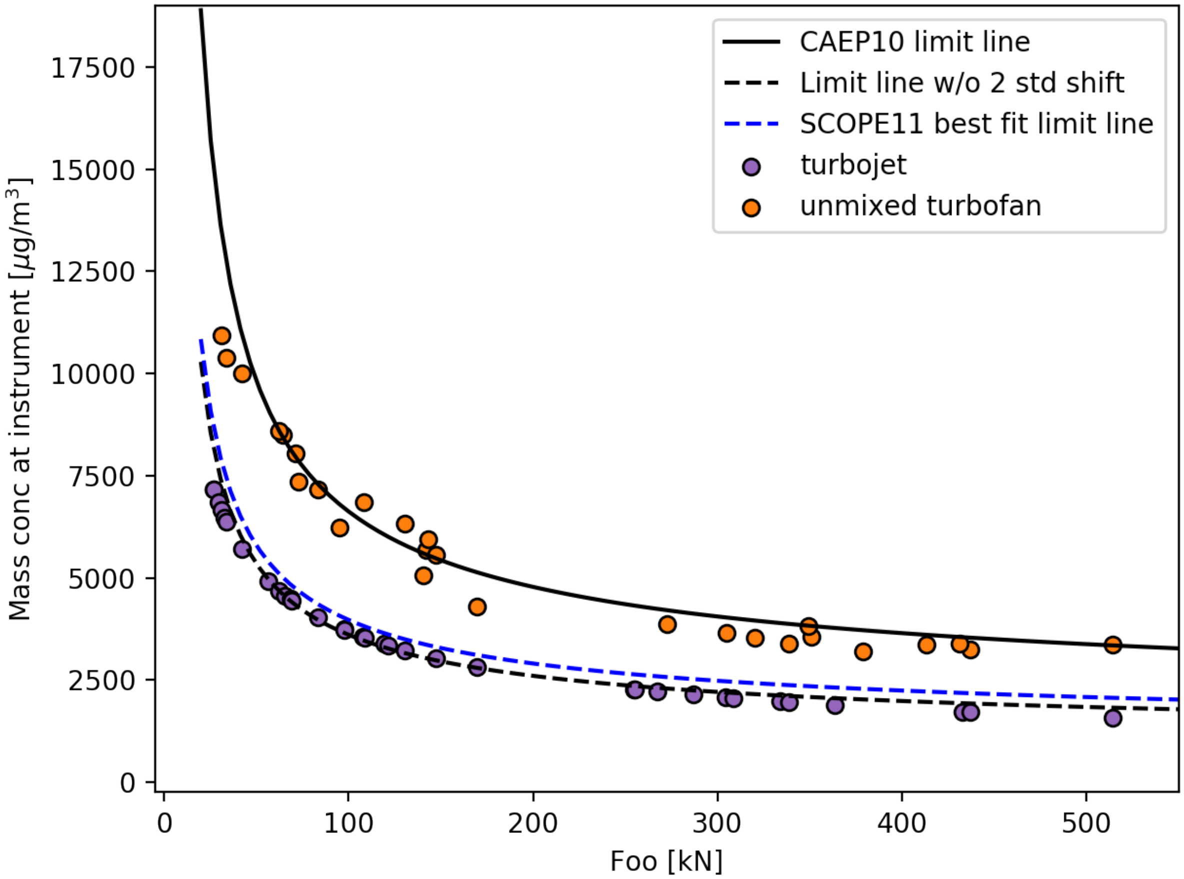

FIGURE B9: THE MASS CONCENTRATION AT 98% VISIBILITY AGAINST RATED THRUST FOR TURBOJETS AS FOUND IN FIGURE B5 IN PURPLE AND FOR UNMIXED TURBOFANS IN ORANGE.

4.8 These results show that the CAEP/10 limit line is at a transmission of around 98% for unmixed turbofan engines. The variation in the results around the limit line is driven by differences in the bypass ratio. Modern engines have gas generators with a higher specific power, driven by improvements in component efficiency and higher turbine inlet temperatures. Furthermore, the trends also have reduced fan pressure ratio for increased propulsive efficiency. These trends result in a smaller core nozzle diameter and larger bypass ratio. Thus, modern turbofan engines have a higher allowable mass concentration to prevent a visibility of 98%.

5. VISIBILITY FOR MIXED-FLOW ENGINES

5.1 The mixing between the core and bypass streams of mixed-flow engines changes the visibility of the plume at the exit plane. Firstly, the relevant nozzle diameter changes. For unmixed changes, we were interested in the core nozzle diameter, but for mixed-flow engines, there is only one exhaust diameter to measure. Secondly, the mixing process leads to a lower density at the exit plane and accordingly a smaller correction to STP conditions. Combining these two effects together, we expect that the mass concentration at a 98% transmission to be lower for mixed-flow engines compared with unmixed engines. At the same time, for a given core nvPM mass concentration, the mixing process reduces the mass concentration at the exit plane by the factor $(1 + BPR)$. This gives mixed-flow engines an advantage under the current CAEP/10 limit line.

5.2 To study the visibility of mixed-flow engines, we must adapt our iterative gas turbine model to account for the mixing process. In the engine, the static pressure at the location of mixing should be equal. This condition requires knowledge of the internal velocities or areas, which is difficult to estimate in our simple model. Instead, we impose that the stagnation pressure must be equal at this stage. Although this is technically incorrect, it may be reasonable if we assume the velocities are low and similar in the core and bypass streams prior to mixing. This model is described in Appendix J.3.

5.3 As with the unmixed engines, we have attempted to predict fan diameter using our predicted mass flow rate and a hub-to-tip ratio of 0.33. The results are shown in Figure B10, which shows engines that are actually unmixed in blue and engines that are actually mixed-flow in yellow. It should be noted that all the engines were modelled as mixed-flow whether they are actually mixed or unmixed.

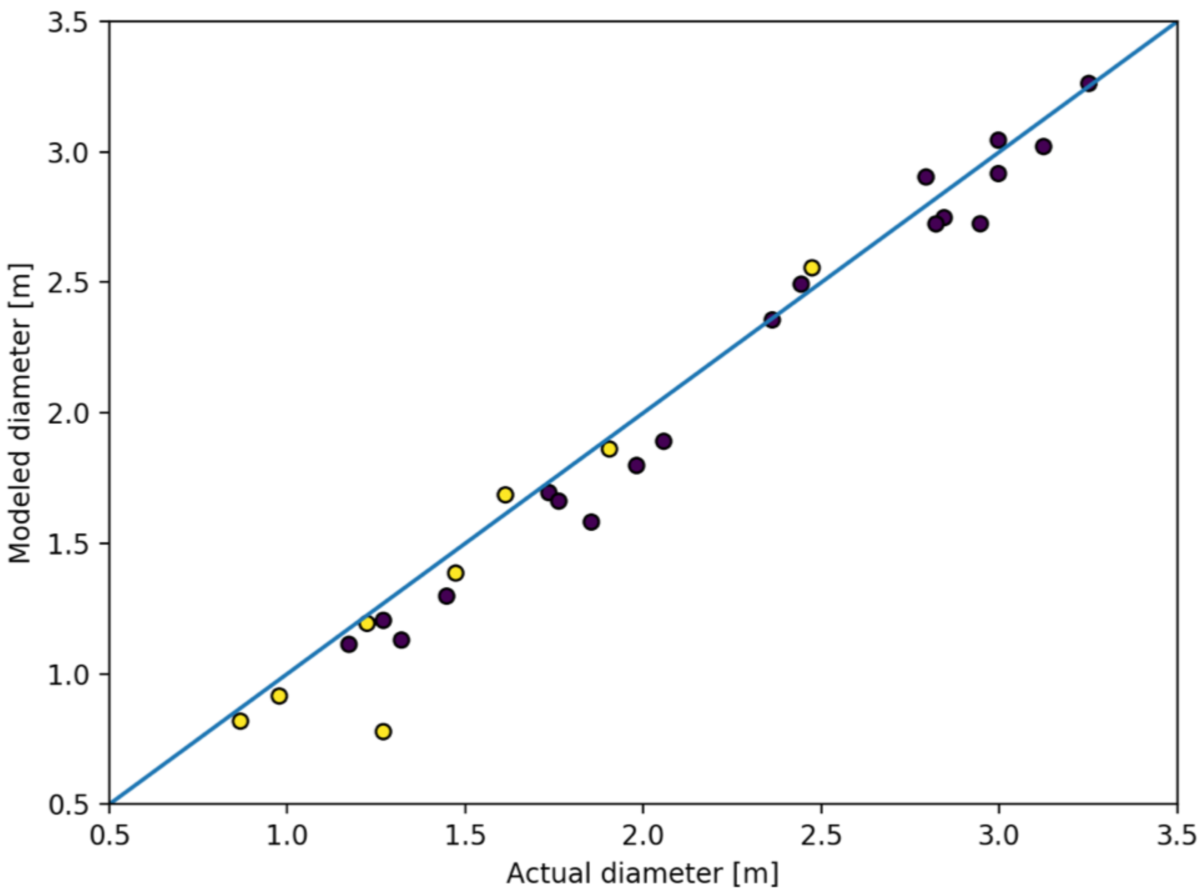

FIGURE B10: ACTUAL VERSUS PREDICTED DIAMETER USING THE SIMPLE GAS TURBINE MODEL. ALL ENGINES WERE MODELED AS IF THEY WERE MIXED-FLOW. ENGINES THAT ARE ACTUALLY MIXED-FLOW ARE SHOWN IN YELLOW AND THOSE THAT ARE UNMIXED ARE SHOWN IN BLUE.

5.4 For all the mixed-flow engines, the error in predicting fan diameter is under 10%, except for 1 engine where the actual fan diameter includes the nacelle size. We also run a subset of mixed-flow engines in GasTurb and the ability to predict exhaust nozzle diameter is shown in Figure B11. These results suggest that we consistently under-predict the exhaust nozzle diameter and we expect this to be caused by the stagnation pressure condition that was enforced at the mixing plane.

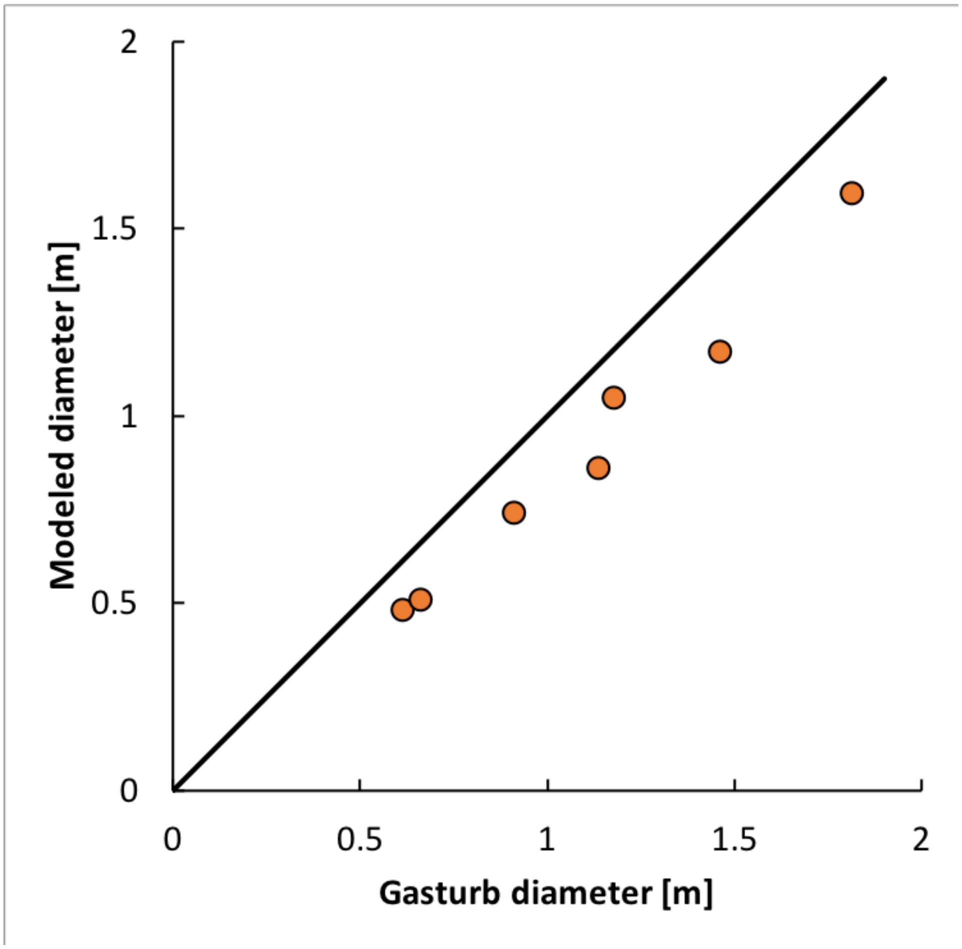

FIGURE B11: COMPARISON BETWEEN NOZZLE DIAMETER FROM GASTURB AND THE MODELED, ITERATIVE GAS TURBINE CYCLE FOR MIXED-FLOW ENGINES.

5.5 Despite this consistent under-prediction of nozzle diameter, the results from our iterative model can still be used to provide a mass concentration at 98% transmission. The absolute value of this mass concentration would be slightly higher than using the GasTurb diameter, however would provide an upper bound on the results. These results, as well as those for the turbojet and unmixed turbofan, are shown in Figure B12.

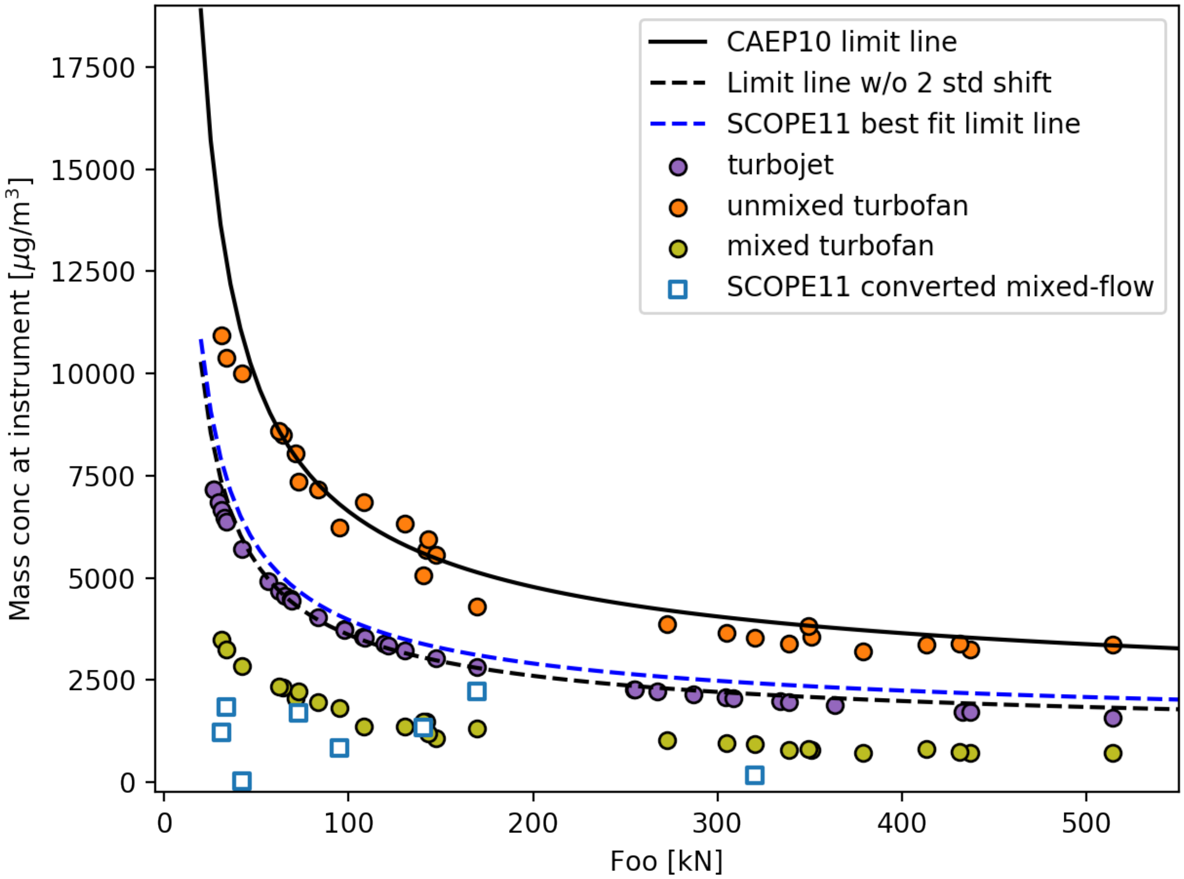

FIGURE B12: THE MASS CONCENTRATION AT 98% VISIBILITY AGAINST RATED THRUST FOR TURBOJETS IN PURPLE, UNMIXED TURBOFANS IN ORANGE AND MIXED-FLOW ENGINES IN GREEN. THE UNFILLED BLUE SQUARES REPRESENT THE MASS CONCENTRATION OF MIXED-FLOW ENGINES ESTIMATED BY CONVERTING THE MAXIMUM SN FROM THE EDB USING THE SCOPE11 METHOD.

5.6 On average, the mass concentration at 98% transmission for mixed-flow engines is 25% that for unmixed engines. The mixed-flow results lie below the SN limit line in mass concentration space and the mass concentration at 98% transmission of turbojet engines. This trend occurs in spite of the under-estimate in the nozzle diameter and so we expect the mass concentration at 98% transmission of mixed flow engines to be even lower. These results suggest that the SN and CAEP/10 limit lines would not prevent the visibility of plumes from mixed-flow engines at the 98% transmission level.

5.7 Figure B12 also includes the mass concentration of mixed flow engines estimated by converting the maximum SN from the EDB using the SCOPE11 method in the unfilled blue squares. These results show that all but one of the selected engines lie below our estimated mass concentration at 98% transmission for mixed-flow engines. Only one other engine lies within 10% of the estimated mass concentration at 98% transmission. These results suggest that mixed flow engines with a mass concentration at the CAEP/10 limit line or a smoke number at the SN limit line would have a transmission below 98% and thus may be visible.

6. CONCLUSIONS

6.1 The SN limit line is reproducible if we consider turbojet engines and apply appropriate corrections to STP conditions and system losses. Our results suggest that the SN limit line is at a transmission of 98% for these engines.

6.2 First-order cycle models can be used to estimate the nozzle diameter of unmixed and mixed-flow engines using data from the EEDB, which is needed to determine the mass concentration at 98% transmission. Validation using publicly available fan diameters and GasTurb simulations showed that the unmixed turbofan model is accurate within 3%, while the mixed-flow turbofan model underestimates nozzle diameter by ~20%.

6.3 For unmixed turbofan engines, the mass concentration at 98% transmission was found to be close to the CAEP/10 limit line, however there was variability around this line driven by the differences in bypass ratio.

6.4 For mixed-flow engines, the mass concentration at 98% transmission was found to be below both the CAEP/10 and SN limit lines. This means that both these limit lines would not prevent the visibility of plumes from mixed-flow engines.

6.5 Comparing the mass concentration at a 98% transmission with mass concentration estimated using the SCOPE11 method for in-production mixed-flow engines, we found that all mixed-flow engines, except 1, lay below the mass concentration at 98% transmission, suggesting that these mixed-flow engines would not have a visible plume.

7. REFERENCES

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8. APPENDIX J.1 – TURBOJET CYCLE MODEL

8.1 Eq 4 shows how the engine nozzle diameter is found

$$\mathrm{L} = \sqrt{\frac{4\mathrm{F}_{00}}{\pi\gamma_c P_9}} \qquad \text{Eq 4}$$

where F_{00} is the engine rated thrust, γ_c is the heat capacity ratio in the compressor and P_9 is the static pressure at the exit plane. To estimate P_9, we have developed a turbojet cycle model. This also lets us estimate the density at the exit plane in order to correct the mass concentration to STP conditions.

8.2 The model requires the input of two variables: the overall pressure ratio (OPR) and the air-fuel ratio (AFR). The OPR is found from the EEDB, where we use rated thrust and OPR pairs in order to sample the domain space. The AFR is assumed to be 55 for all turbojets and we assume overall compressor and turbine polytropic efficiencies to be 0.78 and 0.83 respectively. Gas properties are also assumed to change after combustion with the heat capacity ratio reducing from 1.4 to 1.3 and the heat capacity at constant pressure increasing from $c_{pc} = 1{,}005$ to $c_{pt} = 1{,}250$ J/kg/K. The fuel is assumed to have a lower calorific value (LCV) of 43.2 MJ/kg.

8.3 Conditions at the combustor exit are calculated using Eq 5.

$$\mathrm{P}_{\mathrm{t}3} = \mathrm{OPR} \cdot \mathrm{P}_{\mathrm{t}2}$$
$$T_{t3} = T_{t2}\mathrm{OPR}^{\frac{\gamma_c - 1}{\gamma_c \eta_c}} \qquad \text{Eq 5}$$

where subscript t2 refers to conditions at the engine inlet and t3 to conditions downstream of the compressor, and η_c is the polytropic efficiency of the compressor assumed to 0.78.

8.4 We assume no stagnation pressure loss in the combustor such that $\mathrm{P}_{\mathrm{t}4} = \mathrm{P}_{\mathrm{t}3}$ and then apply an energy balance across the combustor to estimate the turbine inlet conditions (subscript t4).

$$T_{t4} = \frac{\mathrm{AFR}c_{pc}T_{t3} + \mathrm{LCV}}{c_{pt}(1 + \mathrm{AFR})} \qquad \text{Eq 6}$$

8.5 The turbine is used to drive the compressor and thus we use a power balance to estimate conditions downstream of the turbine (subscript t5). The pressure is calculated using a similar version of the second equation in Eq 5.

$$T_{t5} = T_{t4} - (T_{t3} - T_{t2})\frac{c_{pc}}{c_{pt}}$$
$$P_{t5} = P_{t4}\left(\frac{T_{t5}}{T_{t4}}\right)^{\frac{\gamma_t}{(\gamma_t - 1)\eta_t}} \qquad \text{Eq 7}$$

8.6 To calculate conditions at the engine exit plane (subscript 9), we assume that the nozzle is choked. Isentropic relations can thus be used to estimate the static temperature and pressure:

$$T_9 = \frac{\mathrm{T_{t5}}}{1 + \frac{\gamma_t - 1}{2}}$$
$$P_9 = P_{t5}\left(\frac{T_9}{T_{t5}}\right)^{\frac{\gamma_t}{\gamma_t - 1}} \qquad \text{Eq 8}$$

We then use the ideal gas equation to estimate the exit plane density.

$$\rho_9 = \frac{P_9}{R_{air} T_9} \qquad \text{Eq 9}$$

where R_{air} is the specific gas constant for air.

9. APPENDIX J.2 – UNMIXED TURBOFAN CYCLE MODEL

9.1 For unmixed turbofans, the typical method to estimate conditions within the engine are to specify a rated thrust, OPR, BPR and turbine inlet temperature (T_{t4}), while setting the jet velocity ratio to be ~0.9. The EEDB does not provide T_{t4} at take-off conditions, instead supplying the fuel flow rate. This requires us to use an iterative process to converge on a solution for this engine.

9.2 We use a least-squares solver in Python in order to identify the value of fan pressure ratio (FPR) that leads to a converged solution. The first step therefore involves guessing a FPR. With this value, we can estimate the conditions downstream of the fan as well as the bypass jet velocity.

$$\mathrm{P_{t13}} = \mathrm{FPR} \cdot \mathrm{P_{t2}} \qquad \text{Eq 10}$$
$$T_{t13} = T_{t2}\mathrm{FPR}^{\frac{\gamma_c - 1}{\gamma_c \eta_f}}$$

where subscript 13 refers to conditions downstream of the fan in the bypass stream and η_f is the fan polytropic efficiency assumed to be 0.9. The bypass jet velocity (V_{19}) is then found using Eq 11.

$$V_{19} = \sqrt{2c_{pc}T_{t13}\left(1 - \left(\frac{P_{amb}}{P_{t13}}\right)^{\frac{\gamma_c - 1}{\gamma_c}}\right)} \qquad \text{Eq 11}$$

where subscript 19 refers to the bypass nozzle exit plane and P_{amb} is the ambient pressure. This method assumes that the bypass nozzle is perfectly expanded. This may not be reasonable particularly for smaller engines with a higher FPR. Thus, we check the exit Mach number to see if it is subsonic. If it is supersonic, we force the Mach number to be 1 and back out the exit plane pressure accordingly.

9.3 The conditions in the gas generator can then be estimated following a similar method to that for turbojet engines. We apply Eq 5 to estimate conditions downstream of the compressor assuming

$\eta_c = 0.9$. Before we apply the combustor energy balance in Eq 6, we must identify the AFR. This is found using the jet velocity ratio of 0.9 to estimate the core jet velocity (V_9) from the bypass jet velocity found in Eq 11 and then applying a momentum balance around the whole engine.

$$V_9 = \frac{V_{19}}{\alpha} \qquad \dot{m}_c = \frac{F_{00}}{V_9(1 + \mathrm{BPR} \cdot \alpha)} \quad \text{Eq 12}$$

Knowing the core mass flow rate, $\dot{m}_c$, we can the calculate the AFR $= \frac{\dot{m}_c}{\dot{m}_f}$ and subsequently apply Eq 6 to estimate conditions at the combustor exit/turbine inlet location.

9.4 We then conduct a power balance similar to that for turbojet engines but extending to include the power drawn by the fan to estimate conditions downstream of the turbine.

$$T_{t5} = T_{t4} - (T_{t3} - T_{t2})\frac{c_{pc}}{c_{pt}} - (T_{t13} - T_{t2})\frac{c_{pc}}{c_{pt}}\ \mathrm{BPR} \qquad P_{t5} = P_{t4}\left(\frac{T_{t5}}{T_{t4}}\right)^{\frac{\gamma_t}{(\gamma_t - 1)\eta_t}} \quad \text{Eq 13}$$

where $\eta_t = 0.95$ is the polytropic efficiency of the turbine.

9.5 We can now use the turbine exit conditions to estimate the core jet velocity following Eq 14.

$$V_9 = \sqrt{2c_{pt}T_{t5}\left(1 - \left(\frac{P_{amb}}{P_{t5}}\right)^{\frac{\gamma_t - 1}{\gamma_t}}\right)} \quad \text{Eq 14}$$

9.6 V_9 was also estimated in Eq 12 using the jet velocity ratio. To ensure that the original FPR used is correct, we compare the two V_9 values in order to check if they are equal. If they are equal, then the calculation procedure is complete, otherwise we loop round again with a different value of the FPR.

9.7 Upon completing the cycle calculations, the core exit nozzle diameter can be found using the core mass flow rate.

$$d_9 = \sqrt{\frac{4\dot{m}_c}{\pi \rho_9 V_9}} \quad \text{Eq 15}$$

where ρ_9 is found using Eq 9.

10. APPENDIX J.3 – MIXED-FLOW TURBOFAN CYCLE MODEL

10.1 For mixed-flow engines, the jet velocity ratio cannot be fixed since there is a single stream exiting the engine. Instead, the static pressure in the core and bypass stream must be equal at the mixer. To force this condition, we require information on the velocities at the mixer, which in turn requires details of the areas at these locations. An alternative, less accurate option is to enforce that the stagnation pressures at the mixer match. This is expected to give reasonable results since the velocity tends to be subsonic and thus leads to stagnation pressures being close to matching.

10.2 The method begins in a similar fashion to unmixed turbofan engines. We guess a FPR and apply Eq 10 to estimate conditions downstream of the fan in the bypass stream.

10.3 We then need a method to estimate the core mass flow rate that leads to the stagnation pressure downstream of the turbine being equal to that downstream of the fan in the bypass. This requires a second, embedded iteration loop where we cycle over the core mass flow rate, solving Eq 6 across the combustor and Eq 13 across the turbine until the stagnation pressure condition is found. This gives us the stagnation conditions at the turbine exit.

10.4 The final step involves modelling the mixing process between the core and bypass streams. We assume that the flow perfectly mixes with no stagnation pressure loss and calculate the mixed out conditions by mass-averaging between the core and bypass conditions.

$$T_{tm} = \frac{T_{t13}\text{BPR} + T_{t5}}{1 + \text{BPR}} \qquad \text{Eq 16}$$
$$c_{pm} = \frac{c_{pc}\text{BPR} + c_{pt}}{1 + \text{BPR}}$$

where subscript m refers to the mixed out conditions.

10.5 Finally, these mixed out conditions can be used to find the jet velocity and thus the gross thrust of the engine. This is compared with the rated thrust input to the solver and if the error is low enough then the solver completes. If not then, the iteration loops over a different FPR.

11. APPENDIX J.4 – GASTURB SIMULATIONS

11.1 To validate both the unmixed and mixed flow solvers, we have used the GasTurb software to model a subset of engines.

11.2 GasTurb is a fast and accurate solver that allows us to iterate over certain variables to model engines. The OPR and BPR are provided in the EEDB and set as fixed variables in the solver.

11.2.1 For unmixed engines, we set three variables that we iterate over: (1) T_{t4} until the desired fuel flow rate from the EEDB is found; (2) FPR until the jet velocity ratio, set as 0.9, is found; and (3) air mass flow rate until the fan diameter is found. The fan diameter is publicly available and we believe is better for estimating the nozzle dimensions than rated thrust.

11.2.2 For mixed flow engines, a very similar set of variables are selected to iterate over, however the jet velocity ratio is no longer available to us.

12. APPENDIX J.5 – SN LIMIT LINE CONVERTED USING THE SCOPE11 CORRELATION

12.1 The SCOPE11 method provides a correlation to convert smoke number to mass concentration and so we can use this to convert the smoke number limit line to a mass concentration basis. This is found to be

$$\text{SCOPE11 best fit limit}\left[\frac{\mu g}{m^3}\right] = \frac{648.4\, e^{6.4 F_{00}^{-0.274}}}{1 + e^{-1.098\cdot(83.6 F_{00}^{-0.274} - 3.064)}} \qquad \text{Eq 17}$$

12.2 The SCOPE11 best fit limit line is between 5% and 12% greater than the limit line without a 2 standard deviation shift.

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议程项目 4：航空器噪声

4.1 第 1 工作组的报告—噪声技术

4.1.1 第 1 工作组（WG1 — 噪声技术）共同报告员介绍了该小组自 CAEP/10 以来进行的工作。第 1 工作组的主要目的是使国际民航组织的飞机噪声标准和建议措施保持最新和有效，同时确保审定合格程序尽可能简单和便宜。本报告概述了与这些目标相关的每个工作项目的进展情况。

4.1.2 第 1 工作组提出了修订附件 16 第 I 卷和国际民航组织 Doc 9501 号文件《环境技术手册（ETM）》第 I 卷 —《航空器噪声合格审定程序》的提案（N.02），此前它已获得 2018 年航空环境保护委员会指导小组会议的认可。这些修订案文包括对该附件和《环境技术手册》的监督、监测该附件和《环境技术手册》中引用的国际电工委员会（IEC）标准的进展和状态以及制定航迹测量的指导材料。

4.1.3 在 CAEP/11 期间，对国际民航组织噪声合格审定数据库（NoisedB）进行了多次更新和扩展。2018 年 9 月，第 1 工作组同意发布国际民航组织噪声合格审定数据库（NoisedB）2.26 版。与之前的版本（v2.25）相比，结合了 272 架飞机的改变，噪声合格审定数据库（NoisedB）2.26 版本于 2018 年 10 月 4 日发布。

4.1.4 第 1 工作组还继续监测各种国家和国际研究方案的目标和里程碑（任务 N.04.01），并提供了有关这项活动的报告，其中提出了有关政府和业界对解决平衡方法的技术方面问题作出强有力的承诺的看法。

4.1.5 第 1 工作组审查了四个与超音速飞机噪声相关的工作项目的进展情况（任务 N.05.01 至 N.05.04）。2016 年 6 月 9 日向空中航行委员会（ANC）介绍了有关超音速飞机的标准和建议措施（SARPs）的制定、业界项目和最新的研究的现况。

4.1.6 关于直升机噪声问题，第 1 工作组报告了将审定噪声水平与运行噪声水平相关联的可行性。本报告载于有关本议程项目报告的附录 B。第 1 工作组还评估了当前的直升机噪声审定合格机制是否适用于评估悬停噪声，包括是否足够联系到一个或多个现有参考条件的问题。本报告载于有关本议程项目报告的附录 C。

讨论和结论

4.1.7 会议感谢第 1 工作组持续更新和关注附件 16 第 I 卷，以及会议批准了有关本议程项目的报告附录 A 所载的修正案。会议还批准了工作组报告所载的 2018 年航空环境保护委员会指导小组会议之前批准的《环境技术手册》第 I 卷的修订案文。

4.1.8 会议批准了关于将直升机审定噪声水平与运行噪声水平相关联的可行性报告，以及关于直升机悬停噪声的报告。一位观察员赞赏第 1 工作组在 CAEP/11 期间就直升机任务 N.08 进行的工作，强调直升机噪声是她国内的主要噪声问题。观察员强调，当有新数据时，第 1 工作组需要继续执行这些任务。

4.1.9 建议

4.1.9.1 鉴于前述讨论，会议拟定了以下建议：

RSPP

RSPP 建议 4/1 — 对附件 16 —《环境保护》，第 I 卷 —《航空器噪声》的修订

附件 16 第 I 卷将按照关于本议程项目的报告附录 A 的内容作出修订。

建议 4/2 — 对《环境技术手册》第 I 卷 —《航空器噪声合格审定程序》的修订

修订《环境技术手册》第 I 卷和嗣后航空环境保护委员会指导小组会议批准修订版本并在国际民航组织网站免费提供。

4.2 关于制定超音速航路（爆音）噪声标准的进展

4.2.1 第 1 工作组共同报告员报告了关于制定超音速飞机航路（爆音）噪声审定合格标准的进展情况。这项工作的重点是：确定可行的爆音数据处理机制选项；大气和湿度标准的候选参考数值；更新爆音指标分析；爆音参考飞行条件。还介绍了最近有关超音速噪声技术的研究。

4.2.2 第 1 工作组超音速研究联络点（RFP）介绍了有关爆音技术的最新进展，概述了美国、日本、欧洲和业界各组织在超音速技术方面的许多发展。每个组织都将其部分资源用于了解大气湍流对超音速航空器传播声学特征的影响和建立其模型，并已在这一重要研究领域取得重大进展。大气湍流会使传播的波形失真，导致地面特征比静止大气中的预测声音水平更响亮或更安静。这些新模型在理解安静的超音速航空器在日常操作的噪声水平出现可能变化方面具有重要作用。另一个结论是，目前仍然存在许多与在陆地上方飞行的超音速飞行相关的未知数，并且继续仔细监测超音速航空器方面的发展符合航空环境保护委员会的最佳利益。

4.2.3 若干成员和观察员认为，地面上方的爆音被视为是一种新的骚扰形式，因此任何民用超音速飞机都应接受航路噪声的合格审定，以确定其爆音噪声水平。

4.2.4 一位观察员以第 1 工作组的名义介绍了业界在超音速领域所作的努力，包括与仅在水上超音速飞行有关的飞机开发项目以及支持能够在陆地上进行超音速运行的低爆音飞机技术。在 CAEP/11 周期期间，出现了六个主要发展，这表明各个国际业界成员和国家研究机构正在作出持续投资。

讨论和结论

4.2.5 一位成员祝贺第 1 工作组就爆音噪声标准所进行的工作，注意到第 1 工作组提出具有挑战性的时间表，该时间表表明它预计将在 CAEP/13 完成这项工作。该成员鼓励进一步研究爆音的影响，特别是关于抖动、振动和对睡眠造成的干扰。

4.2.6 第 1 工作组超音速研究联络点（RFP）在回答一位成员提出的问题时指出，根据当前美国航空航天局社区测试的结果，75 PLdB 强度的噪声被确定为爆音噪声可能无法与背景噪声区分的阈值。第 1 工作组共同报告员就一个相关主题指出，第 1 工作组尚未查明制定未来爆音强度的严格度定义所需的数据。

4.2.7 一位成员欢迎美国航空航天局进行的爆音社区测试举措，认为最终的爆音审定合格机制应仅适用于符合“低爆音”审定合格的设计。一位观察员强调指出，这项研究只是对这个问题的了解的开始，其他因素也应列入考虑，例如文化、爆音类型和地点等。会议鼓励继续进行国家支持的超音速噪声研究。 航空环境保护委员会秘书感谢第 1 工作组超音速研究联络点（RFP）的情况介绍，强调提供的信息对支持航空环境保护委员会的工作至为重要。

4.2.8 会议认识到迄今为超音速标准进行的工作，它注意到第 1 工作组概述的情况，认为应根据可得的数据合理安排各项基本技术活动。

4.2.9 会议进行了重新评估以便列入与低爆音有关的实验室新数据后，核可了六项最后核定的爆音指标（史蒂文·马克 VII 感觉噪声级（PL）；室内爆音干扰预测指标（ISBAP）；A 加权声曝露级（ASEL）；B 加权声曝露级（BSEL）；E 加权声曝露级（ESEL）；D 加权声曝露级（DSEL））。

4.2.10 会议同意第 1 工作组应解决爆音数据处理方案、大气—湿度参考标准、航路参考飞行条件和测量位置、低爆音标准和建议措施用于非低爆音设计的适用性等问题、继续探索马赫分界点运行的管理办法和继续收集为制定标准和建议措施所需考虑的“其他因素”的数据。这些因素可能包括“超过设计范围”的马赫数的爆音、来自加速和转弯的爆音、次级爆音、限制水上的 N 波爆音、夜间的睡眠干扰和爆音、对动物的影响和雪崩等。

4.3 制定超音速飞机着陆和起飞（LTO）噪声标准的进展

4.3.1 第 1 工作组共同报告员报告了有关制定超音速飞机着陆和起飞噪声审定合格标准的进展情况。第 1 工作组首先对当前相关法规取得共同理解，审查民用超音速航空器的历史数据，审查程序递减率（PLR）的细节和审查亚音速飞机和超音速飞机之间的设计差异。此外，在速度和配置方面突出起飞和着陆的差异。

4.3.2 在缺乏制造商的数据的情况下，第 1 工作组开始使用美国航空航天局研制的 55 吨超音速技术概念飞机（STCA）进行制造商的监督和交叉检查。日本太空发展署（JAXA）和俄罗斯中央空气流体动力学研究院（TsAGI）也通过使用相同的公开数据对独立预测这种超音速技术概念飞机（STCA）的噪声水平做出了贡献。

4.3.3 在最终拟定保密协议之后，向第 1 工作组成员提供了三架项目飞机的制造商数据，包括噪声强度估计、机重信息、航程距离、平衡场长度、马赫数、发动机信息、操作程序等。

4.3.4 在 2017 年航空环境保护委员会指导小组会议上，航空环境保护委员会认识到，一般而言，超音速和亚音速航空器的各项基本设计特性 — T/W（推重比）、W/S（机翼载荷）和 CLMax（最大可用升力系数）根本不同，并且只有拥有具体的设计才能更精确地评估这些差异。提供给第 1 工作组的项目飞机数据证明了亚音速和超音速飞机之间的一些关键差异。从 55 吨的超音速技术概念飞机（STCA）得到的数据也显示出这些差异。

4.3.5 第 1 工作组评估了目前为亚音速飞机制定的着陆和起飞（LTO）噪声审定合格标准和《环境技术手册》用于以超音速飞行的航空器的适用性。根据这一评估，第 1 工作组确定了一些需要或可能需要进一步调查以确定其适用性的类别。所有不符合这些类别的亚音速标准都需作出少量措辞改变或不作任何改变使其适用于超音速航空器。

4.3.6 采用有效感应噪声水平（EPNL）作为单一噪声指标，并在 2017 年航空环境保护委员会指导小组会议期间达成一致，预计它将不加修改地获得使用。虽然需要适用性定义，但这些定义的拟定将在稍后阶段完成。第 1 工作组的大多数成员同意第 14 章的噪声限值应用于每个参考点，但有些成员认为，在程序问题进行进一步讨论之前，做出这一决定为时尚早。第 1 工作组未就累计噪声水平是否成为进一步审查项目的问题达成任何协议。该小组也未就相关参数与第 1 工作组的现有知识一起作为进一步审查的项目达成任何共识。不过，第 1 工作组同意考虑使用一个额外相关参数，以适应一系列设计的马赫数，前提是原始设备制造商（OEM）的数据和计算分析数据都提供给工作组使用。关于程序问题，第 1 工作组同意需要进一步审查起飞的测试和参考日速度。《环境技术手册》中亚音速航空器的可变噪声降低系统（VNRS）已被允许使用，但在超音速航空器的标准和建议措施中，可能需要一些额外的指导。预计程序递减率（PLR）将成为超音速产品的一个特征，这被认为是根据可变噪声降低系统（VNRS）的规定纳入的。此时，没有足够的数据来决定是否需要对第 14 章（用作起点）的其他几个部分进行更改，包括进近程序。

4.3.7 一位观察员认为很快需要对超音速机队的预测，包括该机队的运行方式和地点，这将有助于对监管影响进行富有成效的讨论。该观察员为这项工作提供了资源，并支持建立一个制定超音速运输机（SST）标准和建议措施的协调小组。

4.3.8 第 1 工作组共同报告员在回答一个问题时指出，利用三个测量点的每一个测量点第 14 章提出了噪声限值，但利用这些测量点的累计边际数值也提出了一个限值。这使得一种设计可以符合三个单独限值的规定，但不符合累计噪声的限值，因此不符合第 14 章的规定。

4.3.9 一位成员强调指出 — 他的观点得到第 1 工作组共同报告员的同意 — 目前第 1 工作组关于超音速的规定是否符合第 14 章的要求的各种分析尚无定论，因为它们仅得到来自两架项目航空器的数据的支持，但不包括来自具有更高设计巡航马赫数的第三架项目航空器的数据。

4.3.10 若干成员和观察员提出他们对制定超音速飞机着陆和起飞（LTO）噪声标准有关的看法。他们重申他们的观点，即超音速飞机的噪声（包括着陆和起飞噪声和爆音）的标准和建议措施的制定必须以国际民航组织大会第 A39-1 号决议为基础，确保不会为公众造成无法接受的情况。关于着陆和起飞噪声，他们认为民用超音速飞机的噪声不应比目前和未来亚音速飞机着陆和起飞运行时的噪声更大。此外，他们认为，民用超音速飞机应根据第 14 章进行合格审定，并在必要时，进行一些技术调整，因此，他们认为没有必要考虑一套新的严格度选项或对可能的选项进行相对成本效益分析。

4.3.11 一位成员提出航空环境保护委员会的未来工作项目，其中包括更新第 14 章关于亚音速飞机噪声规定的范围界定研究。这将在议程项目 12 未来的工作项下审议。

4.3.12 一位成员认为，每个国家可以用不同的方式解释 A39-1 号决议提到的不可接受的情况，因此，认为在提到爆音影响时，可以加入“居住的土地”一词作出澄清。一位成员指出，这方面可以通过适当的运作规则加以解决。

4.3.13 一些成员和观察员认为，超音速航空器应符合适用于当前和未来亚音速航空器的噪声标准，而其他成员认为应该按照第 1 工作组的建议，在作出任何决定之前，收集更多数据和作出分析。

4.3.14 一位成员提出他对航空环境保护委员会内超音速噪声工作的看法。该成员建议航空环境保护委员会制定标准和建议措施，对民用超音速航空器的着陆和起飞噪声进行相关严格度评估，以便在 2022 年举行的 CAEP/12 予以审议。该成员认识到亚音速和超音速航空器类型之间存在根本性的技术差异，这可能导致对标准制定采用不同方法，或至少需要在作出政策结论之前，进行技术审查和分析。该成员强调指出，大会第 A39-1 号决议第 1.1 段重申，“重点是确保爆音不造成任何公众不可接受的情况”。该会员对特定于音爆问题的用语作出了解释，确保音爆不会导致“不可接受的情况”。该会员不支持在第 A39-1 号决议基础创建一个“公众可接受性”的概念，因为他认为，这一术语具有主观性、不精确并且与航空环境保护委员会的长期职权范围不一致，而其职权范围的前提是技术可行性、环境效益和成本效益。

4.3.15 该成员在回答一个问题时确认，在完成适当的技术分析后，可以考虑制定比第 14 章的限值更严格的超音速噪声限值。该成员还认为，航空环境保护委员会必须调整它的标准制定程序，以解决由于缺乏超音速审定合格噪声数据而导致的独特情况，并指出鉴于这种调整的特殊性，它们不应成为未来进行各种分析的先例。

4.3.16 一位成员支持在航空运输方面的各种创新，只要它们不会产生不可接受的环境影响，但认为超音速具有严重的潜在环境影响，这只有在其审定合格中适用现有的亚音速标准才能避免。该成员还指出，超音速和亚音速将在同一市场竞争，因此，超音速的不同噪声限制将为它们带来竞争优势。

4.3.17 一位观察员对制定超音速着陆和起飞标准和建议措施之事表示关切，表示为了使机场周围的社区能够接受，超音速航空器在亚音速运行下不能比亚音速飞机的噪声更高（同等级的最大起飞质量），并且还必须遵守当前和未来亚音速噪声和排放标准和建议措施。该观察员还提议，除了有效感应噪声水平（EPNL）之外，使用其他噪声指标进一步分析机场周围超音速运行对社区噪声的影响，认为应将国际民航组织大会第 A39-1 号决议用于超音速运输机的着陆和起飞噪声。

4.3.18 成员和观察员对航空环境保护委员会如何使用拟议的社区噪声分析结果提出质疑。该观察员指出，这些结果将用于支持关于超音速的政策决定，但不会质疑把有效感应噪声水平作为噪声审定合格指标的选择。会议同意在未来的工作的议程项目项下讨论这一提案。

4.3.19 两位观察员总结了制定超音速着陆和起飞噪声标准的重大技术进步以及业界作出的贡献。他们强调，原始设备制造商（OEM）正努力在 20 世纪 20 年代中期将超音速飞机投入使用，因此，原始设备制造商需要明确的着陆和起飞噪声规定才能完成项目设计。观察员支持启动制定标准和建议措施的要素并确定资源以实现超音速着陆和起飞噪声标准和建议措施的拟议日期。

4.3.20 一位观察员质疑航空环境保护委员会制定标准和建议措施的传统方法 — 根据测量和审定合格数据设定标准和建议措施的方法 — 与业界建议完全依赖较低技术就绪水平（TRL）的项目航空器和建模数据的新方法之间的一致性。他随后询问是否可以清楚查明项目飞机的技术就绪水平。另一位观察员回答指出，由于涉及的技术种类繁多，这是不可能的。

4.3.21 一位观察员认为，对未来超音速飞机的审定合格必须审慎处理，决不应增加机场噪声和社区干扰。该观察员提议，在拥有能够用于制定超音速噪声标准的强大超音速噪声性能数据之前，新的超音速航空器应符合当前第 14 章亚音速噪声标准。

4.3.22 会议注意到一位成员提供的有关使用起飞推力管理办法降低超音速潜在噪声以及关于超音速噪声、排放和飞行范围之间相互依存关系的信息。根据这些信息，考虑到主发动机噪声源，噪声水平预测表明，即使使用起飞推力控制办法，超音速运输机也无法满足第 14 章的要求。

讨论和结论

4.3.23 会议对航空环境保护委员会的工作目的是至少维护现有环境保护水平的解释进行了审议，即航空环境保护委员会职权范围中所谓的“环境效益”的解释。在回答有关“现有环境保护水平”一词的问题时，一位成员认为，该术语意味着机场周围的现有噪声水平不会恶化。一位观察员询问，航空环境保护委员会的工作是否应该针对职权范围内的一个具体要素或者在四个要素之间取得平衡，一位成员回答指出，业界在技术开发方面的努力仍然可以实现这种平衡。一位观察员认为，“反倒退”一词在航空环境保护委员会标准制定下的环境效益应该是无争议的解释。一位成员担心航空环境保护委员会职权范围中的“环境效益”一词被一些成员和观察员解释为“对整个系统的净环境效益”，这与航空环境保护委员会的过去做法不符。会议注意到航空环境保护委员会职权范围内这一要素的不同解释。

4.3.24 有些成员支持这样的观点，即第 A39-1 号决议中的用语具体针对爆音问题，确保爆音不会导致“不可接受的情况”。其他成员指出，第 A39-1 号决议提到“超音速航空器的运营对于公众可能造成的问题”，认为这些问题包括着陆和起飞噪声及其公众的可接受性。一位成员指出，公众可接受性这个概念对航空环境保护委员会来说并不陌生，因为 CAEP/10 会议指出，航空环境保护委员会 2015 年指导小组会议“承认公众接受爆音是超音速航空器标准的一个先决条件”，而另一位成员认为，航空环境保护委员会应避免引用指导小组的决定，而应采用大会决议的用语，即“由于爆音对公众造成的不可接受的情况”。

4.3.25 鉴于各种不同的看法，会议注意到一位成员表示的看法，即第 A39-1 号决议中的用语具体针对爆音问题，确保爆音不会导致“不可接受的情况”。

4.3.26 会议一致认为，亚音速和超音速民用飞机都是有固定机翼的喷气式飞机，用于客运，而且超音速飞机和亚音速飞机之间的某些基本设计具有根本性的不同。

4.3.27 若干成员和观察员反对在 CAEP/12 工作方案下对超音速进行噪声严格度评估，因为没有对如何进行这种严格度评估以及将使用何种数据作出说明。这些成员和观察员支持将第 14 章作为着陆和起飞噪声的标准，并在必要时作出一些技术调整。一位成员指出，使用现行亚音速标准作为超音速的参考数值将为业界提供监管确定性，这除了环境效益之外，也很重要。

4.3.28 一位成员指出，在没有审定合格数据的情况下，可以使用当前的数据来进行严格度分析。其他成员和观察员认为，目前仍没有足够的数据和分析来决定第 14 章是否可用于超音速航空器，因此，要求第 1 工作组在 CAEP/12 周期期间进行进一步工作。一位成员着重指出超音速和亚音速飞机之间的根本性设计差异，认为将亚音速和超音速飞机等同起来是过于简单的做法。另一位成员提醒指出，第 14 章目前涵盖涡喷发动机和涡轮螺旋桨发动机，它们也根本不同。

4.3.29 在随后的讨论中，会议同意在 CAEP/12 工作方案期间对超音速航空器进行探索性研究的要素如下：

4.3.30 认识到对超音速航空器着陆和起飞噪声进行严格度选项分析的必要性没有达成共识，航空环境保护委员会建议在 CAEP/12 周期期间使用现有数据进行探索性研究。该研究的结果旨使航空环境保护委员会更好地了解采用超音速航空器对机场噪声产生的影响，并且不预先判定是否需要进行严格度选项的分析。这项工作包括根据当前可用的噪声性能信息对一些机场的机队和运行预测以及着陆和起飞的噪声影响评估。它还包括根据附件 16 第 I 卷第 14 章噪声水平和边际规定对所使用的项目航空器进行评估。

4.3.31 这项研究应包含以下各种要素：

1) 程序

— 第1工作组鉴于业界的额外数据需求，在航空环境保护委员会指导小组2019年会议（SG2019）上就着陆和起飞噪声审定合格程序提出建议。

2) 预测情景

— 预测和经济分析支持小组根据业界和航空环境保护委员会各工作组提供的数据，为超音速运输市场制定多种需求情景。

3) 航空器数据

— 航空环境保护委员会明确认识到与现有航空器数据相关的不确定性。

— 第1工作组使用短期飞行冲突告警（STCA）和原始设备制造商（OEM）数据开发环境和绩效建模数据，它将代表一系列作为未来超音速航空器类型的代理概念和项目航空器。

— 在进行可行性评估的情况下，第1工作组根据审定合格程序制定噪声-功率-距离和光谱数据。在适当情况下，当有航空器的新数据可用时应考虑将其包含在内。

— 在进行可行性评估的情况下，第3工作组对着陆和起飞发动机排放以及飞机燃料燃烧和二氧化碳排放数据（巡航和全程飞行）提供相应估计，以便进行探索性分析。

— 影响与科学小组，在需要时利用来自第1工作组和第3工作组的数据，提供有关超音速噪声和排放产生的环境影响的信息。

— 第1工作组和第3工作组提供有关噪声、排放、燃料燃烧和马赫数之间综合评定的信息。

4) 研究

— 建模和数据库小组制定环境建模情景，承认这需要额外的资源以便更新现有模型和数据库和进行探索性研究。

— 包含公务喷气机和混合用途大型机场的区域代表性，并根据需要考虑机场容量限制的可行性，以确保亚音速运行的真实代表性。作为进行着陆和起飞噪声分析的区域机场选择的一部分，起点和终点样式也会被列入，以便能够计算全部航程的燃料燃烧和排放。

— 噪声指标是日夜平均水平和单一事件指标（LA max，声暴露级）。

— 考虑到用于研究的项目航空器数据的不确定性，将对输出结果的相应不确定性进行评估。

— 审议噪声和全程飞行燃料燃烧等的综合评定。

5) 结果

— 分析结果将提交给航空环境保护委员会指导小组2021年会议（SG2021）进行初步审议，最终结果将提交给CAEP/12。

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附录 A

对附件 16 第 I 卷的拟议修订

修订文本是这样编排的：用横线划掉的部分表示删去的文字，灰色阴影中的部分表示新增加的文字。如下所示：

1.	~~要删去的文字用横线将其划掉~~	要删去的文字
2.	新增加的文字放在灰色阴影中标出	新增加的文字
3.	~~要删去的文字用横线将其划掉~~ 其后用灰色阴影中的文字来代替	新增加文字代替原文

国际标准和建议措施修订案文

《国际民用航空公约》

附件 16
《环境保护》

第 I 卷
《航空器噪声》

……

术语：符号和单位

注：以下的很多定义和符号专门用于航空器噪声合格审定。其中一些定义和符号也可适用于航空器噪声合格审定以外的目的。

1.1 速度

符号	单位	含义
C_R	米/秒	基准声速　基准条件下的声速。
C_{HR}	米/秒	基准声速　对应环境温度的基准声速—假设直减率为每 100 米 0.65℃—处于平均海平面之上的飞机基准高度的标准日。
M_{ATR}	—	直升机旋翼基准前行桨尖马赫数　基准旋翼旋转桨尖速度与直升机基准速度之和，除以基准声速。
M_H	—	螺旋桨桨尖马赫数　螺旋桨试验旋转桨尖速度的平方与飞机试验空速的平方之和的平方根，除以试验声速。
M_{HR}	—	螺旋桨桨尖基准马赫数　螺旋桨基准旋转桨尖速度的平方与飞机基准速度的平方之和的平方根，除以基准声速。
最佳 R/C	米/秒	最佳爬升率　在最大功率设定值和发动机转速下的经审定的最大起飞爬升率。
V_{AR}	~~千米/小时~~米/秒	调整后的基准速度　在非标准试验日，为取得与基准条件下的基准速度相同的前行桨尖马赫数而调整的直升机基准速度。

V_{CON}	~~千米/小时~~米/秒	转换模式下的最大空速　转换模式下倾斜旋翼航空器的不可超越空速。
V_G	~~千米/小时~~米/秒	地速　航空器相对于地面的速度。
V_{GR}	~~千米/小时~~米/秒	基准地速　航空器在基准条件下、在地面轨迹方向相对于地面的真速。VGR 是航空器基准速度 VR 的水平分量。
V_H	~~千米/小时~~米/秒	最大平飞空速　直升机在以最大连续功率水平飞行的最大空速。
V_{MCP}	~~千米/小时~~米/秒	最大平飞空速　倾斜旋翼航空器在飞机模式下以最大连续功率水平飞行的最大空速。
V_{MO}	~~千米/小时~~米/秒	最大运行空速　倾斜旋翼航空器不得故意超过的最大使用限制空速。
V_{NE}	~~千米/小时~~米/秒	不可超越空速　不得故意超过的最大使用限制空速。
V_R	~~千米/小时~~米/秒	基准速度　航空器在基准条件下在基准航迹方向上的真速。
		注：该符号不应与通常用于飞机起飞旋转速度的符号相混淆。
V_{REF}	~~千米/小时~~米/秒	基准着陆空速　具有规定着陆构型的飞机下降通过跑道入口高度时的速度。该速度决定了人工着陆时的着陆距离。
V_S	~~千米/小时~~米/秒	失速空速　着陆构型的最小稳定空速。
V_{tip}	米/秒	桨尖速度　试验条件下旋翼或螺旋桨桨尖的旋转速度，不包括航空器速度分量。
V_{tipR}	米/秒	基准桨尖速度　基准条件下旋翼或螺旋桨桨尖的旋转速度，不包括航空器速度分量。
V_Y	~~千米/小时~~米/秒	最佳爬升率速度　最佳起飞爬升率的试验空速。
V_2	~~千米/小时~~米/秒	起飞安全速度　安全起飞的最小空速。

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1.4 噪声的度量

符号	单位	含义
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L_{AE}	dB SEL(A)	声暴露级（SEL） 航空器通过时的单个事件噪声级，是A加权声级（dB (A) 在噪声持续时间上的积分，归一化为1秒的基准持续时间。（相关规范见附录4第3节）
Δ_1	TPNdB	PNLTM调整量 在附录2或附篇F下。在简化的调整方法中，为考虑在PNLTM时刻，试验条件和基准条件之间由于大气声吸收及噪声传播路径长度的差别所致的噪声级的变化而加到由实测噪声值计算出的EPNL上的调整量。
	dB(A)	在附录4下。为考虑由于直升机试验和基准高度之间的差别所致的球面发散和持续时间噪声级的变化而加到实测LAE上的调整量。
	dB(A)	在附录6下。对于不超过8 618公斤的螺旋桨驱动的飞机，为考虑由于飞机试验高度和基准高度之间的差别所致的噪声级的变化而加到实测L_{ASmax}上的调整量。
Δ_2	TPNdB	持续时间调整量 在附录2或附篇F下。在简化的调整方法中，为考虑由于试验航空器相对于传声器的速度和位置与与基准速度和位置的差别造成的噪声持续时间的变化所致的噪声级的变化而加到由实测噪声值计算出的EPNL上的调整量。
	dB(A)	在附录4下。为考虑由于基准和调整空速之间的差别所致的噪声级的变化而加到实测LAE上的调整量。
	dB(A)	在附录6下。对于不超过8 618公斤的螺旋桨驱动的飞机，为考虑到由于试验和基准螺旋桨斜尖马赫数之间的差别所致的噪声级的变化而加到实测L_{ASmax}上的调整量。

符号	单位	含义
Δ_3	TPNdB	源噪声调整量　在附录2下。在简化的或完整的调整方法中，为考虑由于试验条件和基准条件下源噪声产生机制的差别所致的噪声级的变化而加到由实测噪声值计算出的EPNL上的调整量。
	dB(A)	在附录6下。对于不超过8 618公斤的螺旋桨驱动的飞机，为考虑到由于试验和基准发动机功率之间的差别所致的噪声级的变化而加到实测L_{ASmax}上的调整量。
Δ_4	dB(A)	大气声吸收调整量　在附录6下。对于不超过8 618公斤的螺旋桨驱动的飞机，为考虑由于飞机试验高度和基准高度之间的差别所致的大气声吸收的变化而加到由实测噪声值计算出的L_{ASmax}上的调整量。

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1.6 航迹几何位置

符号	单位	含义
H	米	高度　航空器越过或正横于中心传声器时的航迹切入垂直于中央传声器基准地面轨迹的垂直几何平面点的高度。
H_R	米	基准高度　航空器越过或正横于中心传声器时的基准航迹切入垂直于中央传声器基准地面轨迹的垂直几何平面点的基准高度。

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第 11 章　最大起飞审定质量不超过 3 175 公斤的直升机

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11.2　噪声评定的度量

噪声评定的度量必须是附录4中所描述的声暴露级（SEL）L_{AE}。

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11.4　最大噪声级

11.4.1 对于在 11.1.2 和 11.1.3 中规定的直升机，按附录 4 的噪声评定方法确定的最大噪声级不得超过下述数值：对于噪声合格审定所要求的最大审定起飞质量在 788 公斤以下的直升机，最大噪声级不得超过 82 分贝声暴露级 A 加权声级，此后随直升机质量的对数呈线性增加，质量每增加一倍，噪声级增加 3 分贝。

11.4.2 对于在11.1.4中规定的直升机，按附录4的噪声评定方法确定的最大噪声级不得超过下述数值：对于噪声合格审定所要求的最大审定起飞质量在1 417公斤以下的直升机，最大噪声级不得超过82分贝声暴露级A加权声级，此后随直升机质量的对数呈线性增加，质量每增加一倍，噪声级增加3分贝。

注：作为起飞质量函数的允许的最大噪声级的计算公式，见附篇A。

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11.6　试验程序

11.6.1　试验程序必须是为颁证国家的适航和噪声合格审定当局所能接受的。

11.6.2　试验程序和噪声测量值必须以经过批准的方式进行和处理，以得出附录4所述的、被称为声暴露级（SELL_{AE}）的噪声评定的度量，单位为持续时间内积分的 A加权分贝。

11.6.3　试验条件和程序必须与基准条件和程序极为相似，否则，声学数据必须按附录4所述方法，调整到本章所规定的基准条件和程序下。

11.6.4　在试验期间，必须作相等数量的顺风飞行和逆风飞行。

11.6.5　对试验和基准飞行程序之间差异进行的调整不得超过2.0分贝（A）。

11.6.6　试验期间，在10分贝降的期间内，平均旋翼转速偏离最大正常工作转速不得超过±1.0%

11.6.7　在整个10分贝降的期间内，直升机的空速偏离适合于附录4中所述的飞行验证的基准空速不得超过±5.5公里/小时（±3节）。

11.6.8　直升机必须在基准轨迹正上方±10°的范围内飞过基准噪声测量位置。

11.6.9　试验必须在直升机质量不低于90%相关最大审定质量的情况下进行，亦可在直升机质量不超过105%关最大审定质量的情况下进行。

注：关于等效程序的使用的指导材料，见《环境技术手册》（Doc 9501号文件）第I卷 —《航空器噪声合格审定程序》。

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第 13 章　倾斜旋翼航空器

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13.2　噪声评定的度量

噪声评定的度量必须是本附件附录2中所述的、以EPNdB为单位的有效感觉噪声级。关于频谱的不规则性修正必须从50赫兹开始（见附录2的4.3.1）。

注：应该为土地使用规划目的，向审定当局提供以附录4中定义的~~*SEL*~~L_{AE}和L_{ASmax}以及以附录2中定义的与L_{ASmax}相对应的三分之一倍频程SPL计的附加数据。

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附录2 下列飞机的噪声合格审定的评定方法

1. 亚音速喷气式飞机 — 1977年10月6日或以后提交型号合格证申请者

2. 8 618公斤以上的螺旋桨驱动的飞机 — 1985年1月1日或以后提交型号合格证申请者

3. 直升机

4. 倾斜旋翼航空器

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2. 噪声合格审定试验和测量条件

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2.2 试验环境

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2.2.2 大气条件

2.2.2.1 定义和规范

为本章所述噪声合格审定的目的，必须适用下述规定：

平均侧风分量 必须根据一系列在航空器试验期间获得的风样本的“横向”(v) 分量的单个值来确定，所使用的方法是30秒的线性平均法，或不超过30秒的时间常数的平均法，其结果在航空器~~越过或正横于传声器~~的航迹切入垂直于中央传声器基准地面轨迹的垂直几何平面后大约15秒时读出。

注：基准地面轨迹的定义载于8.1.3.5。

平均风速 必须根据一系列在航空器试验期间获得的单个风速样本来确定，所使用的方法是30秒的线性平均法，或不超过30秒的时间常数的平均法，其结果在航空器越过或正横于传声器后大约15秒时读出。或者将每个风速矢量分解为“沿迹”(u) 和“横向”(v) 分量。必须对航空器试验期间获得的一系列单个风样本的u和v分量分别进行平均，所使用的方法是30秒的线性平均法，或不超过30秒的时间常数的平均法，其结果在航空器~~越过或正横于传声器~~的航迹切入垂直于中央传声器基准地面轨迹的垂直几何平面后大约15秒时读出。然后，必须根据勾股定理和“反正切(v/u)”，通过平均u和v分量计算出平均风速和风向（相对于航迹）。

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3. 对地面接收到的航空器噪声的测量

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3.7 分析系统

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3.7.3 在标称中心频率从 50 赫兹到 10 千赫兹（含）的三分之一倍频程滤波器范围内，三分之一倍频程频带分析系统必须符合经修订的 IEC 61260-1[1] 的 1 级电气性能要求。

注 1：审定当局可允许用符合 IEC 61260-1[1] 的 2 级电气性能要求的分析系统来取代或符合 IEC 61260 更早版本的 1 级或 2 级电气性能要求的分析系统。

注 2：应该依照 IEC 61260-3[x1] 所述方法或经审定当局批准的等效程序，对相对衰减、抗混叠滤波器、实时操作、级线性和滤波器积分响应（有效带宽）进行三分之一倍频程频带分析系统测试。

3.7.4 当分析仪进行“慢”时间平均时，三分之一倍频程分析系统在各自三分之一倍频程标称中心频率点对稳定正弦信号的突然开始或中断的响应，必须在开始后的0.5秒、1秒、1.5秒和2秒及中断后的0.5秒和1秒进行瞬时采样测量。上升响应相对于稳定状态必须为：0.5秒，−4±1分贝；1秒，−1.75±0.75分贝；1.5秒，−1±0.5分贝；2秒，−0.5±0.5分贝。下降响应必须为：相对于初始稳定状态的输出信号级与相应的上升响应读数之和上升和对应的下降响应之和必须在0.5秒和1秒，均为−6.5±1分贝。在随后时间里，上升响应和下降响应之和必须为1.5秒，−7.5 −6.5分贝或更低；2秒及相对于初始稳定状态的随后时间里，−7.5分贝或更低。这等同于标称1秒时间常数（即平均时间为2秒）的指数平均过程（“慢”时间加权）。

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4. 根据测得的噪声数据计算有效感觉噪声级

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1. IEC 61260-1：1995 2014 年，标题为“电声学 — 倍频程频带和分数倍频程频带滤波器 — 第一部分：规格”。该出版物在位于瑞士日内瓦凡隆巴街 3 号的国际电工技术委员会中央办公室有售。

x1. IEC 61260-3：2016 年，标题为“电声学 — 倍频程频带和分数倍频程频带滤波器 — 第三部分：定期测试”。该出版物在位于瑞士日内瓦凡隆巴街 3 号的国际电工技术委员会中央办公室有售。

4.7 呐表的数学公式

4.7.1 声压级（SPL）与感觉噪度的对数之间的关系示于表A2-3和图A2-3。

……

表A2-3 呐值数学计算公式中的常数

BAND (i)	ISO BAND	f Hz	SPL(a)	SPL(b)	SPL(c)	SPL(d)	SPL€	M(b)	M(c)	M(d)	M(e)
1	17	50	91.0	64	52	49	55	0.043478	0.030103	0.079520	0.058098
2	18	63	85.9	60	51	44	51	0.040570	0.030103	0.068160	0.058098
3	19	80	87.3	56	49	39	46	0.036831	0.030103	0.068160	0.052288
4	20	100	79.~~0~~9	53	47	34	42	0.036831	0.030103	0.059640	0.047534
5	21	125	79.8	51	46	30	39	0.035336	0.030103	0.053013	0.043573
6	22	160	76.0	48	45	27	36	0.033333	0.030103	0.053013	0.043573
7	23	200	74.0	46	43	24	33	0.033333	0.030103	0.053013	0.040221
8	24	250	74.9	44	42	21	30	0.032051	0.030103	0.053013	0.037349
9	25	315	94.6	42	41	18	27	0.030675	0.030103	0.053013	0.034859
10	26	400	∞	40	40	16	25	0.030103		0.053013	0.034859
11	27	500	∞	40	40	16	25	0.030103		0.053013	0.034859
12	28	630	∞	40	40	16	25	0.030103		0.053013	0.034859
13	29	800	∞	40	40	16	25	0.030103		0.053013	0.034859
14	30	1 000	∞	40	40	16	25	0.030103		0.053013	0.034859
15	31	1 250	∞	38	38	15	23	0.030103		0.059640	0.034859
16	32	1 600	∞	34	34	12	21	0.029960		0.053013	0.040221
17	33	2 000	∞	32	32	9	18	0.029960		0.053013	0.037349
18	34	2 500	∞	30	30	5	15	0.029960		0.047712	0.034859
19	35	3 150	∞	29	29	4	14	0.029960		0.047712	0.034859
20	36	4 000	∞	29	29	5	14	0.029960		0.053013	0.034859
21	37	5 000	∞	30	30	6	15	0.029960		0.053013	0.034859
22	38	6 300	∞	31	31	10	17	0.029960	0.029960	0.068160	0.037349
23	39	8 000	44.3	37	34	17	23	0.042285	0.029960	0.079520	0.037349
24	40	10 000	50.7	41	37	21	29	0.042285	0.029960	0.059640	0.043573

……

8. 航空器飞行试验结果的调整

8.1 飞行剖面和噪声的几何位置

……

8.1.1 飞机飞行剖面

8.1.1.1 全功率下基准横测剖面的特征

图A2-4所示为在横测全功率噪声测量点进行噪声测量时，飞机起飞程序的剖面特征：

a) 飞机以全功率在A点开始起飞滑跑，在B点离地。在B点和C点之间，爬升角逐渐增加。从C点开始，爬升角保持恒定，直至F点，即噪声航迹的终点。

b) 位置K_{2L}和K_{2R}为喷气式飞机的左侧和右侧横测噪声测量点，位于与跑道中心线平行且与之相距规定距离的一条线上，该处起飞时的噪声级最大。位置K_4为螺旋桨驱动飞机的“横测”全功率噪声测量点，该点位于跑道中心线的延长线上，在飞机的爬升航迹上某一指定高度点的正下方。

……

8.1.3 计算EPNL时将实测噪声级从实测剖面调整至基准剖面

……

8.1.3.5 基准地面轨迹被定义为基准航迹在地面上的垂直投影。

……

附录 4　最大起飞审定质量不超过 3 175 公斤的直升机噪声合格审定的评定方法

……

2. 噪声合格审定试验和测量条件

……

2.4 飞行试验条件

……

2.4.3 基准前行桨尖马赫数M_{ATR}被定义为基准桨尖转速V_{tipR}与基准直升机真空速V_R的代数和除以25℃时的基准声速c_R，即：

$$M_{ATR} = \frac{(V_{tipR} + V_R)}{c_R}$$

3. 噪声单位定义

……

3.4 实际上积分时间$(t_2 - t_1)$不得小于10分贝降的区间，在此期间，L_{AS} (t)先升至低于其最大值的10分贝(A)，最后降到其最大值的10分贝(A)以下。

……

4. 对地面接收到的直升机噪声的测量

……

4.3 传感、记录和重放设备

……

4.3.2 声暴露级L_{AE}可根据积分式声级计来直接确定。或者，经过审定当局批准，可将直升机所产生的声压信号用模拟磁带记录仪或数字音频记录器存储下来，以便后期采用积分式声级计进行分析。声暴露级L_{AE}也可通过遵照附录2第3节进行的测量所得的三分之一倍频程数据，使用3.3中的公式计算得出。在这种情况下，每个三分之一倍频程声压级都必须按照国际电工技术委员会第61672-1号出版物[2]中给出的A加权值进行加权。

4.3.3 整个系统在方向响应、频率加权A、时间加权S（慢）、级线性以及短时间信号响应方面所具有的特性，必须符合IEC 61672-1[1]中规定的I类规范。根据IEC 61672-1号出版物[1]，整个系统可以包括磁带记录仪或数字音频记录器。

注：审定当局可以批准使用符合现行IEC标准中II类规范的设备，或者使用符合早期标准中I类或I型规范的设备，只要申请人能够证明该设备之前经过审定当局批准可用于噪声合格审定。这包括利用声级计和图示声级记录仪并使用3.3中给出的公式近似计算声暴露级L_{AE}。审定当局也可批准使用符合旧的IEC 561标准所载规范的磁带记录仪，只要申请人能够证明该设备之前经过审定当局批准可用于噪声合格审定。

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2. IEC 61672-1：2002 年，标题为“电声学 — 声级计 — 第 I 部分：规范”。该出版物在位于瑞士日内瓦凡隆巴街 3 号的国际电工技术委员会中央办公室有售。

……

4.3.5 当直升机的声压信号被记录下来后，~~声暴露级~~L_{AE}可通过把记录信号放到符合IEC 61672-1[3]中I类性能要求的经批准的声级计电输入装置中进行重放来确定。声级计的声学敏感度必须通过对来自声校准器的相关信号记录进行重放，以及对在记录直升机噪声时的主导环境条件下声校准器耦合腔发出的声压级进行了解来确定。

4.3.6 在直升机噪声级的所有测量期间，应该在传声器上装防风罩。当使用防风罩时，其特性必须保证包括防风罩在内的整个系统符合4.3.3中的规范。

……

5. 试验结果的调整

……

5.2 修正和调整

……

5.2.2 对球面发散和持续时间的调整可按下述公式进行近似计算：

$$\Delta_1 = 12.5 \log （H/150\ m）$$

式中H为试验直升机在噪声测量点正上方时的高度，以米为单位。

5.2.3 对基准空速与调整后的基准空速之间的差异的调整按下述公式计算：

$$\Delta_2 = 10\ log\left(\frac{V_{AR}}{V_R}\right)$$

式中 Δ_2 是用分贝表示的量，必须用代数方法将其加到实测~~声暴露级~~L_{AE}上，以便针对调整基准空速对在噪声测量站感受到的飞越测量持续时间产生的影响作出修正。V_R是第Ⅱ部分第11章11.5.2中所描述的基准空速，V_{AR}为本附录2.4.2中所描述的调整后的基准空速。

6. 向审定当局报告数据以及结果的有效性

……

6.3 结果的有效性

6.3.1 必须至少飞越测量点6次。试验结果必须产生一个平均~~声暴露级~~L_{AE}及其90%的置信限，噪声级是所有按基准程序飞越测量点的有效试验飞行的声学测量值修正后的算术平均值。

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3. IEC 61672-1：2002 年，标题为“电声学 — 声级计 — 第 I 部分：规范”。该出版物在位于瑞士日内瓦凡隆巴街 3 号的国际电工技术委员会中央办公室有售。

6.3.2 样本数必须足够大，以在统计上建立不超过±1.5分贝（A）的90%置信限。在平均过程中不得略去任何试验结果，除非审定当局另有规定。

注：计算90%置信区间的方法，见《环境技术手册》（Doc 9501号文件）第I卷 —《航空器噪声合格审定程序》中与置信区间的计算相关的那一节。

……

附录6 不超过8 618公斤的螺旋桨驱动的飞机噪声合格审定的评定方法 — 1988年11月17日或以后提交型号合格证或衍生型合格审定申请者

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5. 试验结果的调整

……

5.2 修正和调整

……

5.2.2 基准条件下的噪声级L_{ASmaxR}是通过把每一上述效应的增量加到试验日的噪声级L_{ASmax}上来获得。

$$L_{ASmaxR} = L_{ASmax} + \Delta_1 + \Delta_2 + \Delta_3 + \Delta_4$$

式中

Δ_1 是针对声传播路径长度所作的调整；
Δ_2 是针对螺旋桨桨尖马赫数所作的调整；
Δ_3 是针对发动机功率所作的调整；和
Δ_4 是针对试验和基准条件之间大气吸声的改变所作的调整。

……

d) 实测声级必须针对发动机功率作调整，方法是按代数方式加上一个增量Δ_3

$$\Delta_3 = k_3 \log（P_{\theta R} /P）$$

式中P和$P_{\theta R}$分别是试验发动机功率和基准发动机功率，由发动机总管压力/扭矩表和发动机转速获得。k_3值必须根据从试验飞机获得的经批准的数据来确定。在没有飞行试验数据的情况下，可根据审定当局的决定，使用k_3=17。基准功率$P_{\theta R}$必须在基准高度温度和气压下得到（以国际民航组织标准大气界定的温度和压力随高度的直减率为假设）。

……

附件16第I卷的附篇

附篇A　作为起飞质量函数的允许的最大噪声级的计算公式

……

10.　第11章11.4.1中所述的条件

M = 最大起飞 质量（1 000 kg）	0	0.788	3.175
噪声级（dB(A) ~~SEL~~）	82	83.03 + 9.97 log M	

11.　第11章11.4.2中所述的条件

M = 最大起飞 质量（1 000 kg）	0	1.417	3.175
噪声级（dB(A) ~~SEL~~）	82	80.49 + 9.97 log M	

……

附篇F　倾斜旋翼航空器噪声合格审定指南

……

2.　噪声评定的度量

噪声评定的度量应该是本附件附录2中所述的、以EPNdB为单位的有效感觉噪声级。

注：应该为土地使用规划目的，向审定当局提供以附录4中定义的~~*SEL*~~ L_{AE}和L_{ASmax}以及以附录2中定义的与L_{ASmax}相对应的三分之一倍频程SPL计的附加数据。

————————

APPENDIX B
(English only)

HELICOPTER NOISE CORRELATION TASK REPORT

1. INTRODUCTION

1.1 The task N.08.01, decided at the CAEP/10, asked to "Investigate the feasibility of correlating certification noise levels with operational noise levels to better assess the helicopter noise certification scheme and its relevance to day- to-day operations, similar to the studies done for jets."

1.2 WG1 reviewed the mentioned study done for jets to facilitate the analysis. In addition, the task description "similar to the studies done for jets" was refined and the task description accordingly reformulated to: "Investigate the feasibility of correlating the ranking of helicopters based on noise certification levels with the ranking based on operational noise data to better assess the helicopter noise certification scheme and its relevance to day-to-day operations". Finally, WG1 discussed basic considerations on typical flight phases during helicopter missions and their possible applicability for the correlation task along with possible sources of operational data.

1.3 WG1 then worked to secure operational noise measurements data. A sample of helicopter noise measurement performed in Sweden was presented during WG1_1. Norway provided helicopter noise measurements performed for two offshore helicopters for development of Noise Power Distance (NPD) data typically used for land-use planning purposes. In order to acquire available measurements to support the analysis, the group agreed to prepare a State Letter to request helicopter noise data from ICAO contracting states. Additionally, measurement information on eight different helicopters in various flight conditions came from the Public European Environmental Model Suite for Aviation. Finally, WG1 decided to review data from a 1984 operational noise test conducted by the FAA at Dulles Airport near Washington, DC where eight helicopters models were measured.

2. DATA REVIEW AND PRELIMINARY RESULTS

2.1 <u>Methodology Review:</u> WG1 reviewed a correlation analyses between noise certification EPNL and operational SEL for the eight helicopter models included in operational noise testing conducted by the FAA at Dulles Airport near Washington DC in 1984. The correlations give preliminary indications that noise certification data can provide adequate rank ordering of operational noise emissions for helicopters.

2.2 <u>Data Review</u>: As feedback to the state letter, data from four members (Latvia, Australia, Japan, Russia) involving operational data was provided. WG1 reviewed available information received in response to the state letter and determined that only the Australian noise data sets were considered to be sufficient for the correlation task. Either the other data sets represented certification data only or the number of different helicopter models contained was too small to allow a meaningful statistical analysis. For example, the Latvian data is of similar nature to the Australian data but heavily dominated by only one helicopter model and thus not appropriate for a statistically relevant analysis.

2.3 Among the data sets supplied by Australia, the operational data obtained around Sydney Airport was identified as most promising for the correlation task due to the large number of different helicopter models combined with a significant number of recorded movements. Based on the location of the operational measurements relative to the Sydney Airport, however, correlations were limited to Flyover only.

2.4 Data Analysis: Substantial effort was needed to utilize the Sydney Airport data for the correlation task, since the helicopters in the Australian data set are only characterized by their ICAO type designation. In order to assign the respective noise certification level to each database entry, the unique helicopter model identifier needed to be established. WG1 requested this information from Australia but unfortunately, the information is not available in their database. Therefore, the identification of models has been conducted manually by the OEMs by correlating the noise data base with Australian CAA registration data and in-house information from the respective sales departments. Using this methodology, an identification of helicopter models operated in the Sydney area has been achieved for many models.

2.5 Based on the operational noise dataset around Sidney Airport, a statistical analysis was establish to compare the rankings of helicopter models based on operational and certification noise data. This statistical analysis concludes that "there is a good correlation between the certified noise level in EPNdB on Flyover and the noise levels measured in operational conditions in SEL. The sample is composed of very different helicopter types (twin-engine and single engine, different power, different MTOM, different manufacturer)." WG1 also suggests that to confirm this trend, a larger dataset should be investigated.

2.6 Aside from the operational data received in response to the ICAO state letter, two large scale test campaigns in Europe and the US have been conducted in 2017/2018. However, the data is not yet available.

3. **CONCLUSIONS**

3.1 Considerable effort has been put in the search for adequate data and the pre-processing of this data to render it accessible for a noise ranking correlation analyses.

3.2 Analysis of a 1984 FAA measurement campaign at Dulles Airport with eight helicopters indicates a preliminary feasibility of correlating the ranking of helicopters based on certification noise levels with a ranking based on operational noise levels.

3.3 Analysis of operational noise measurement data acquired around Sydney Airport for five different helicopter models showed a good correlation between the ranking of helicopters based on flyover noise certification with the ranking of helicopters based on operational data.

3.4 Results of the analyses of the earlier FAA noise data and the more recent operational noise data support further extending the correlation analysis when the additional European and U.S. noise test data becomes available.

3.5 The achievability of the task is limited particularly by the lack of adequate operational data. Even with the lack of data, the feasibility analyses of the information available to date indicate a potential for correlation between the ranking of helicopters based on certification noise levels and a ranking based on operational noise levels, while noting that a low number of aircraft models were represented on the current analysis.

3.6 WG1 agreed that the information available to date suggests that the helicopter noise certification scheme has relevancy to day-to-day operations especially for flyover.

3.7 WG1 discussed the need for additional data to support further investigations on this topic, and it was agreed that additional data should ideally contain helicopter model and tail number associated with the noise measurements.

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APPENDIX C
(English only)

HELICOPTER HOVER TASK REPORT

1. INTRODUCTION

1.1 Working Group 1 was tasked to review any past evaluations of a noise certification scheme for the hover condition, and assess whether the current helicopter noise certification scheme is applicable for assessing hover noise including the sufficiency of a correlation with one or more of the existing reference conditions.

1.2 Including a hover reference point for helicopter noise certification was examined as part of the original development of Chapter 8 of the Annex during CAN/5 and CAN/6. During this development period for the Annex, it was concluded that the hover condition did not provide the repeatability and accuracy needed for a noise certification reference point. This conclusion was primarily based on the results of measurement programs carried out by Member States.

1.3 WG1 conducted a more detailed review of the hover work done during and subsequent to CAN/5 and CAN/6. To facilitate this review, WG1 collected the relevant documentation produced during CAN/5 – CAN/6 and identified additional relevant WG1 documentation from CAEP/6.

1.4 WG1 identified a 2016 European test campaign where hover data was measured. An evaluation of hover noise data acquired during the 2016 European test campaign indicated that measurement of hover noise lacks adequate repeatability for noise certification purposes. In addition, the U.S. conducted a test campaign in 2017, which also had a goal of collecting hover data.

1.5 In summary, WG1 found no new information to alter the conclusion reached by CAN/5 and CAN/6 during development of Chapter 8 of the Annex to exclude the hover condition or to change the recommendation to exclude hover from Land Use Planning guidelines developed during CAEP/6, which stated "The hover flight configuration should not be included in any noise measurement programme (noise certification or Land Use Planning)."

2. DATA ANALYSIS

2.1 Considering that final data from the European and US test campaigns have not yet been analysed, WG1 examined In-Ground Effect (IGE) and Out-of-Ground Effect (OGE) hover noise data for several helicopter models acquired by the FAA during 1983 and 1984. While a preliminary rank order analysis of three of the helicopter models was completed, it illustrated some of the issues in defining a hover noise measurement/metric for correlation with the noise certification test points such as hard vs. soft surface and average vs. maximum azimuthal level. WG1 also conducted a correlation analyses between noise certification EPNL and hover noise data for nine of the helicopter models tested by the FAA in 1983 and 1984. Three correlation methods were examined including comparisons of noise level correlations with gross weight, direct correlations of hover noise levels with noise certification levels and rank order comparisons of hover noise and noise certification levels. In general, no or inconclusive statistical correlations between hover and certification noise levels were observed. More specifically, only a correlation of Out-of-Ground Effect (OGE) hover noise levels vs. gross weight provided any indication of comparative results to noise certification levels, albeit with insufficient correlation strength/data points to be considered conclusive. OGE hover noise data for more helicopter models over a broader gross weight range could potentially provide a more conclusive result. The prospect for additional data would be enhanced with the establishment of guidelines for acquisition of hover noise data to ensure more consistent testing procedures.

3. CONCLUSIONS

3.1 The review of past evaluations of a noise certification scheme for the hover conditions (In-Ground Effect - IGE and Out-of-Ground Effect - OGE) is complete and further data is not available at the time being. Based on the information available to date, it does not appear feasible to define a measurement method for the hover condition with the accuracy and repeatability needed for a reference noise certification point in Annex 16, Chapters 8 and 11.

3.2 The limited IGE and OGE hover noise data acquired during FAA noise testing in 1983-84 do not support, or indicate the feasibility of, correlating hover noise levels with the current helicopter noise certification test scheme. While the possibility of having a trend between OGE hover noise and helicopter gross weight was discussed, it was recognized that the current trend identified is supported by a single point in the low-weight helicopter range. Therefore, this investigation could benefit from additional data from helicopters with gross weights in that weight range. On that note, WG1 agreed that further work is needed to substantiate if there is a trend between OGE hover noise and gross weight comparable to that of noise certification test conditions.

3.3 WG1 recommends that if new data becomes available, the feasibility of correlating hover noise with the current helicopter noise certification scheme should be further examined.

3.4 WG1 recommends that the CAEP/12 work programme include the development of measurement guidelines for hover noise data in support of future hover noise work. Members of ICCAIA will consider sharing OEM hover measurement procedures and hover data.

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议程项目 5：机场与运营

5.1 航空系统组块升级（ASBU）组块 1 分析

5.1.1 在 CAEP/10 周期开展的工作的基础上，第 2 工作组与建模和数据库小组合作，为 2025 年航空系统组块升级（ASBU）组块 B0 和组块 B1 相关模块的实施，对燃料燃烧和二氧化碳减排进行了组块 0(B0)和组块 1(B1)进行了综合分析。到 2025 年，在 ASBU 框架内，目前和计划实施的 B0/B1ASBU 要素估计每年全球可节省 167 至 307 千克燃料/每次飞行，相当于减少 2,620 万吨二氧化碳至 4,820 万吨二氧化碳或节省 50 亿美元至 92 亿美元。

讨论和结论

5.1.2 会议欢迎 ASBUB0/B1 综合分析的结果，认可第 2 工作组和建模和数据库小组进行的密集数据分析。

5.1.3 国际民航组织空中航行局局长（D/NB）在会议发言，他在概述全球空中航行计划（GANP）和 ASBU 组块时，强调需要通过具体数据支持空中交通管理（ATM）的改进，其效益预期会在安全、运量、效率和环境保护等领域带来好处并能量化实施对业界的实际价值。他着重指出第 2 工作组在支持制定方法和评估实施运行措施产生的环境效益方面所进行的工作。空中航行局局长还指出，空中交通管理系统的改进必须够付成本，而且投资产生的效益应包括二氧化碳的减排。

5.1.4 航空环境保护委员会秘书强调指出，运行改进是国际民航组织关于二氧化碳排放的一揽子措施中的一个要素，而国际民航组织所做的工作有助于量化每个要素产生的影响。为此，目前已经开发了一些工具，例如国际民航组织节油估算工具（IFSET），旨在帮助各国以航空环境保护委员会批准并与全球空中航行计划一致的模式估算节省的油量。

5.1.5 会议进一步思考了 B0/B1 综合分析结果的应用，认为将 2025 年作为一个起点，这些结果可被纳入国际民航组织的趋势。

5.1.6 **建议**

5.1.6.1 鉴于前述讨论，会议拟定了以下建议：

建议 5/1 — 航空系统组块升级（ASBU）组块 1 — 环境分析

邀请各国使用航空环境保护委员会进行的 ASBU B0/B1 综合环境分析结果，以支持 B0 和 B1 的实施，并通报各国国内运行改进取得的环境效益。

5.2 全球空中交通管理效率和无法弥补的交通增长对环境的影响

5.2.1 第 2 工作组使用新的全球数据源（ADS-B 监视数据）和单一参数进行了第一次全球水平飞行效率（HFE）分析，以估计不同交通流量的效率。按国际民航组织的地区对 2017 年数据进行分析，其结果显示效率水平在 94%至 98%之间变化。得出的结论显示各种局限性，例如这种水平飞行效率分析与空中交通管理效率分析之间可能存在混淆，并且 ADS-B 监测数据虽然越来越多，但估计它仅覆盖全球所有航运的 68%，尽管有地区的差异性。第 2 工作组认为，评估全球飞行效率所需的进一步步骤需要解决垂直飞行效率（VFE）、水平飞行效率和垂直飞行效率之间关系、终端空域和机场地面效率以及试图填补这项分析中确定的数据缺口等问题。

讨论和结论

5.2.2 会议对第 2 工作组进行全球水平飞行效率分析表示赞赏，并极有兴趣进行全球垂直飞行效率分析的后续工作，这将在议程项目 12 未来的工作项下进行审议。这有助于估计空中交通管理系统中所需的低效率百分比，以确保其绩效的最佳水平。事实上，一位观察员告知会议，提出的飞行计划可能不是最佳的飞行路线，并且在天气等某些运行情况下，实际飞行路线并不符合飞行计划。

5.2.3 第 2 工作组共同报告员回答一位成员提出的问题时指出，这项分析以一系列假设为基础，但没有提供不确定性的范围。

5.2.4 会议同意水平飞行效率分析的结果应与支持准确判读结果的背景要素在全球一级以及向国际民航组织地区办事处发布。

5.2.5 **建议**

5.2.5.1 鉴于前述讨论，会议拟定了以下建议：

建议 5/2 — 全球空中交通管理效率和无法弥补的交通增长对环境的影响

水平飞行效率（HFE）分析的结果和相关结论在国际民航组织网站的专门网页免费发布。

5.3 **第 2 工作组活动现况**

5.3.1 第 2 工作组共同报告员概述了该工作组在 CAEP/11 期间的活动。作为 CAEP/10 相互依存性的任务的后续工作，第 2 工作组改进了国际民航组织专门网站的用户友好性，分享了有关评估国际民航组织文件中相互关系信息的报告。第 2 工作组还更新了国际民航组织 Doc 9184 号文件 —*《机场规划手册》*，第 II 部分 —*《土地使用和环境管理》*，并利用收集的个案研究编制了该文件的新附录。对更新"航空和全球大气"（任务 O.10）提出了意见，并且第 2 工作组密切关注更新国际民航组织 Doc 9889 号文件 —*《机场空气质量手册》*的

后续行动。此外，对国际民航组织空中航行局的特别支持包括与第 1 工作组（噪声）和第 3 工作组（排放）协调评估可能适用的环境绩效指标。各项分析任务加上全球水平飞行效率分析和 ASBU B0 和 B1 的二氧化碳排放效益的综合分析再次成为第 2 工作组工作方案的重要组成部分。编制了有关基于性能的导航（PBN）、气候变化适应以及航空器报废和回收利用的环境社区参与的新报告。第 2 工作组还启动了关于减少航空器噪声的运行机会的新指导材料的工作，并提交了三期生态机场工具包电子文集。

讨论和结论

5.3.2 会议支持第 2 工作组开展的工作以及支持发布第 2 工作组提供的信息，因为第 2 工作组的作用是收集最佳做法和制定指导材料。会议着重指出，这项工作的主要受益者是通常不参加第 2 工作组会议的国家；不过，一位成员肯定了这项工作对包括他的国家在内的所有国家的重要性，因为获得全球最佳做法可以促成进一步改进环境管理政策。

5.3.3 审议了是否能够得到第 2 工作组相关文件的问题并请国际民航组织秘书处在国际民航组织网站提供文件之外的外联活动。

5.3.4 航空环境保护委员会秘书强调指出，根据国际民航组织“不让任何国家掉队”的倡议，第 2 工作组的工作具有全球影响力，也是提供国际民航组织所有成员国能力建设的重要工具。航空环境保护委员会秘书还提到生态机场工具包电子文集，这是收集和发布机场环境管理的最佳做法和指导材料的创新方式，指出这个文集得到很好的接受。

5.4 基于性能导航的环境社区参与

5.4.1 第 2 工作组编制了一份提交 CAEP/11 的报告，重点关注社区参与基于性能导航的实施和相关挑战的问题。该报告是根据对航空环境保护委员会成员和观察员的问卷收集而得的信息、文献的回顾和国际民航组织国家基于性能导航的实施计划的分析起草的。向 CAEP/11 会议提交了结论和发布文件的选项。

讨论和结论

5.4.2 一位成员认识到社区参与实施基于性能导航活动的重要组成部分，第 2 工作组在制定全球社区参与原则与量身定制社区参与实践以符合当地情况的必要性之间取得了平衡。该成员建议不参与全面散发任务 O.01 报告的战略，而是将其在国际民航组织网站上公布。一位成员强调指出，在这个问题方面缺乏专门性的能力建设活动可能会使某些国家无法对国际民航组织就这项工作散发的问卷作出答复。会议强调提高对列入航空环境保护委员会报告的信息的认识的好处。

5.4.3 一位成员认为该报告包含了非常有用的材料，但社区参与是一个快速发展的主题，应该有机会在国际民航组织网页上发布更多信息。其他成员对该报告和至今完成的工作表示欢迎，并建议将其发布，以便协助各国和培训机构。

5.4.4 建议

5.4.4.1 鉴于前述讨论，会议拟定了以下建议：

建议 5/3 —基于性能导航的环境社区参与

载于航空环境保护委员会报告中的信息应适于在国际民航组织公共网站传播和外联。

5.5 减少航空器噪声的运行机会

5.5.1 第 2 工作组开始制定新的指导材料，为国际民航组织成员国和国际航空利害攸关方提供关于减少机场和机场附近航空器噪声措施的实施情况的详细和具体信息。这包括减少噪声操作程序，它是航空器噪声平衡做法的支柱之一。这份指导文件预计将在 CAEP/12 期间编制完成。

讨论和结论

5.5.2 一位观察员强调指出，列入未来这份国际民航组织指导文件的每个运行程序必须是安全的，并且原则上应基于国际民航组织的标准或现行做法。有人指出，在这个任务范围内审查的减噪程序并非在于取代目前的标准化程序，而是首先从安全的角度提供一套有待审议的非规范性备选方案。提交给 CAEP/12 会议的指导文件将包括为此目的精心起草的案文。会议讨论了在完成任务之前举办讲习班的机会，以便收集可为指导文件提供信息的其他做法；或在通过未来的指导文件后举办讲习班，以便发布其内容。一位成员表示，鉴于第 2 工作组下一个周期的预期工作量，最好不举办此类讲习班。航空环境保护委员会秘书认为，可以确定与国际民航组织其他活动产生的协同作用，以便以符合成本效益的方式为该任务提供最佳信息。

5.6 气候适应综述

5.6.1 第 2 工作组提出了气候适应综述，它源自于 CAEP/10 对国际民航组织 Doc 9184 号文件 —《机场规划手册》第 II 部分的更新。通过文献审查和在航空环境保护委员会备忘录的封面下和在国家级信件下分发的调查问卷收集了更多信息。在整个过程中，确保了与影响和科学小组（ISG）进行了协调。因此，汇总报告包括有关航空部门各种预期的气候影响的信息以及国际航空利害攸关方关于它们如何影响其运作、其准备程度和期望的看法。

讨论和结论

5.6.2　会议赞扬了第 2 工作组进行的气候适应综述，鼓励传播其中所载的信息并要求考虑定期进行更新。

5.6.3　若干成员鼓励发布载于气候适应综述内的信息以及设法定期更新这项工作。若干成员和观察员强调这项工作对小岛屿发展中国家（SIDS）和群岛国家的重要性，因为这些国家特别容易受到气候变化的影响。一位成员鉴于第 2 工作组工作的广泛范围和效益，承诺对第 2 工作组的工作给予持续支持。

5.6.4　一位观察员支持这项任务和未来的工作提案，同意将对其成员进行关于气候变化的复原能力和适应能力的调查，其中将纳入环境保护之外的其他各个方面。该观察员打算向委员会通报进展情况。

5.6.5　航空环境保护委员会秘书提供了国际民航组织在灾害风险和气候适应领域开展的工作的背景信息，并向会议通报这项工作具有两个方面，即具有灾后复原部分和具有气候变化风险评估和气候复原能力部分。她指出，在机场的设计阶段已开始结合气候变化的适应能力和复原能力，例如土耳其伊斯坦布尔的新机场。会议表示支持有关气候变化风险评估的持续活动。

5.6.6　**建议**

5.6.6.1　鉴于前述讨论，会议拟定了以下建议：

建议 5/4 — 气候适应综述

载于航空环境保护委员会报告中的信息应适于传播和外联以及可进行生态机场电子文集的发布。

5.7　**生态机场工具包电子文集**

5.7.1　第 2 工作组开发了一系列实用且易于使用的电子出版物，旨在支持机场环境管理措施的实施。2018 年航空环境保护委员会指导小组会议分别批准了三份出版物，分别是机场可再生能源、废物管理和机场环境管理系统，这些出版物都在国际民航组织网站免费提供。

5.7.2　第 2 工作组向航空环境保护委员会介绍了生态设计机场建筑物的最新问题，以及将在 CAEP/12 周期推进的一系列专题建议。

讨论和结论

5.7.3　会议对这项任务表示支持。会议认识到收集在生态机场工具包电子文集内的各个主题的重要性以及能主动向国际航空界提供实用和易用的信息的能力。一位观察员询问是否存在供参与机场设计的工程师使用的环境指导材料。国际民航组织 Doc 9184 号文件《*机场规划手册*》，第 2 部分 —《*土地使用和环境管理*》被认定是这方面最相关的文件。

5.7.4 会议指出，生态机场工具包电子文集旨在提供关于技术主题的一般信息，并为便于参考，为每份电子出版物提供了可用的资源清单。会议还强调了出版案例研究的必要性，因为它们补充了列于生态机场工具包电子文集的信息，并且通过实际例子说明这些信息，其他机场可从中汲取灵感。

5.7.5 **建议**

5.7.5.1 鉴于前述讨论，会议拟定了以下建议：

建议 5/5 — 生态机场工具包电子文集

关于机场建筑物生态设计的生态机场工具包电子文集在国际民航组织网站的生态机场工具包专门网页免费发布。

5.8 **航空器报废和回收**

5.8.1 第 2 工作组提交了关于航空器报废和回收的现状报告，其中概述了与航空器报废程序的环境管理有关的相关国际政策和业界指导材料。认识到第 2 工作组所做的优质工作，有人指出，鉴于航空环境保护委员会缺乏所需的专门知识，对任务范围已作出调整。

讨论和结论

5.8.2 会议对报告所列信息表示欢迎，并承认根据有关主题的可用专业知识，现况报告是第 2 工作组能够提供的最全面信息。第 2 工作组共同报告员指出，2018 年指导小组会议认为，国际民航组织可以通过建立一个涵盖飞机报废和回收的法律、安全、适航和环境各方面问题的多学科小组来开展更多工作。

5.8.3 第 2 工作组共同报告员提请会议注意，在提交 CAEP/11-WP/35 号文件后，已经发布了报告中审查的一份出版物。会议同意在现况报告中列出该出版物的链接。

5.8.4 **建议**

5.8.4.1 鉴于前述讨论，会议拟定了以下建议：

建议 5/6 — 航空器的报废和回收

列入航空环境保护委员会报告的信息专门用于沟通和外联活动，并应在国际民航组织网站的专门网页免费发布。

5.9 **第 2 工作组未来的工作**

5.9.1 若干成员和观察员表示了他们对第 2 工作组工作方案的看法。强调了 CAEP/11 工作方案的一些关键交付成果，并要求提供任务 O.01、任务 O.07 和任务 O.09 的交付成果，因为这些成果有利于航空界为加强机场的国际运行的环境可持续性正在作出的努力。此外，他们确定了 CAEP/12 周期的关键工作领域，包括继续进行全球飞行效率的工作、评估与更新全球空中航行计划（GANP）相关的新材料以及推动有关超音速运输的“社区接受”概念的工作。

5.9.2 大家对在 CAEP/12 周期制定与超音速航空器有关的运行问题的机会发表了不同意见。

5.9.3 一名成员支持国际民航组织设立一个多学科小组以推进航空器报废和回收专题的倡议，因为从全球机队退役的航空器数量将不断增加。

5.9.4 会议同意提供任务 O.01、任务 O.07 和任务 O.09 的成果的请求，并将未来工作的进一步行动推迟到议程项目 12。

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议程项目 6：国际航空碳抵消和减排计划 — 监测、报告和核查（MRV）
议程项目 7：国际航空碳抵消和减排计划 — 排放单位
议程项目 8：国际航空碳抵消和减排计划 — 登记册

6.1.1 全球基于市场措施技术工作队（GMTF）共同报告员介绍了在航空环境保护委员会第十一次会议周期内开展的工作。全球基于市场措施技术工作队（GMTF）共同报告员概述了工作队的结构、领导和组成成员以及在 CAEP/11 周期举行的 7 次会议的日期。全球基于市场措施技术工作队（GMTF）共同报告员指出，根据国际民航组织大会第 39 届会议的要求，全球基于市场措施技术工作队的重点工作是起草国际航空碳抵消和减排计划的一揽子计划，其中包括附件 16 第 IV 卷（即与国际航空碳抵消和减排计划有关的标准和建议措施）草案、《环境技术手册》（Doc 9501 号文件）第 IV 卷和国际航空碳抵消和减排计划实施要素。通过优先推动这项工作，全球基于市场措施技术工作队及时交付了国际航空碳抵消和减排计划的一揽子计划，供航空环境保护委员会指导小组 2017 年会议审议，这使国际民航组织理事会第 214 届会议（2018 年 6 月）能够通过附件 16 第 IV 卷。会议还被告知全球基于市场措施技术工作队还取得以下成果：2018 年版国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具及相关技术方法；国际航空碳抵消和减排计划中央登记处（CCR）的职能要求；它们都得到国际民航组织理事会第 214 届会议的批准。除此之外，全球基于市场措施技术工作队共同报告员还介绍了在 CAEP/11 周期列入全球基于市场措施技术工作队工作方案的 23 项任务项下的工作所取得的成果，指出全球基于市场措施技术工作队顺利地完成了它的任务并确定了未来将在 CAEP/12 周期进行的工作。

6.1.2 全球基于市场措施技术工作队的排放单位标准任务组（GMTF-EUC）介绍了全球基于市场措施技术工作队就排放单位的供应、需求和价格进行的工作。考虑到文献审查的结果和其他各种报告，这项工作是对 2016 年初步分析结果的更新，表明供应、需求和价格之间的关系以及它们如何因应各种外来因素。共有 31 份报告为这项分析提供了信息。考虑到各种经济、政治和技术因素，详细的定量分析不在此时提供。利用历史数据取得的经验以及未来的估算和预测，分析结果表明，只要边界条件设置得当，市场就能应对航空公司行业抵消需求的增长，也不会实质制约供应。它认为，提交给 CAEP/10 的结果即“市场将能够对国际航空全球基于市场措施的未来需求的明确信号作出反应”仍然有效。或许必须依照航空环境保护委员会的具体要求进行更多工作。

6.1.3 在一位成员要求作出澄清的情况下，全球基于市场措施技术工作队排放单位标准任务组（GMTF-EUC）共同负责人确认，在分析范围内纳入或排除产生排放单位的任何类型方案或活动都将对市场可用的排放单位的供应水平及其价格的分析结果产生影响。

6.1.4 全球基于市场措施技术工作队的方案检测组（GMTF-PTG）介绍了方案检测组在 CAEP/11 周期进行的工作。方案检测组是航空环境保护委员会根据国际民航组织理事会第 211 届会议（2017 年 6 月 5 日至 23 日）的要求成立的，以进一步推进适用排放单位标准（EUC）的工作，包括根据该标准对某些方案进行非正式测试。方案检测组向会议提交了完整报告及其执行摘要，它由航空环境保护委员会接受并与理事会第 215 届会议（2018 年 10 月 29 日至 11 月 16 日）分享。方案检测组向会议介绍了它得出的主要结论和提出的建议，并对方案检测组适用的航空环境保护委员会的建议程序和指导方针作出说明。

6.1.5 有一位成员要求对特定类型活动是否适用国际航空碳抵消和减排计划作出说明，方案检测组提醒会议，它的工作主要是测试排放单位标准的适用性，而不是参与非正式测试的排放单位计划的资格。根据观察员关于适用某些标准（即重复计算和额外性）具有细微差别的评论，方案检测组提醒会议，全球基于市场措施技术工作队方案检测组（GMTF-PTG）的报告反映了该小组根据它在非正式测试期间的经验对这些问题提出的建议。

6.1.6 全球基于市场措施技术工作队国际航空碳抵消和减排计划二氧化碳估算和报告工具组（GMTF-CCG）共同负责人对 2018 年版国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具的编制情况和编制该工具 2019 年版的计划活动提出报告。他在发言时指出，国际民航组织理事会第 214 届会议（2018 年 6 月 11 日至 29 日）核准了 2018 年版国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具以及二氧化碳估算和报告工具的技术方法。关于二氧化碳估算模型（CEM），会议获知可以通过国际民航组织国际航空碳抵消和减排计划网站得到二氧化碳估算模型。会议获悉，GMTF-CCG 已开始开发更为详细的 2019 版国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具（ICAO CORSIA CERT）架构，并且为了满足该工具不断增长的需求，2019 年版本增加的功能包括：根据大圆距离改善二氧化碳估算模型和根据轮档时间投入开发新的二氧化碳估算模型。会议获悉 GMTF-CCG 期望在 CAEP/12 周期通过全部转移到航空环境保护委员会下新的 CORSIA 工作组继续工作，并将建立一个机制每年定期向航空环境保护委员会成员及时提交 ICAO CORSIA CERT 及其基本功能供理事会审议。

6.1.7 一位成员要求说明飞机运营人安全使用 ICAO CORSIA CERT 的情况，会议获悉 2018 年版 ICAO CORSIA CERT 可从 ICAO CORSIA 网站下载，下载这个工具的运营人可用他们下载这个工具的硬件特性所决定的安全级别使用这个工具。

6.1.8 向会议提供了关于 CORSIA 预计成本和二氧化碳减排估算的补充 GMTF 分析的最新情况（根据大会决议 A39-3），包括评估实施 CORSIA 监控、报告和核实（MRV）系统和登记册的潜在成本。状态更新源于 根据更新的假设和全球基于市场措施技术工作队最近关于已经宣布它们决定自愿从一开始就自愿参加国际航空碳抵消和减排计划的国家的建议对现况作出的更新估计了合格使用简化程序的运营人的核查成本和更新基于最近发布的 2017 年收入吨公里数（RTK）进行的敏感性分析。根据国际航空碳抵消和减排计划预计对飞机运营人、国家和国际民航组织二氧化碳减排和成本的估算，这项分析包括以下观察结果：估计 2021 年到 2035 年的总抵消量约为 25 亿吨二氧化碳；国际航空碳抵消和减排计划的总费用绝大部分来自抵消要求（即 98％）的费用，这些费用仅占总运营费用或国际航空收入的一小部分；建立监测、报告和核实系统和登记册的费用由飞机运营人、成员国和国际民航组织承担，分别占国际航空碳抵消和减排计划总费用的 1.4%、0.5%和 0.02%；对抵消要求费用与建立监测、报告和核实系统和登记册费用的比较显示各个国家的成本分布不均匀。会议获悉，如果航空环境保护委员会成员提出要求，这项分析可在 CAEP/12 周期加以更新。

6.1.9 会议对这份分析表示欢迎，一位观察员强调发布这份分析的好处。对确认全球基于市场措施技术工作队进行的分析作为 CAEP/10 二氧化碳排放趋势的参考，并且未来的更新可考虑 CAEP/11 二氧化碳的排放趋势。会议获悉，可以对这份分析作出更新，以便提供国际航空碳抵消和减排计划的实施将对飞机运营人的总收

入产生何种程度的影响以及对每个航班和每位乘客产生何种费用的信息。会议还收到对小型运营人与中型及大型运营人之间区别的分析的说明，这种区别是根据适用的阈值（按年度二氧化碳排放量）进行的，以确定运营人是否可以按附件 16 第 IV 卷使用 ICAO CORSIA CERT 估算其二氧化碳排放量。在一位成员要求作出说明后，会议获悉，根据运营人或国家之间的差异，飞机运营人和国家分担实施国际航空碳抵消和减排计划的总费用的百分比一直存在某种程度的可变性。

6.1.10 全球基于市场措施技术工作队（GMTF）共同报告员介绍了全球基于市场措施技术工作队登记册任务组在以下两个具体领域的工作成果：国际民航组织和各国公布以及通过符合条件的排放单位登记册提供信息和数据；界定登记册的各项规定以促进标准和建议措施的适用。关于公布信息的问题，全球基于市场措施技术工作队共同报告员概述了有关国际民航组织发布附件 16 第 IV 卷第 II 部分第 1 章注 2 所列文件以及各国根据附件 16 第 IV 卷第 II 部分第 4 章 4.3.3 段的建议取消排放单位的各项主要建议。这些建议既适用于公共信息应如何提出，也适用于文件发布的时间，因为附件 16 第 IV 卷没有载明具体的截止日期。关于建立计划登记册的要求，全球基于市场措施技术工作队共同报告员详细阐述了可能需要的计划登记册的要求，这些要求是对载于排放单位标准和指导意见中的要求的增添或补充，专家建议在必要时应确保计划登记册使飞机运营人能实施国际航空碳抵消和减排计划中的相关规定。全球基于市场措施技术工作队共同报告员还向航空环境保护委员会通报了关于继续讨论该主题的建议，以便确定和评估实施这些要求的可能方法，同时考虑到迄今为止取得的工作成果。

6.1.11 考虑到排放单位方案及其登记册的特征可能大不相同，一位成员提出了为计划登记册确定共同规则的合理性。

6.1.12 会议认识到需要在 CAEP/12 周期进一步开展工作，以确定和建议适用计划登记册的各项规定的方法，并且必须为在 CAEP/12 周期进行这项任务的工作安排展开讨论，因为它与国际航空碳抵消和减排计划的其他工作领域有联系。

6.1.13 全球基于市场措施技术工作队概述了国际航空碳抵消和减排计划标准和建议措施起草小组（SDG）就国际航空碳抵消和减排计划一揽子方案持续开展的工作。全球基于市场措施技术工作队（GMTF）共同报告员介绍了全球基于市场措施技术工作队和代用燃料任务组（AFTF）确定了认为有利于国际航空碳抵消和减排计划实施的其他指导意见后对《*环境技术手册*》第 IV 卷的拟议修订案文。这包括飞机运营人取消国际航空碳抵消和减排计划合格排放单位的进程和相关核查活动的指导意见。全球基于市场措施技术工作队共同报告员还详细说明了对《*环境技术手册*》第 IV 卷作出修订了理由。

6.1.14 两位成员强调指出，《*环境技术手册*》第 IV 卷包含的材料是对附件 16 第 IV 卷所载的标准的指导意见。一位成员赞赏全球基于市场措施技术工作队就此事项开展的工作，建议对《*环境技术手册*》第 IV 卷的拟议修订作出修正（将太平洋认证合作（PAC）重新命名为亚太认证合作（APAC））。

6.1.15 全球基于市场措施技术工作队（GMTF）共同报告员介绍了它在 CAEP/12 周期为航空环境保护委员会就国际航空碳抵消和减排计划拟议进行的六项任务：维护附件 16 第 IV 卷和相关指导材料；制定 2019 年版本及以后版本的 ICAO CORSIA CO2 估算和报告工具（CERT）；制定有关国际航空碳抵消和减排计划的监测、报告和核查（MRV）的进一步指导意见；为国际航空碳抵消和减排计划的实施进一步评估排放单位的供应、需求和价格；制定关于管理排放单位标准（EUC）的技术方法的建议；确定适用计划登记册各项规定的方法以促进标准和建议措施的应用。对每项拟议任务，全球基于市场措施技术工作队详细说明了其主要特点，其中包括：理由和效益；时间期限；执行任务的方法；交付成果。

6.1.16 在一位成员要求作出说明的情况下，全球基于市场措施技术工作队共同报告员解释指出，类似全球基于市场措施技术工作队在 CAEP/11 周期进行的工作，已经拟议进行维护附件 16 第 IV 卷和相关指导材料的工作，并且还将为国际航空碳抵消和减排计划制定监测、报告和核查的进一步指导意见的任务，其交付成果可包括修订附件 16 第 IV 卷和相关的《*环境技术手册*》第 IV 卷的提案。

6.1.17 一些成员和观察员表示了他们对国际航空碳抵消和减排计划的工作的看法。他们赞赏在 CAEP/11 周期取得的成果，重申需要推进全球基于市场措施技术工作队共同报告员提出的关于国际航空碳抵消和减排计划的一揽子方案的工作。在这方面，他们支持设立一个关于国际航空碳抵消和减排计划问题的特设工作组。他们还指出应避免重复计算排放单位，要求对计划登记册采用强制性规定，表明需要根据证据对排放单位进行资格审查，并拟定飞机运营人不遵守国际航空碳抵消和减排计划的后果的工作。

6.1.18 一些成员和观察员提出了他们的看法，要求对一些成员和观察员提出的关于国际航空碳抵消和减排计划的未来工作的一些看法作出说明。关于对排放单位和基础计划以及可能的项目进行基于证据的资格审查的提案，两位成员对这项提案表示保留，因为提案内容不明确，并且这项工作有可能在国际航空碳抵消和减排计划定期审查的背景下进行。关于飞机运营人不遵守国际航空碳抵消和减排计划的后果的拟议工作，航空环境保护委员会秘书指出，大会第 A39-3 号决议第 20 段 j)要求成员国采取必要行动，确保为遵守和执行该计划建立必要的国家政策和监管框架；一些成员和一位观察员表示，国际民航组织不应对各国及其运营人制定有关违规问题的规则。关于设立一个小组来确定实际和未来潜在重复计算的表现方式并制定防止这种现象的机制，一些成员和一位观察员不支持建立这样的一个小组，因为重复计算这一事实已被纳入排放单位标准，并将由技术咨询机构（TAB）进行审议。一些成员表示他们倾向于将此视为未来工作中管理排放单位标准这项任务的一部分，并且国际民航组织将继续监测并考虑到正在进行的关于气候公约进程下有关重复计算的讨论。

6.1.19 一位成员提出他对全球基于市场措施技术工作队和国际航空碳抵消和减排计划的看法，表示支持在《*环境技术手册*》中提供更多指导意见，特别是关于排放单位取消报告（EUCR）的指导意见。该成员指出，只有在对符合国际航空碳抵消和减排计划资格的排放单位计划作出决定后进行关于合格排放单位的供应和价格的进一步工作才会有效。该成员支持继续开展管理排放单位标准以及二氧化碳排放核算和报告工具（CERT）的工作。该成员支持全球基于市场措施技术工作队关于发布与国际航空碳抵消和减排计划相关数据的建议，指出系统透明度的重要性。此外，该成员还支持全球基于市场措施技术工作队共同报告员在介绍其关于登记册的工作时所述的对项目登记册要求采用“证明”方法。该成员建议成立一个常设工作组，以便在 CAEP/12 周期对国际航空碳抵消和减排计划继续开展工作。该成员还支持航空环境保护委员会的工作，以支持国际民航组织理事会由这个新设的工作组进行的 2022 年国际航空碳抵消和减排计划的定期审查。

6.1.20　一位观察员就航空环境保护委员会就国际航空碳抵消和减排计划（CORSIA）的监测、审查和核查（MRV）相关的工作提出了他的看法。该观察员支持将全球基于市场措施技术工作队制定的更多指导意见，包括对核查制定的更多指导意见，纳入《环境技术手册》第 IV 卷的修订版。该观察员还支持根据实施国际航空碳抵消和减排计划的经验审查未来国际航空碳抵消和减排计划的监测、报告和核查要求，并在未来的工作方案中包含一个维护国际航空碳抵消和减排计划的一揽子计划的项目。该观察员支持 CORSIA CERT 小组（CCG）进行的工作，着重指出它的组成成员承诺继续为 ICAO CORSIA CERT 的发展做出贡献，重申它的组成成员认为应允许飞机运营人、当局和核查人员为促进遵守国际航空碳抵消和减排计划的规定在其信息技术系统中实施二氧化碳估算模型（CEMs）。该观察员还支持考虑分享国际航空碳抵消和减排计划预期成本和二氧化碳减排的最新分析的方法，重申航空环境保护委员会指导小组 2017 年会议提出的要求。

6.1.21　该观察员对一些国家对附件 16 第 IV 卷的监测、报告和核查规定提出差异表示关切。另一位观察员解释指出，他的国家已经提出了差异，其中包括国家要求其运营人按每次航班报告二氧化碳排放量。表达了这个关切的这位观察员指出，这种差异不是他关切的根源，而是可能影响运营人计算每年二氧化碳排放量的方式的差异，从而影响到运营人的抵消要求。

6.1.22　一位观察员就航空环境保护委员会关于合格排放单位的工作提出了他的看法。该观察员指出，目前的供应、需求和价格预测没有考虑到其他部门和国家新的潜在需求，因此，这种分析应该注意到如果将其纳入 CAEP/11 报告或提交给理事会的局限性。观察员强调，应通过批准排放单位标准、计划和项目类型的方式，尽快为抵消项目投资者和合规实体提供确定性。一位观察员认为，关于标准和合格单位的决定不应限制排放单位的供应，而应保证其环境完整性。该观察员支持通过排放单位取消报告以及制定了避免重复计算的措施方案的标准有关目前重复计算的方法。该观察员指出，联合国气候变化框架公约进程是确保排放单位不被重复计算的关键部分。此外，该观察员欢迎全球基于市场措施技术工作队就管理排放单位标准所做的工作，强调需要市场确定性和购买者信心。

讨论和结论

6.1.23　会议注意到全球基于市场措施技术工作队就其在 CAEP/11 周期进行的工作提供的信息。

6.1.24　会议同意对《环境技术手册》第 IV 卷提出的更新，要求尽快在国际民航组织网站公布修订后的文件。

6.1.25　会议同意在这些议程项目的报告附录 A 中所述有关国际民航组织公布关于国际民航组织国际航空碳抵消和减排计划实施要素的信息的建议。会议要求将这些建议编入一份载有航空环境保护委员会向秘书处提出的建议的文件中，供航空环境保护委员会和秘书处便于参考。

6.1.26 会议同意按这些议程项目的报告附录 B 的规定为促进适用标准和建议措施而建议的计划登记册相关要求，并同意为了需要解决治理问题，以便确定和建议适用这些要求的方法，在 CAEP/12 周期需要开展进一步工作。

6.1.27 会议同意，除了已在国际民航组织国际航空碳抵消和减排计划网站公开提供的材料以外，秘书处认为最好的方法是列入全球基于市场措施技术工作队对国际航空碳抵消和减排计划得到的预期成本和二氧化碳减排的最新分析。

6.1.28 会议认识到全球基于市场措施技术工作队对供应、需求和价格的最新分析的局限性，同意如全球基于市场措施技术工作队指出的情况，考虑到需要为完善分析开展进一步工作的情况下，在航空环境保护委员会之外分享此项分析结果时，需要谨慎进行。

6.1.29 会议同意，全球基于市场措施技术工作队已经圆满完成它在 CAEP/11 周期的工作方案并完成交付成果，注意到航空环境保护委员会成员和观察员广泛支持全球基于市场措施技术工作队取得的成果。

6.1.30 会议注意到全球基于市场措施技术工作队提出的未来工作提案，同意将这些提案在会议议程项目 12 未来的工作项下作为进行讨论的基础，注意到航空环境保护委员会一些成员和观察员支持全球基于市场措施技术工作队的提案以及赞成成立关于国际航空碳抵消和减排计划问题工作组的看法，在 CAEP/12 周期开展有关国际航空碳抵消和减排计划的工作，以便将各个具体方面的工作，例如有关国际民航组织的国际航空碳抵消和减排计划二氧化碳估算和报告工具（CERT）的工作或与排放单位标准和排放单位资格相关的各个具体方面整合到新的关于国际航空碳抵消和减排计划问题工作组以及 CAEP/12 周期航空环境保护委员会工作的更广泛背景。

6.1.31 会议认识到理事会批准排放单位标准的重要性，强调应尽快开始审查和批准排放单位方案和项目类型。

6.1.32 向会议提交了技术咨询机构（TAB）的议事规则草案。会议同意该规则案文，但最后一节除外，内容如下：

> [12. **技术咨询机构建议的传播**
>
> 12.1 *根据技术咨询机构的建议，理事会关于符合条件的排放单位方案（和潜在项目类型）清单的决定将在国际民航组织国际航空碳抵消和减排计划网站公布。*]

6.1.33 虽然认识到国际民航组织理事会以前的决定已经规定当国际航空碳抵消和减排计划实施要素包括其符合条件的排放单位一旦得到理事会的批准，就需要在国际民航组织国际航空碳抵消和减排计划网站公布，会议再次强调，需要确保这项进程的透明度，包括是否应公布技术咨询机构的建议的问题，因此，要求在提交航空环境保护委员会关于技术咨询机构议事规则的建议时，应将这方面的问题提请国际民航组织理事会注意。尽管如此，会议同意删除上文第 6.1.32 段的案文，因为它提到的行动不属于技术咨询机构的职权范围，因此，它不应成为技术咨询机构议事规则的一部分。

6.1.34　观察员表示，技术咨询机构一旦设立，就需要有一段说明公共信息时期的具体期限。一位成员强调技术咨询机构应确定它完成任务的详细工作方案和时限。一位成员指出，技术咨询机构的议事规则不应过于严格，而应根据计划测试组（PTG）的建议，对技术咨询机构能够进行审议模式的详细程序提供总体指导。如技术咨询机构议事规则第 8.7 段所述，关于技术咨询机构作出决定的进程，一位成员认为，在技术咨询机构的建议未能达成共识的情况下，投票比率的结果应包括在技术咨询机构为支持该项建议所提出的信息中。

6.1.35　会议同意载于这些议程项目的报告附录 C 的 B 部分的技术咨询机构（TAB）议事规则，并将其提交理事会审议。

6.1.36　会议认识到国际民航组织排放工具的重要性并支持其一致性的目标，例如国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具（CERT）以及国际民航组织碳排放计算器。

6.1.37　还有一个问题是作为公共工具使用的国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具是否可用于国际航空碳抵消和减排计划之外的目的。

6.1.38　会议认识到，在 CAEP/11 会议之后必须开展进一步工作，以便调查使用国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具和用于国际民航组织二氧化碳排放计算器的二氧化碳估算模型（CEM）的可行性。这将包括确保国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具符合用途，并且以这种方式使用国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具得到适当的使用协议的支持，以支持非国际航空碳抵消和减排计划的使用，这可能意味着修改现有协议。评估可由国际航空碳抵消和减排计划二氧化碳估算和报告工具小组（CCG）进行，秘书处将与提供数据的国家和组织一起更新使用协议，以便在 2019 年 5 月底之前找到合适的解决方案。

6.1.39　会议同意国际航空碳抵消和减排计划二氧化碳估算和报告工具小组（CCG）考虑非国际民航组织使用国际民航组织国际航空碳抵消和减排计划二氧化碳估算和报告工具的问题，并及时提出相关建议。

6.1.40　**建议**

6.1.40.1　鉴于前述讨论，会议拟定了以下建议：

建议 8/1 — 对《环境技术手册》第 IV 卷的修订

依照全球基于市场措施技术工作队的报告修订和公布《环境技术手册》第 IV 卷。

建议 8/2 — 技术咨询机构（TAB）的议事规则

提交技术咨询小组（TAB）议事规则供理事会第 216 届会议审议。

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APPENDIX A
(English only)

RECOMMENDATIONS ON OPERATIONALIZATION OF THE PUBLICATION OF DATA BY ICAO

1.1 The recommendations in this section apply to ICAO, and are relevant to the documents listed in Note 2 of Part II, Chapter 1 of Annex 16, Volume IV. The Registries Task Group acknowledges the standard practice of the ICAO Secretariat is that the documents listed in Table 1 should follow the harmonized format rules and be presented in a downloadable .pdf.

1.2 Table 1 presents a list of documents referred to in paragraph 1.1, including information on SARPs data submission and publication deadlines, as well as any additional relevant information. Specific recommendations for the documents in Table 1 are:

1.2.1 Table 1, Document 2 '*ICAO CORSIA* CO_2 *Estimation and Reporting Tool*' should be published as soon as practicable for each year of CORSIA.

1.2.2 Table 1, Document 8 '*CORSIA Eligible Emissions Units*' should present information in a format which shows the eligibility parameters of eligible units.

1.2.3 Table 1, Document 14, part containing '*List of verification bodies accredited in each State*', should be published as soon as practicable, but no later than 31 May 2019. Further updates to this list should be published as soon as practicable on an ongoing basis, subject to the provision of updated information from States as per Annex 16, Volume IV, Part II, Chapter 1, 1.3.7.

1.2.4 Table 1, Document 14, part containing '*Total average* CO_2 *emissions for 2019 and 2020 aggregated for all Aeroplane Operators on each State pair route*', should be published as soon as practicable, but no later than 30 November 2021.

1.2.5 Table 1, Document 14, part containing '*CCR State reported emissions*', should be published in accordance with Note 2, of Table A5-8, in Appendix 5 of Annex 16, Volume IV, as soon as practicable, but no later than 31 October 2022 (for 2021 emissions). The same day and month should apply to subsequent years.

1.2.6 Table 1, Document 14, part containing '*CCR State reported emissions unit cancellations*', should be published in accordance with Note 2, of Table A5-8, in Appendix 5 of Annex 16, Volume IV, as soon as practicable, but for the Pilot Phase no later than 31 October 2025. The same day and month should apply to subsequent compliance periods.

1.3 ICAO public information relating to identification of States, aeroplane operators, verification bodies, or other entities will be as notified to ICAO by the States. This is to ensure a high level of consistency of data published by ICAO and States.

1.4 Public information should be available free of charge. The web pages containing this information should be available to the general public, with no credentials required, and with no prior authorization necessary to access them.

1.5 When there is an update to the information, a change log should be published alongside the new version of the document. The change log should include the modifications occurring since the previous version, as well as the date when the modifications occurred. For data for which this is relevant, the change log should include the beginning of the validity of the modifications. Previous versions of the implementation elements may be required for various purposes and should be archived (but downloadable) for State and public use. The exception is where there are two (or more) versions of the same document could be simultaneously valid and should remain clearly visible and available for download. In this case, it should be clearly specified under which circumstances each version is applicable.

1.6 Where a State or ICAO identifies a discrepancy of data already published, it is recommended that ICAO and States coordinate in order to publish the correction with a minimum of delay between each other, to reduce the time interval when the data is discrepant between the two web pages. To ensure transparency, previous versions (editions) of documents which have been modified should be retained and made available on the web page, while making clear they have been subsequently updated.

1.7 The CORSIA public web pages should have contact information for further enquiries by the general public. It is recommended that there is a dedicated online form or electronic mailbox for CORSIA enquiries.

1.8 In addition to any web-based presentation / summary information, and any presentation of information in a downloadable document, where large quantities of information are to be published, the recommendation is for the information to be published in a machine-readable, downloadable format, e.g. xlsx.

1.9 Where large quantities of information are to be presented by ICAO on a publicly accessible website, it is recommended that all such available information can be searched on the website by each relevant data field, subject to the availability of financial resources.

Table 1: Documents referenced in Note 2 of Part II, Chapter 1 of Annex 16, Volume IV

#	Information	Data availability date	SARPs Publication Deadline	Update frequency
1	**CORSIA States for Chapter 3 State Pairs**	30.06.2020	01.08.2020	Annually
Note: This ICAO document will only show participating States from 2021 for the purpose of determining Chapter 3 State pairs and not the State pairs themselves.				
2	**ICAO CORSIA CO_2 Estimation and Reporting Tool**	31.07.2018	See 1.2.1	Annually
Note: Approved recommendations relating to this document are as per GMTF/11-WP/03 pages D-5 and D-16 and CAEPSG.20172.ICAO CORSIA Package, Draft Supporting Information and Supporting Documents, pages 8 and p29.				
3	**CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes**	Following approval by the ICAO Council	Following approval by the ICAO Council	Ongoing
Note: This document was approved at SG2018 (ref WP11 https://portal.icao.int/CAEP/2018%20Singapore%20Meeting/CAEPSG.20183.WP.011.4.en.pdf).				
4	**CORSIA Approved Sustainability Certification Schemes**	Following approval by the ICAO Council	Following approval by the ICAO Council	Ongoing
Note: The format for this table was approved at SG2018 (ref WP11 https://portal.icao.int/CAEP/2018%20Singapore%20Meeting/CAEPSG.20183.WP.011.4.en.pdf). It is a single table with three columns.				
5	**CORSIA Sustainability Criteria for CORSIA Eligible Fuels**	Following approval by the ICAO Council	Following approval by the ICAO Council	Ongoing
Note: The criteria will be presented in a table format and followed / accompanied by Guidance.				
6	**CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels**	Following approval by the ICAO Council	Following approval by the ICAO Council	Ongoing
Note: There is no official expiry date for the values, but they are subject to the regular review process of the Annex. In case of changes, it is not clear if it will affect previously certified fuels; therefore, this would need further discussion and agreement within the CAEP/AFTF. In any case, this should not have an impact on the fact that the values are published together with the validity date.				
7	**CORSIA Methodology for Calculating Actual Life Cycle Emissions Values**	Following approval by the ICAO Council	Following approval by the ICAO Council	Ongoing
8	**CORSIA Eligible Emissions Units**	Following approval by the ICAO Council	Following approval by the ICAO Council	Ongoing
Recommendation: The information should be presented in a format which shows the eligibility parameters of eligible units.				
9	**CORSIA Emissions Units Eligibility Criteria**	Following approval by the ICAO Council	Following approval by the ICAO Council	Ongoing
10	**CORSIA Central Registry (CCR):**	See rows 11 - 13		

	Information and Data for the Implementation of CORSIA			
11	**CORSIA Aeroplane Operator to States Attributions**	30.11.2018	31.12.2018	Annually
12	**CORSIA 2020 Emissions**	31.08.2021	Following approval by the ICAO Council	Once
Note: This will be just one number.				
13	**CORSIA Annual Sector's Growth Factor (SGF)**	31.07.2022	31.10.2022	Annually
Note: This will be a list showing a numerical value for each year.				
14	**CORSIA Central Registry (CCR): Information and Data for Transparency**	See rows 14.1 – 14.4		
14.1	List of verification bodies accredited in each State	30.04.2019	See 1.2.3	Ongoing
14.2	Total average CO_2 emissions for 2019 and 2020 aggregated for all Aeroplane Operators on each State pair route	30.09.2021	See 1.2.4	Once
14.3	CCR State reported emissions	31.07.2022	See 1.2.5	Annually
Recommendation: Publish in accordance with Note 2, of Table A5-8, in Appendix 5 of Annex 16, Volume IV.				
14.4	CCR State reported emissions unit cancellations	31.07.2025	See 1.2.6	Once per period
Recommendation: Publish in accordance with Note 2, of Table A5-8, in Appendix 5 of Annex 16, Volume IV.				

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APPENDIX B
(English only)

PROPOSED PROGRAM REGISTRY-RELATED CONSIDERATIONS AND REQUIREMENTS

1.1. The following proposed registry-related considerations and requirements follow from the contents of the proposed draft Emissions Unit Program Registry Attestation (Section 4).

1.1.1. *Recommended definition of Emissions Unit Program Registry*: An Emissions Unit Program Registry is a registry that the program designates to provide its registry services; and is described in the information that the program submits to ICAO.

1.1.2. *Recommended definition of the emissions unit program – registry relationship*: The application of the EUC to determine program eligibility includes an assessment of the program's provisions and procedures governing the program registry, as represented by the program in the information that the program submits to ICAO. ICAO does not separately or independently evaluate the program registry. The program registry's provision of registry services relevant to the CORSIA shall be subject to the terms and conditions of the program's eligibility. Such terms include, *inter alia*, the program's commitment to administer any and all provisions and procedures governing the program registry in the manner represented by the program in the information that the program submits to ICAO.

1.1.3. *Recommendation on timing of applicability of registry requirements*: The program registry can provide registry services to Aeroplane Operators prior to the program's and program registry's demonstration of the registry's consistency with these registry requirements. However, the program registry can only claim to support and can only provide for Airplane Operators to fulfill CORSIA SARPs involving emissions unit cancellation-, reporting-, and verification-related actions after its consistency with these requirements is demonstrated, and published on the CORSIA website along with the list of CORSIA Eligible Emissions Units.

1.1.4. *Recommendation on registry affirmation of program information*: The program registry shall / should affirm that the program's representation of its provisions and procedures governing the program registry, and of program registry functionality, as contained in the most recent information that the program submits to ICAO, is true, accurate, and complete, to the best of the registry representative's knowledge;

1.1.5. *Recommendation on notification of material changes to registry*: The program registry shall / should notify the program of any material changes[1] to the program registry, such that the program can maintain consistency with relevant criteria and guidelines.

1.1.6. *Recommendation on registry non-discrimination based solely on account applicant location*: The program registry shall / should not deny a CORSIA participant's request for a registry account solely on the basis of the country in which the requestor is headquartered or based.

[1] As referred to in CAEP-11/SG20161/WP-015, "Material" change is defined as "…updates that would alter the program's response(s) to questions in application form." In the context of an emissions unit program registry, the same applies to any changes to the registry procedures or functions that are addressed in the EUC, Guidelines, or the requirements in Section 2 of this Appendix that would alter the program's response(s) to questions in application form or contradict the confirmation of the registry's adherence to the requirements contained in Section 2 of this Appendix.

1.1.7. *Recommendation on functionality for designating purpose of cancellation*: The program registry shall / should have the capability to designate the participant's cancellation of units for the purpose of reconciling offsetting requirements under the CORSIA, including by compliance cycle.

1.1.8. *Recommendation on publishing the cancellation information*: The program registry shall / should, within 1 – 3 business days[2] of receipt of formal instruction from a duly authorized representative of the owner of an account capable of holding and cancelling CORSIA Eligible Emission Units within the registry, and barring system downtime that is scheduled in advance or beyond the control of the registry administrator, make visible on the program registry's public website the account owners cancellations of CORSIA Eligible Emission Units as instructed. Such cancellation information shall / should include all fields that are specified for this purpose in the CORSIA SARPs

1.1.9. *Recommendation on public accessibility of cancelation information*: The program registry shall / should ensure that all cancellation information on its website is presented in a user-friendly format; is available at no cost and with no credentials required; is capable of being searched based on data fields; and can be downloaded in a machine-readable format, e.g., .xlsx.

1.1.10. *Recommendation on generation of reports, upon request*: The program registry shall / should, upon request of the CORSIA participant account holder or participant's designee, generate report(s) containing the information specified for this purpose in the CORSIA SARPs.

1.1.11. *Recommendation on verifier registry access*: The program registry shall / should, upon request of an account owner, provide a verification body with "viewing-privileges-only" access to the relevant account(s) and/or cancelled emissions units.

1.1.12. *Recommendation on document and data retention*: The program registry shall / should retain documents and data relevant to CORSIA Eligible Emissions Units and cancellations on an ongoing basis and for at least three years beyond the end date of the latest compliance period in which the emissions unit program is determined to be eligible; and consistent with the program's long-term planning, including plans for possible dissolution.

1.1.13. *Recommendation on registry security provisions*: The program registry shall / should maintain security practices that ensure the integrity of, and authenticated and secure access to, the registry data of CORSIA participant account holders or participants' designees, and transaction events carried out by a user; and disclose documentation of such practices upon request. The program registry shall / should utilize appropriate method(s) to authenticate the identity of each user accessing an account; grant each user access only to the information and functions that a user is entitled to; and ensure each event initiated by a user (i.e. transfer of units between accounts; cancellation / retirement of a unit, update of data, etc.) is an intentional transaction event confirmed by the user. Such security features should meet and be periodically updated in accordance with industry best practice.

1.1.14. *Recommendation on notification of breach of data security or integrity*: The program registry shall / should, upon identifying any breach of program registry data security or integrity that affects a CORSIA participant account holder or participant's designee, notify the CORSIA participant account holder or their designee, and inform the program, which will notify and engage with ICAO on the matter in the same manner as conducted for any material changes to program procedures.

[2] Business days as defined by the registry administrator.

1.1.15. *Recommendation on irreversibility of emissions units cancellation*: The program registry shall / should ensure the irreversibility of emissions unit cancellations and the designation of the purpose of emissions units cancellations as per the requirements contained in paragraphs 2.1.7 and 2.1.8, and as defined and required in Annex 16 Volume IV, Chapter 4: Standard and Recommend Practices (SARPs) for the CORSIA[3]. Without prejudice to the aforementioned, such requirement would not prevent a program registry from utilizing secure, time-bound and auditable methods for correcting unintentional user-entry errors.

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[3] From Annex 16, Volume IV, Chapter 4: Standards and Recommend Practices (SARPs) for the CORSIA: "'*Cancel' means the permanent removal and single use of an CORSIA Eligible Emissions Unit within a CORSIA Eligible Emissions Unit Program designated Registry such that the same emissions unit may not be used more than once. This is sometimes also referred to as 'retirement', 'cancelled', 'cancelling' or 'cancellation'*."

APPENDIX C
(English only)

BASIC TOR AND PROPOSED ADDITIONAL RULES OF PROCEDURE FOR THE TECHNICAL ADVISORY BODY (TAB)

Part A: Basic TOR for the TAB (as approved by the Council as C-DEC 215/7, Appendix)

Secretariat note: Upon approval of Part B by the Council, Part A and Part B will be integrated as the TOR for TAB.

1. **MANDATE OF TAB**

1.1 In line with the Assembly request, the mandate of the TAB is to make recommendations to the Council on the eligible emissions units for use by the CORSIA.

2. **TASKS OF TAB**

2.1 In fulfilling this mandate, the TAB is tasked to:

1) undertake the assessment of emissions unit programmes (and potentially project types) against the emissions units criteria, applying as a starting point the CAEP Programme Testing Group's procedures and guidelines for applying the emissions units criteria;

2) ensure that emissions unit programmes around the world can receive advance notice of, and are given ample time to apply for, the assessment by TAB; ensure outreach and ample notice and opportunity for input from stakeholders, with the support of the ICAO Secretariat;

3) develop, in a transparent manner, recommendations on the list of eligible emissions unit programmes (and potentially project types) whose emissions units would be eligible based on the emissions units criteria, for the compliance use under the CORSIA, for presentation to the Council;

4) adjust its work, if needed, in light of any developments of work by the ICAO Council, with technical contribution of CAEP, in any reviews of the emissions unit criteria, which are set out in the ICAO CORSIA Implementation Elements; and

5) undertake any other tasks as instructed by the Council.

3. EXPERTISE AND EXPERIENCE REQUIREMENTS

3.1 In order for the TAB to undertake the tasks as outlined in paragraph 2 above, TAB members are required to have relevant expertise and experience such as in carbon markets, carbon offset project development, carbon offset programmes and methodologies, and climate policy and related subjects. TAB members are required to meet at least two of the following five technical expertise requirements, which have to be substantiated at the time of nomination:

a) experience in the design, development, operation or evaluation of market-based measures for the reduction of greenhouse gas emissions (e.g. emissions trading systems, offsetting standards or programmes, the international carbon market);

b) experience in the quantification or forecasting of greenhouse gas emissions;

c) experience in the creation or use of emissions units (offset credits or allowances);

d) experience in developing, operating or using emissions units registries/carbon trading registries and emissions inventories;

e) experience in ensuring the transparency and accountability of carbon market programmes and carbon market operations.

3.2 In addition, it would be desirable (though not essential) that TAB members have experience with ICAO processes, in particular those related to CORSIA.

4. AVOIDANCE OF CONFLICTS OF INTEREST

4.1 Thorough evaluation is undertaken to avoid conflicts of interest of TAB members. In particular, TAB members should not be holding a financial and/or commercial interest in any organization, project, and/or programme that would benefit from the member's appointment. This has to be substantiated at the time of nomination, through a personal declaration.

5. DURATION OF SERVICE

5.1 Regarding the duration of service by TAB members and to ensure consistency in the work of TAB, TAB membership is aligned with the compliance cycles of the CORSIA (potentially with a short term for work undertaken prior to 2021), and a statement of commitment to the work of TAB for at least one full compliance cycle of CORSIA is provided at the time of nomination.

6. MEMBERSHIP SIZE

6.1 In principle, the size of the TAB should be in the order of 14 to 16 experts, nominated by States, taking into account the need for balanced geographical representation.

Part B: Proposed Additional Rules of Procedure for the TAB

Secretariat note: The Council, in November 2018, requested CAEP to provide further advice regarding additional rules of procedure for the TAB, which would complement the approved basic TOR, for the Council consideration and approval by its 216th Session in March 2019 (C-DEC 215/7, paragraph 32 e)).

Secretariat note: Upon approval of Part B by the Council, Part A and Part B will be integrated as the TOR for TAB.

7. **MEMBERSHIP**

Selection of Co-Chairpersons for TAB

7.1 The TAB selects two Co-Chairpersons from among its members at the first TAB meeting.

7.2 The Co-Chairpersons should not be from the same geographical region.

Conduct of TAB members:

7.3 TAB members are to conduct themselves in accordance with the TAB's TOR.

7.4 The TAB Co-Chairpersons may bring to the Council's attention any serious concerns regarding a member's consistency with the TOR, which may become apparent in the course of the TAB's work, in particular concerns related to the participation of TAB members and conflicts of interest should be informed to the Council.

Replacement of TAB Members during a CORSIA compliance cycle

7.5 The replacement of an existing TAB Member during a compliance cycle of the CORSIA is approved by the Council.

7.6 The replacement must meet the same criteria as outlined in the TOR for the TAB.

7.7 The outgoing member's nominating State should first be allowed to nominate a replacement.

7.7.1 If a replacement is not nominated by that State or should the Council reject the nominated replacement, ICAO would then seek nominations from the outgoing member's geographic region.

7.7.2 If a replacement is not nominated by a State from that geographical region or should the Council reject the nominated replacement(s), ICAO would then seek nominations from all States.

7.7.3 Where possible, the replacement of TAB members should be staggered over CORSIA compliance cycles to ensure continuity of knowledge and expertise.

8. WORKING METHODS

Modality and frequency of TAB meetings

8.1 Face-to-face meetings of the TAB are the primary means of organizing the TAB's work, making significant decisions in particular TAB's recommendations to the Council, and resolving substantive issues.

8.2 The TAB is also expected to conduct business via teleconferences and emails between the face-to-face meetings to progress the work.

8.3 TAB discusses and agrees on a schedule of meetings, which can be reviewed later as necessary. The number of TAB meetings should be sufficient to achieve the deliverables for the TAB as set by the Council.

8.4 If changes to the meeting schedule or additional meetings are required, the Co-Chairpersons will, after consultations with TAB members, give notice of any changes in the meeting schedule and/or additional meetings.

Note. The Co-Chairpersons are encouraged to give approximately 8 weeks' notice of any changes in the face-to-face meeting schedule and/or additional face-to-face meetings.

Quorum for TAB recommendations

8.5 A majority of TAB Members, at least from three geographical regions, must be present at a TAB meeting in order to constitute a quorum to make TAB recommendations. This rule would not apply to the meetings of a sub-group or other structural arrangements by TAB, to make progress on specific work.

Working language for TAB meetings

8.6 The working language of the TAB is English. The recommendations of TAB are translated in all six languages, for consideration by the Council.

Decision process

8.7 TAB's final recommendations to the Council, including the underlining decisions by the TAB, are taken by consensus. If there is no consensus, then the prevailing and alternative conclusions will be described and substantiated, and presented to the Council for decision.

Openness of TAB meetings

8.8 As a general rule, TAB meetings will only be open to TAB Members, with support provided by the ICAO Secretariat.

8.9 Other participants may, upon request by the TAB, be invited by the ICAO Secretariat to participate in TAB meetings relating to matters under consideration by the TAB.

Secretariat

8.10 The ICAO Secretariat will:

a) publish general information related to TAB on the ICAO CORSIA website, including the membership, TOR, and the latest timeline of work;

b) provide administrative and logistical support for TAB meetings and business conducted by TAB

c) facilitate all communications between emissions unit programmes and the TAB; and

d) support the preparation of necessary documentation and reports related to TAB.

9. TAB WORK PROGRAMME

9.1 Based on the TOR, TAB will initiate its work by defining its work programme and timeline, and use as a starting point the CAEP Programme Testing Group's procedures and guidelines for applying the emissions unit criteria, including as a source of guidance on any specific procedures or issues not addressed in the TOR.

10. PROGRAMME APPLICATION AND ADMINISTRATIVE PROCESS

10.1 The TAB, with the support of the ICAO Secretariat, will issue an open invitation on the ICAO CORSIA public website, by which emissions unit programmes that wish to be considered for eligibility in CORSIA can apply. To facilitate the applications by emissions unit programmes, the website will include an application form and other information that need to be prepared and submitted electronically to ICAO.

10.2 Once the application process is initiated, the status of applications submitted by emissions units programmes will be made available on the ICAO CORSIA public website.

11. PUBLIC INFORMATION AND TRANSPARENCY

11.1 Applications and other information submitted by emissions unit programmes will be publicly available on the ICAO CORSIA website, except for materials which the applicants designate as business confidential.

11.2 The public will be invited to submit comments on the programmes applications including regarding their consistency with the emissions units criteria (EUC), through the ICAO CORSIA website, for consideration by the TAB following its initial assessment of programmes applications.

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议程项目 9：可持续航空燃料

9.1 代用燃料工作队的报告

9.1.1 代用燃料工作队共同报告员总结了 CAEP/10 以来该工作队取得的进展。代用燃料工作队在整个 CAEP/11 周期期间侧重于七项任务并为完成与国际航空碳抵消和减排计划合格燃料相关的国际航空碳抵消和减排计划实施要素的所有缺失部分提出了各项提案。代用燃料工作队的工作仅审议与可持续航空燃料（SAF）的问题，因为“国际航空碳抵消和减排计划低碳航空燃料”（LCAF）的定义在国际民航组织理事会第 214 届会议（2018 年 6 月）期间才获得通过，因此“低碳航空燃料”没有被列入代用燃料工作队 CAEP/11 的工作方案。

9.1.2 一些成员和观察员认为有关技术咨询机构（TAB）和燃料咨询机构（FAB）的工作应同时完成。他们重申支持航空环境保护委员会建议的全套标准，以确保符合国际航空碳抵消和减排计划条件的燃料的社会经济和环境可持续性。他们注意到在引发土地利用变化（ILUC）和低引发土地利用变化风险实践方面所完成的工作的重要性，同时指出在 CAEP/12 周期需要进行更多工作。这些成员还认为，在试图解决诸如重复计算等问题时，作为一项预防性临时措施，不应允许燃料的负生命周期排放值（LSf）。成员和观察员建议可持续航空燃料（SAF）和低碳航空燃料的未来工作项目均应由航空环境保护委员会进行。

9.1.3 一位成员对各个具体未决议题提出了他的看法，支持代用燃料工作队为垃圾填埋排放额度（LEC）和回收利用排放额度（REC）提出的方法是合理的，前提是排放额度不能用于获得生命周期排放值（LSf）的负值，指出这将减轻重复计算减排的风险。该成员还建议，由于可能会出现意外的后果，不再考虑为国际航空碳抵消和减排计划使用的任何燃料给予任何额度。

9.1.4 一位观察员认为，代用燃料工作队用于计算国际航空碳抵消和减排计划下的可持续航空燃料的方法是严格和适当的。他们指出，他们认为核心可持续性要求需要以更广泛的可持续性标准作出补充。一位观察员支持代用燃料工作队对生命周期分析（LCA）方法的建议，强调从城市固体废弃物（MSW）原料中识别垃圾填埋排放额度（LEC）和回收利用排放额度（REC）的重要性。

9.2 可持续性标准（任务 S.05）

9.2.1 在 CAEP/11 周期期间，代用燃料工作队尽可能在现有可持续性标准和框架的基础上，致力于在国际航空碳抵消和减排计划背景下制定关于可持续航空燃料的可持续性标准的建议。虽然这项任务已经完成，但作为国际民航组织理事会第 212 届会议的一项成果，预计航空环境保护委员会将进一步开展理事会第 212 届会议上未批准的可持续航空燃料可持续性主题和标准方面的工作（航空环境保护委员会以前建议作为‘主题 3 至主题 12’的工作）。代用燃料工作队共同报告员根据理事会的要求，提交了与国际民航组织秘书处共同编制的“可持续航空燃料的可持续性主题、原则和标准报告”，作为处理可持续性标准工作的第一步。

讨论和结论

9.2.2　会议注意到若干航空环境保护委员会成员和观察员对部署可持续航空燃料的支持。

9.2.3　若干成员和观察员对“关于可持续航空燃料的可持续性主题、原则和标准报告”表示支持，建议尽快将其提交理事会，但一些成员要求在报告中列入适当的警告，指明目前的工作只考虑到可持续航空燃料，并且航空环境保护委员会将制定在可持续性范围内适当审议低碳航空燃料的进一步工作。航空环境保护委员会秘书指出，这份报告将作为 CAEP/11 报告的一部分提供给理事会。一位成员注意到代用燃料工作队共同报告员提出的观点，即该报告并不排除对低碳航空燃料的任何审议，因此支持继续开展工作，但这样做并不会减缓可持续航空燃料的发展。

9.2.4　会议同意接受在本议程项目下提交的报告附录 A 提供的“关于可持续航空燃料的额外可持续性主题、原则和标准的报告”，以此作为向理事会通报航空环境保护委员会工作进展的第一步。国际民航组织理事会在其第 212 届会议（2017 年 11 月）期间要求就额外的可持续性标准和在其第 214 届会议（2018 年 6 月）期间为加强国际航空碳抵消和减排计划合格燃料的可持续性标准展开进一步工作，同时认识到航空环境保护委员会需要展开进一步工作来制定航空环境保护委员会关于这项主题的建议。

9.2.5　会议注意到将在国际航空碳抵消和减排计划试点阶段适用的两个可持续性标准，它们作为理事会第 212 届会议期间的一项决定的一部分进行审议，这些标准应反映在国际民航组织“国际航空碳抵消和减排计划合格燃料的可持续性标准”的文件中，该文件载于作为与“国际航空碳抵消和减排计划合格燃料”有关的国际航空碳抵消和减排计划完整实施要素的一部分发布的附录 B。

建议 9/1 — 附件 16 第 IV 卷提及的国际民航组织文件“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划可持续性标准”

关于这个议程项目的报告附录 B 的材料应列入作为国际民航组织文件“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划可持续性标准”发布。

9.3　可持续性审定合格机制的评估

9.3.1　代用燃料工作队共同报告员提出了关于称为燃料咨询机构（FAB）的（1）作用、（2）成员组成、（3）功能和（4）专门技术机构的管理的初步构想，这个机构将负责就国际航空碳抵消和减排计划下的可持续性审定合格机制（SCS）的资格提供咨询意见。

讨论和结论

9.3.2　若干成员支持航空环境保护委员会成员提名的人员组成的燃料咨询机构（FAB），前提是该机构内必须确保不同的地理代表性。

9.3.3　就可能设立的燃料咨询机构和技术咨询机构进行比较的看法，代用燃料工作队共同报告员解释指出，与燃料咨询机构相关的工作范围和数量预计与技术咨询机构有很大不同。考虑到这一点，代用燃料工作队共同报告员认为这样的一个小组可以直接作为航空环境保护委员会的一个小组设立。航空环境保护委员会秘书也支

持这一观点，重申燃料咨询机构与技术咨询机构之间没有真正的相似之处。航空环境保护委员会秘书还指出，包括符合条件的可持续性审定合格机制（SCS）清单在内的国际航空碳抵消和减排计划实施要素必须得到理事会的批准，因此燃料咨询机构就符合条件的可持续性审定合格机制提出的任何建议都将受到理事会的最终审查和批准，无论这个小组设立在何处。一位成员指出，除了可持续航空燃料（SAF）之外，燃料咨询机构组件的最终要求还应包括与低碳航空燃料（LCAF）相关的能力。

9.3.4 在随后的讨论中，会议注意到"燃料咨询机构"这一名称没有恰当反映这个小组的具体作用，但同意"可持续性审定合格机制评估小组（SCSEG）"的名称。会议同意将可持续性审定合格机制评估小组（SCSEG）创建为航空环境保护委员会的一个小组，其任务是向理事会提出有关可持续性审定合格机制（SCS）的资格的技术建议。

9.3.5 会议同意可持续性审定合格机制评估小组的组成应由航空环境保护委员会成员提名的独立专家组成。成员组成应反映平衡的地域代表性。会议同意载于这个议程项目的报告附录 C 内所载的可持续性审定合格机制评估小组（SCSEG）的职权范围。

9.3.6 会议同意有关可持续性审定合格机制评估小组（SCSEG）工作的以下时间表和交付成果：

a) 到2019年6月：在理事会批准CAEP/12周期工作方案包括航空环境保护委员会可持续性审定合格机制评估小组（SCSEG）的职责范围的情况下，航空环境保护委员会将邀请航空环境保护委员会成员提名组成成员。

b) 到2019年8月：航空环境保护委员会成员将任命可持续性审定合格机制评估小组（SCSEG）成员。

c) 到2019年9月：航空环境保护委员会可持续性审定合格机制评估小组（SCSEG）将在国际民航组织秘书处的支持下，在国际民航组织国际航空碳抵消和减排计划公共网站发出公开邀请，希望在国际航空碳抵消和减排计划中考虑符合资格的可持续性审定合格机制（SCS）可以提出申请。申请表的模板将包括"国际民航组织文件国际航空碳抵消和减排计划可持续性审定合格机制资格框架和要求的资格要求"一节内的表格所设定的要求；和

d) 到航空环境保护委员会指导小组2019年会议：航空环境保护委员会可持续性审定合格机制评估小组（SCSEG）将评估可持续性审定合格机制（SCS）提出的申请，制定有关合格的可持续性审定合格机制清单的技术建议，在最早于2020年3月提交理事会之前，供航空环境保护委员会提出意见。

9.4 计算用于全球基于市场措施（GMBM）的监测、审查和核查（MRV）的喷射代用燃料生命周期排放的默认值

9.4.1 在 CAEP/11 周期，航空代用燃料工作队计算了可供运营人报告因使用可持续航空燃料所产生减排量的"核心"生命周期分析默认值。根据协议，航空代用燃料工作队使用了来自巴西、加拿大、欧洲和美国的一组研究人员进行了计算。在这项工作的基础上，代用燃料工作队共同报告员提出了在国际民航组织题为"国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划默认生命周期排放值"的文件的表格添加核心生命周期分析值的建议。

9.4.2　为了配合这项工作，代用燃料工作队共同报告员提交了国际民航组织文件“国际航空碳抵消和减排计划计算实际生命周期排放值方法”的“原料类别”和“技术报告要求”部分的案文以及支持文件“生命周期分析 — 核心生命周期分析计算”的提案，其中还包括有关生命周期分析模型和如何得到结果的技术信息。

9.4.3　一位观察员建议，为避免重复计算减排量和不恰当的默认值，在作出进一步分析之前，已经停止了“封闭池塘棕榈油”途径的默认核心生命周期分析值的协议。该观察者提出了适当指定核心生命周期分析默认值的建议，这将避免将生命周期排放值（LSf）赋予具有显着更高碳强度的途径。

讨论和结论

9.4.4　会议同意，排除“封闭池塘棕榈油”途径为时尚早。

9.4.5　会议认识到代用燃料工作队进行的工作，同意纳入国际民航组织题为“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划默认生命周期排放值”的文件中提供的核心生命周期分析值。

9.4.6　会议同意国际民航组织题为“计算实际生命周期排放值的国际航空碳抵消和减排计划方法”的文件中关于“技术报告要求”和“原料类别”部分提出的案文，其中包括代用燃料工作队共同报告员指出的编辑修订案文。

9.5　排放额度

9.5.1　代用燃料工作队共同报告员提出了计算避免与城市固体废弃物（MSW）衍生的可持续航空燃料（SAF）相关的垃圾填埋排放额度（LEC）和回收利用排放额度（REC）的方法，以便在计算生命周期排放值（LSf）时纳入排放额度，并将其纳入国际民航组织题为“国际航空碳抵消和减排计划计算实际生命周期排放值的方法”的文件。

9.5.2　一位观察员由于对拟议的垃圾填埋排放额度（LEC）和回收利用排放额度（REC）不会产生国际航空碳抵消和减排计划排放单位类似质量的额度表示关切，认为目前这些排放额度不应列入国际航空碳抵消和减排计划的一揽子计划。作为临时替代办法，若干成员认为符合排放额度的燃料的生命周期排放值（LSf）应限定为零。

9.5.3　一位观察员认为生命周期排放值（LSf）不应限定为零，因为这会限制减排量的数值并且不对称地对待以城市固体废弃物（MSW）为基础的国际航空碳抵消和减排计划合格燃料的生产者。该观察员提出一种解决重复计算国际航空碳抵消和减排计划合格燃料（CEF）的不同方法，即在生产国际航空碳抵消和减排计划合格燃料的国家的财务结算中作出相应调整。为此，该观察员提出应列入国际民航组织“国际航空碳抵消和减排计划可持续性审定合格机制资格框架和要求”文件的规定，这将从国际航空碳抵消和减排计划开始就避免国际航空碳抵消和减排计划合格燃料的重复计算。一位观察员认为，代用燃料工作队提出的排放配额方法并未防止对管理不善的垃圾填埋场给予意外激励，也没有解决重复计算的风险，而且垃圾填埋排放配额代表了一种前所未有的方法，与在其他地方适用的气候公约计算配额的规则不一致。因此，该观察员提出了计算垃圾填埋排放额度（LEC）和回收利用排放额度（REC）的方法的建议。

讨论和结论

9.5.4 有些成员指出，虽然将生命周期排放值（LSf）定为零是一种不完善的方法，但它可作为一种临时措施。若干成员还认为只应在城市固体废弃物（MSW）的背景下考虑排放额度，但一些成员和观察员认为，这种方法过于激进，因为未来应该还有机会考虑其他类型的排放额度。一位成员还提醒会议，航空环境保护委员会以前曾经商定需要界定适用于排放额度的一般规则。一些成员着重指出，有必要限制无意间激励管理不善的垃圾填埋场和解决与这些排放额度相关的重复计算风险的做法。

9.5.5 在考虑了将生命周期排放值（LSf）限制为零与限制排放额度的类型之间各种相互矛盾的观点之后，会议同意可从废弃物和残留物生产可持续航空燃料（SAF）产生的排放额度，这已界定在国际民航组织题为"国际航空碳抵消和减排计划计算实际生命周期排放值的方法"的文件内"原料类别"一节。会议还认为航空环境保护委员会应进一步努力改善与排放额度相关的方法。会议同意在国际民航组织"国际航空碳抵消和减排计划计算实际生命周期排放值的方法"的相关部分纳入相应的变更协议。会议同意在国际航空碳抵消和减排计划的试点阶段，直到制定额外的要求和指导，以（a）确保根据国际航空碳抵消和减排计划产生的可持续航空燃料排放额度与排放单位的质量相当；（b）解决有关在减去适用于可持续航空燃料的垃圾填埋排放额度和/或回收利用排放额度之后重复计算的问题，总生命周期排放值不能小于 0 gCO2e / MJ。

9.5.6 在随后的讨论中，会议同意对国际民航组织文件"国际航空碳抵消和减排计划可持续性审定合格机制资格框架和要求"的建议。

建议 9/2 — 附件 16 第 IV 卷提及的国际民航组织文件"国际航空碳抵消和减排计划可持续性审定合格机制资格框架和要求"

本议程项目的报告附录 D 内的材料应列入国际民航组织文件"国际航空碳抵消和减排计划可持续性审定合格机制资格框架和要求"。

9.6 计算代用燃料土地利用变化的排放以便用于全球基于市场措施的监测、报告和核查（任务 S.01）

9.6.1 代用燃料工作队共同报告员介绍了在不同世界地区生产的可持续航空燃料（SAF）计算的引发土地利用变化排放量（ILUC）的结果。引发土地利用变化建模取决于结构上基于生命周期评估相应方法的经济模型。代用燃料工作队使用的两个全球模型是全球贸易分析项目—生物燃料模型（GTAP-BIO）—普渡大学公开提供的可计算一般均衡模型和全球生物圈管理模型（GLOBIOM）—国际应用系统分析研究所（IIASA）的约束优化部分均衡模型。对四个地区的原料和途径进行了引发土地利用变化分析：美国、巴西、欧盟和马来西亚/印度尼西亚。代用燃料工作队建议使用区域值，因为引发土地利用变化值的基本特征因地区而大不相同。代用燃料工作队共同报告员对描述相关各方能如何使航空环境保护委员会制定引发土地利用变化值的用语提出建议。

9.6.2 代用燃料工作队共同报告员还介绍了可持续性审定合格机制（SCS）确定一种原料是否可归类为"低土地利用变化（LUC）风险"的方法，但指出这种方法应该是临时的，仅应在国际航空碳抵消和减排计划的试点阶段使用，例如当可持续性审定合格机制有足够的时间来测试它时。

9.6.3 一位成员表示倾向于使用全球贸易分析项目—生物燃料模型（GTAP-BIO）作为国际航空碳抵消和减排计划下计算引发土地利用变化的单一模型，同时同意代用燃料工作队提出的折衷方案。该成员还认为应该使用地区引发土地利用变化值，因为它们可以更准确地估算一个地区内可持续航空燃料（SAF）途径的引发土地利用变化排放值。该成员还支持在国际航空碳抵消和减排计划下添加新的生命周期默认值的过程，但强调指出，应提供额外信息来界定这个过程以及构成地区数据充足性标准的要素。

9.6.4 一位观察员指出，代用燃料工作队需要大量改进其提出的低土地利用变化（LUC）风险方法，以确保其在生物质生产中产生实际和可衡量的净改进，并提出改进措施以解决这一问题。该观察员提出他对引发土地利用变化（ILUC）值的看法，建议将使用每一种模型估算的两个单独的引发土地利用变化排放因素加以平均，以避免失去有价值的信息和防止不确定的温室气体减排计算。该观察员还建议，不要改变基于风险的引发土地利用变化方法，为原料提供模拟的负引发土地利用变化值。

讨论和结论

9.6.5 关于引发土地利用变化（ILUC）的价值观和方法，特别是拟定地区引发土地利用变化值，一些成员质疑“地区”的定义，指出目前包含在代用燃料工作队工作内的单个“地区”可包括不同类型的土地。代用燃料工作队共同报告员指出，对“地区”的更精确定义可在未来的工作项下审议。

9.6.6 高级生物燃料协会（ABFA）对使用多个模型来拟定一个引发土地利用变化默认值的做法表示关切，认为这种进程会延迟对某个默认值达成一致。一位成员回答指出，他们支持使用两种模型，因为这将确保方法的质量、数据和结果。

9.6.7 代用燃料工作队共同报告员在回答一个问题时指出，考虑到目前可持续航空燃料的产量不多，在国际航空碳抵消和减排计划试点阶段排除低土地利用变化（LUC）相关的风险非常小。高级生物燃料协会（ABFA）支持不溯及既往的做法，指出目前正在开发一些预计会有未来效益的项目。

9.6.8 关于推动低土地利用变化方法的临时做法，会议同意，为确定何种做法和土地用途符合增产和未使用的土地方法的资格而提供的标准和方法，作为国际航空碳抵消和减排计划试点阶段的临时方法，在此期间可持续性审定合格机制（SCS）会有时间测试各种方法。

9.6.9 在审议了会议对低引发土地利用变化（ILUC）的设定和其他未决问题的时间框架所提出的不同看法后，会议就“低引发土地利用变化（LUC）风险实践”部分达成一致意见，其中包括列入本议程项目报告附录 F 的“增产方法”和“未使用的土地方法”部分。

9.6.10 会议注意到一些成员对重复计算和永久性问题表示的关切，认为引发土地利用变化负值代表某些原料可能产生的碳储存的模拟效益。会议同意，在国际航空碳抵消和减排计划试点阶段，暂时允许使用引发土地利用变化负值获得负的生命周期排放值（LSf）。由于引发土地利用变化负值减少，将在试点阶段结束时对是否继续使用负的生命周期排放值作出决定。会议同意将此措辞纳入国际民航组织文件“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划默认生命周期排放值”。

9.6.11 会议同意向理事会提出关于允许使用负的生命周期排放值的建议，它来自引发土地利用变化负值。拟定这个建议的基础是基于重复计算与引发土地利用变化负值相关的生命周期减排相关的永久性减碳的工作结果。这项建议将在 CAEP/12 期间提出。由于引发土地利用变化负值的减少，不会追溯负的生命周期排放值。

9.6.12 会议注意到一位成员倾向于将全球贸易分析项目-生物燃料模型作为单一模型、更公开/更广泛地加以利用和确定引发土地利用变化值以便纳入国际航空碳抵消和减排计划的更低廉的选项。会议根据 GTAP-BIO 和 GLOBIOM 的结果，核可了采用引发土地利用变化（ILUC）排放强度计算的协议。因此，会议同意将代用燃料工作队提出的引发土地利用变化（ILUC）值纳入国际民航组织题为“国际航空碳抵消和减排计划符合条件的燃料的国际航空碳抵消和减排计划默认生命周期排放值”的文件。会议注意到代用燃料工作队用于设定国际航空碳抵消和减排计划可持续航空燃料的默认引发土地利用变化生命周期分析值，同意将该方法的细节作为国际航空碳抵消和减排计划支持文件“生命周期分析方法”的一部分。

9.6.13 在随后的讨论中，会议同意对国际民航组织文件“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划默认生命周期排放值”提出的建议。

建议 9/3 — 附件 16 第 IV 卷提及的国际民航组织文件“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划默认生命周期排放值”

这个议程项目的报告附录 E 的材料应列入作为国际民航组织文件“国际航空碳抵消和减排计划合格燃料的国际航空碳抵消和减排计划默认生命周期排放值”发布。

9.6.14 在随后的讨论中，会议同意对国际民航组织文件“国际航空碳抵消和减排计划计算实际生命周期排放值的方法”提出的建议。

建议 9/4 — 附件 16 第 IV 卷提及的国际民航组织文件“国际航空碳抵消和减排计划计算实际生命周期排放值的方法”

这个议程项目的报告附录 F 的材料应列入作为国际民航组织文件“国际航空碳抵消和减排计划计算实际生命周期排放值的方法”发布。

9.6.15 关于增加新的默认生命周期值的进程，会议同意支持文件“生命周期分析方法”中“增加新的默认生命周期值”部分的拟议文本，其中包括一位成员指出的更正，即代用燃料工作队（或其继任机构）将对模型模拟结果达成一致。

9.6.16 在随后的讨论中，会议同意对国际航空碳抵消和减排计划支持文件“国际航空碳抵消和减排计划合格燃料—生命周期分析方法”提出的建议。

建议 9/5 — 国际航空碳抵消和减排计划支持文件“国际航空碳抵消和减排计划合格燃料 — 生命周期分析方法”

题为“国际航空碳抵消和减排计划合格燃料—生命周期分析方法”的国际航空碳抵消和减排计划支持文件根据代用燃料工作队报告的要求发布。

9.7 关于潜在政策的指导（任务 S.04）

9.7.1 代用燃料工作队共同报告员介绍了代用燃料工作队关于审查旨在激励部署可持续航空燃料的现有政策工具以及障碍、抑制机制或政策外部效应的工作结果，以帮助查明已证明可行、有效和实用的“潜在政策”。作为这项工作的一部分，代用燃料工作队对一些可持续航空燃料途径进行了随机技术经济分析（TEA）。代用燃料工作队共同报告员介绍了这项分析的目的和方法，描述了分析的局限性并提出了初步结果。要求就是否应在航空环境保护委员会未来的工作计划中保留政策分析任务提出反馈意见，以便作为分析的结果提供进一步指导材料。

9.7.2 一位成员对这项工作表示欢迎，建议以一种可向国际民航组织所有成员国包括航空环境保护委员会以外的成员国提供的格式提供结果，作为决策者的支持工具。一位成员表示他支持进行技术经济分析，希望将来这一分析会扩大到更广泛的范围，涵盖国际航空碳抵消和减排计划下的所有类型燃料，并表示他的国家希望将来支持这项研究。

9.7.3 两位成员概述了他们共同希望制定国家可持续燃料目标，通过国家和业界之间的对话达成均衡的妥协，这将促进可持续航空燃料的部署而不损害航空运输业的竞争力，目标是到 2025 年达到可持续航空燃料占 2%。

9.7.4 航空环境保护委员会注意到这些成员采取的举措，其他许多成员和观察员概述了他们的倡议和政策考虑因素。航空环境保护委员会秘书提醒会议即将于 2019 年 4 月 30 日至 5 月 1 日在加拿大蒙特利尔举行的第一届国际民航组织 2050 年可持续航空燃料愿景评估研讨会，因为这项活动将为会员和观察员提供有关其可持续航空燃料项目进一步信息的机会。

9.7.5 若干成员和观察员指出，在 2025 年实现使用 2%可持续航空燃料的目标具有挑战性，并且缺乏可行性研究来支持这个目标的实现，而另一些成员和观察员则强调为可持续航空燃料生产商提供更多确定性而制订全球政策的重要性。会议认识到监管机构 — 业界达成“平衡妥协”作为建立国家可持续航空燃料供应目标的手段的概念。会议注意到两个提出文件的成员的观点，认为依照他们各自国家的情况，到 2025 年实现使用 2%可持续航空燃料是一项合理的政策目标，以便依照第二次航空与代用燃料会议（CAAF/2）核可的 2050 年国际民航组织可持续航空燃料愿景促进使用可持续航空燃料。一位观察员认为，虽然监管机构— 业界对话对于制定支持开发可持续航空燃料的政策至关重要，但在“平衡妥协”概念能够得到承认之前，航空环境保护委员会需要对其进行更多讨论。

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APPENDIX A
(English only)

REPORT ON SUSTAINABILITY THEMES, PRINCIPLES AND CRITERIA FOR SUSTAINABLE AVIATION FUELS

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EXECUTIVE SUMMARY

The ICAO Council's adoption of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) Standards and Recommended Practices (SARPs) in 2018 established the requirement that both sustainable aviation fuels and lower carbon aviation fuels need to comply with a set of Sustainability Criteria to be eligible to reduce offsetting obligations under the Scheme.

The First ICAO International Conference on Aviation and Alternative Fuels (CAAF, Rio de Janeiro 2009) recognized the need for a common definition of sustainability requirements at the international level.

The ICAO Assembly, at its 38th session (2013), acknowledged the need for sustainable aviation fuels to be developed and deployed in an economically feasible, socially and environmentally acceptable manner and the need for increased harmonization of the approaches to sustainability.

The 39th Assembly requested States to recognize existing approaches to assess sustainability, which should achieve net GHG emissions reduction, contribute to local social and economic development; competition with food and water should be avoided.

In addition, the Second ICAO International Conference on Aviation and Alternative Fuels (CAAF/2, Mexico City, 2017) recognized that the sustainability of alternative aviation fuels is of essential importance to the efforts of international civil aviation to reduce its CO_2 emissions, and that this is ensured by application of sustainability criteria to aviation fuels.

Considering these agreements from the Assembly, the Committee on Aviation Environmental Protection (CAEP) developed a list of 12 Sustainability Principles and Themes with 17 associated Criteria that should be met for a sustainable aviation fuel to generate carbon offset reductions under CORSIA. This list was agreed by CAEP on its 2017 Steering Group meeting (Montreal, Canada, 11 to 15 September 2017), and covers the three aspects of sustainability acknowledged by the ICAO Assembly (environmental, social and economic). CAEP also agreed to the inclusion of specific guidance for assessing compliance with the socio-economic themes (8 to 12), aiming to address concerns of national sovereignty, as well as to address aspects that are beyond the fuel producer control.

This report provides the rationale underlying the CAEP recommendation. For that, a detailed comparison is done with the main approaches in place worldwide to assess sustainability. This analysis supports the conclusion that the list of Sustainability Themes, Principles and Criteria recommended by CAEP builds on existing approaches or combination of approaches to sustainability, including work developed by other UN bodies, fulfilling the ICAO Assembly directive of ensuring the sustainability of aviation fuels.

Consideration of Sustainability Criteria in different approaches

	EXISTING APPROACHES TO SUSTAINABILITY									
	FAO SAFA	GBEP	ISO	EU RED	ISPO	RFS2	Bonsucro	ISCC	RSB	RSPO
3.1 Water Quality	x	x	x	x	x	x	x	x	x	x
3.2 Water Use	x	x	x	x	x	x	x	x	x	x
4.1 Soil Health	x	x	x	x	x	x	x	x	x	x
5.1 Air Pollution	x	x	x	x	x	x	x	x	x	x
6.1 Conservation – Use of Protected Areas	x	x	x	x	x	x	x	x	x	x
6.2 Conservation – Invasive Feedstocks	x	x		x		x		x	x	
6.3 Conservation – Effects on Protected Areas	x	x	x	x	x	x	x	x	x	x
7.1 Waste and Chemicals - Use and Disposal	x	x	x	x	x		x	x	x	x
7.2 Waste and Chemicals – Pesticide Use	x				x	x	x	x	x	x
8.1 Human and Labour Rights	x	x	x	x	x		x	x	x	x
9.1 Land use rights and land use	x	x	x	x	x		x	x	x	x
10.1 Water use rights	x		x				x	x	x	x
11.1 Local and social development	x	x		x	x	x	x	x	x	x
12.1 Food security	x	x	x	x		x		x	x	
total criteria covered	**14**	**12**	**11**	**12**	**11**	**10**	**12**	**14**	**14**	**12**

CHAPTER 1. HISTORY OF ICAO WORK ON SUSTAINABILITY OF AVIATION FUELS

1.1 ICAO ASSEMBLY RESOLUTIONS AND CONFERENCES

The first reference to alternative fuels in ICAO Assembly Resolutions was registered in its 36th Session (2007), when the Assembly recognized the importance of research and development in fuel efficiency and alternative fuels for aviation that will enable international air transport operations with a lower environmental impact, and encouraged the Council to promote improved understanding of the potential use, and the related emissions impacts, of alternative aviation fuels.

In 2009, ICAO organized the first Conference on Aviation and Alternative Fuels (CAAF), which endorsed the use of sustainable alternative fuels for aviation, particularly the use of drop-in fuels in the short- to mid-term, as an important means of reducing aviation emissions. The Conference also recognized the need for a common definition of sustainability requirements at the international level, and declared that Member States and stakeholders "work together through ICAO and other relevant international bodies, to exchange information and best practices, and in particular to reach a common definition of sustainability requirements for alternative fuels". It also acknowledged that the technology exists to produce substitute, sustainable fuels for aviation that take into consideration the world´s food security, energy and sustainable development needs.

These outcomes were reflected in the ICAO Assembly Resolution A37-18 (2010), which requested the Council to encourage Member States and invite industry to actively participate in further work on sustainable alternative fuels for aviation.

Building on the successful outcomes of the ICAO SUSTAF Workshop (Montréal, 18 - 20 October 2011) and on the discussions in the third meeting of the 194th Session of the ICAO Council, ICAO created the SUSTAF Expert Group in June 2012 to develop recommendations to further facilitate the global development and deployment of sustainable alternative fuels for aviation, leading up to the 38th Session of the ICAO Assembly. One of the conclusions of this expert group was that States should focus on developing and deploying sustainable alternative fuels for aviation and acknowledge the environmental, social and economic dimensions of sustainability. Similar conclusions were later included in the ICAO Assembly Resolution A38-18 (2013), as follows:

> *A38-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection — Climate change*
>
> *(…)*
>
> *Acknowledging the need for such fuels to be developed and deployed in an economically feasible, socially and environmentally acceptable manner and the need for increased harmonization of the approaches to sustainability;*
>
> *(…)*
>
> *The Assembly:*
>
> *(…)*

32. Requests States to:

j) recognize existing approaches to assess the sustainability of all alternative fuels in general, including those for use in aviation which should:

i. achieve net GHG emissions reduction on a life cycle basis;

ii. respect the areas of high importance for biodiversity, conservation and benefits for people from ecosystems, in accordance with international and national regulations; and

iii. contribute to local social and economic development, and competition with food and water should be avoided;

k) adopt measures to ensure the sustainability of alternative fuels for aviation, building on existing approaches or combination of approaches, and monitor, at a national level, the sustainability of the production of alternative fuels for aviation.

Similar requests related to sustainability of aviation fuels were made by the ICAO Assembly during its 39th Session (2016).

A39-2 Consolidated statement of continuing ICAO policies and practices related to environmental protection — Climate change

Recognizing that the technological feasibility of drop-in sustainable alternative fuels for aviation is proven and that the introduction of appropriate policies and incentives to create a long-term market perspective is required;

Acknowledging the need for such fuels to be developed and deployed in an economically feasible, socially and environmentally acceptable manner and the progress achieved in the harmonization of the approaches to sustainability;

The Assembly

32. Requests States to:

i) recognize existing approaches to assess the sustainability of all alternative fuels in general, including those for use in aviation which should achieve net GHG emissions reduction on a life cycle basis, contribute to local social and economic development; competition with food and water should be avoided; and

j) adopt measures to ensure the sustainability of alternative fuels for aviation, building on existing approaches or combination of approaches, monitor, at a national level, the sustainability of the production of alternative fuels for aviation, and work together through ICAO and other relevant international bodies, to exchange information and best practices, including for the harmonization on the sustainability criteria of aviation alternative fuels;

In 2017, ICAO organized the second Conference on Aviation and Alternative Fuels (CAAF/2), which recognized that the sustainability of alternative aviation fuels is of essential importance to the efforts of international civil aviation to reduce its CO_2 emissions, and that this is ensured by application of sustainability criteria to aviation fuels. The Conference also noted that the introduction of sustainable aviation fuels (SAF) may realize economic, social, and environmental advantages that contribute to the vision set out in 13 out of 17 of the United Nations Sustainable

Development Goals (SDGs). Details on the potential contribution of SAFs to the SDGs are available at CAAF/2-WP-12.

1.2 CAEP AND AFTF

In response to the ICAO Assembly Resolution requests, the ICAO Committee on Aviation Environmental Protection (CAEP) established the Alternative Fuels Task Force (AFTF) in 2013 to provide technical support to all aspects of ICAO work on aviation fuels, including sustainability.

During the CAEP/10 cycle (from 2013 to 2016), the CAEP-AFTF developed a scoping exercise for future work on sustainability criteria for aviation fuels[1].

Based on this scoping exercise, in the CAEP/11 cycle (2016-2019) CAEP tasked AFTF to develop recommendations on sustainability criteria for alternative fuels in the context of the recognition under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) . CAEP instructed AFTF to prioritize the development of environmental criteria first, followed by social and economic criteria at a later stage, and planned the work to build as much as possible upon existing sustainability standards and frameworks, which would be analysed and compared in order to develop recommendations for CAEP.

To develop such a task, AFTF set up the “Sustainability Task Group”, composed of 72 experts[2] nominated by 11 CAEP Member States and seven international organizations.

1.3 THE CAEP APPROACH

In the development of the CAEP approach, the AFTF recommended that ICAO should rely on existing sustainability standards, whether regulatory or voluntary, for the actual sustainability demonstration of alternative fuels as long as: (1) their scope matches with the sustainability criteria agreed upon within ICAO, and (2) their effectiveness has been demonstrated, including how the standards are implemented, verified and monitored.

Certification and conformity of a product, service or system to meet certain requirements is a common approach applied to assess sustainability and recommended by the International Organization for Standardization (ISO) to promote sustainable growth.

The AFTF refers to this approach as the development of an “umbrella standard” in which a set of sustainability criteria is defined and existing regulatory or voluntary Sustainability Certification Schemes (SCS) can be recognized as a means of compliance if they cover all criteria of the “umbrella standard.” Existing SCS covering only part of the “umbrella standard” criteria will require additional certification to comply with the CORSIA sustainability requirements.

Under the current CORSIA framework, SCSs interested in being recognized under CORSIA will need to be approved by the ICAO Council, after being evaluated by a “Fuels Advisory Body” to be created under the auspices of ICAO.

This “umbrella standard” approach is similar to the approach adopted by some regulatory sustainability approaches (e.g. the European Union’s Renewable Energy Directive), which

[1] CAEP/10-WP/42
[2] As of 11/Jun/2018

defines sustainability criteria without specific indicators, which should be developed by the SCS. CAEP agreed to this approach at its 2016 Steering Group meeting and all of the sustainability criteria subsequently agreed to by CAEP and presented to the Council followed this approach.

1.4 CAEP RECOMMENDATION OF SUSTAINABILITY THEMES, PRINCIPLES, CRITERIA AND GUIDANCE

In the course of four meetings and 12 conference calls, AFTF developed a recommended set of 12 Sustainability Themes, Principles and Criteria to be adopted as part of CORSIA requirements for sustainable aviation fuels. To ensure that the proposed sustainably criteria are based on current best practices of sustainability certification, AFTF compared 10 existing approaches to sustainability, with various scopes and formats.

These Sustainability Themes, Principles and Criteria were adjusted by CAEP during its 2017 Steering Group meeting, which also agreed on specific guidance to the application of the socio-economic criteria. With regards to Themes 8, 9 and 10, the guidance aims to address concerns of national sovereignty related to the compliance with these themes. Additionally, the agreed guidance recognizes that Themes 11 and 12 are largely beyond the economic operator’s control, and ensures that compliance with them is granted exclusively on the basis of requiring the economic operator to report actions being taken to meet the related criteria, without further judgement of those actions by the SCS.

These recommendations were presented to the ICAO Council during its 212th Session (November, 2017) for consideration, as provided in **Table 1**. The detailed list of documents presented in CAEP to develop these recommendations is provided in Appendix C.

It is important to note that these recommendations from CAEP did not consider the concept of “CORSIA lower carbon aviation fuels” adopted by the ICAO Council during its 214th Session (June 2018). Further work will be conducted by CAEP to assess the suitability of these sustainability Themes, Principles and Criteria for the “CORSIA eligible fuels” (including “CORSIA lower carbon aviation fuels”), in line with the Council request for CAEP to develop further proposals, at the latest by the end of the pilot phase, on strengthened Sustainability Criteria, including Themes 1 and 2, specifically applicable to CORSIA eligible fuels (C-DEC214/10, 2 i).

Table 1 - Sustainability Themes, Principles, Criteria and Guidance recommended by CAEP during its 2017 Steering Group Meeting

Theme	Principle	Criteria
1. Greenhouse Gases (GHG)	Principle: Sustainable alternative jet fuel should generate lower carbon emissions than conventional kerosene on a life cycle basis.	Criterion 1: Sustainable alternative jet fuel shall achieve net greenhouse gas emissions reductions of at least 10% compared to fossil jet fuel on a life cycle basis.
2 Carbon stock	Principle: Sustainable alternative jet fuel should not be made from biomass obtained from land with high carbon stock.	Criterion 1: Sustainable alternative jet fuel shall not be made from biomass obtained from land converted after 1 January 2008 that was primary forests, wetlands, or peat lands and/or contributes to degradation of the carbon stock in primary forests, wetlands, or peat lands as these lands all have high carbon stocks.
		Criterion 2: In the event of land use conversion after 1 January 2008, as defined based on IPCC land categories, direct land use change (DLUC) emissions shall be calculated. If DLUC greenhouse gas emissions exceed the default induced land use change (ILUC) value, the DLUC value shall replace the default ILUC value.
3. Water	Principle: Production of sustainable alternative jet fuel should maintain or enhance water quality and availability.	Criterion 1: Operational practices shall be implemented to maintain or enhance water quality.
		Criterion 2: Operational practices shall be implemented to use water efficiently and to avoid the depletion of surface or groundwater resources beyond replenishment capacities.
4. Soil	Principle: Production of sustainable alternative jet fuels should maintain or enhance soil health.	Criterion 1: Agricultural and forestry best management practices for feedstock production or residue collection shall be implemented to maintain or enhance soil health, such as physical, chemical and biological conditions.
5. Air	Principle: Production of sustainable alternative jet fuel should minimize negative effects on air quality.	Criterion 1: Air pollution emissions shall be limited.
6. Conservation	Principle: Production of sustainable alternative jet fuel should maintain or enhance biodiversity, conservation and ecosystem services.	Criterion 1: Sustainable alternative jet fuel shall not be made from biomass obtained from areas that are protected for their biodiversity, conservation value, or ecosystem services unless evidence is provided that shows the activity does not interfere with the protection purposes.
		Criterion 2: Low invasive-risk feedstock shall be selected for cultivation and appropriate controls shall be adopted with the intention of preventing the uncontrolled spread of cultivated non-native species and modified microorganisms
		Criterion 3: Operational practices shall be implemented to avoid adverse effects on areas that are protected for their biodiversity, conservation value, or ecosystem services.
7. Waste and Chemicals	Principle: Production of sustainable alternative jet fuel should promote responsible management of waste and use of chemicals.	Criterion 1: Operational practices shall be implemented to ensure that waste arising from production processes as well as chemicals used are stored, handled and disposed of responsibly.
		Criterion 2: Operational practices shall be implemented to limit or reduce pesticide use.
8. Human and labour rights	Principle: Production of sustainable alternative jet fuel should respect human and labour rights.	Criterion 1: Sustainable alternative jet fuel production shall respect human and labour rights.
9. Land use rights and land use	Principle: Production of sustainable alternative jet fuel should respect land rights and land use rights including indigenous and/or customary rights.	Criterion 1: Sustainable alternative jet fuel production shall respect existing land rights and land use rights including indigenous peoples' rights, both formal and informal.
10. Water use rights	Principle: Production of sustainable alternative jet fuel should respect prior formal or customary water use rights.	Criterion 1: Sustainable alternative jet fuel production shall respect the existing water use rights of local and indigenous communities.
11. Local and social development	Principle: Production of sustainable alternative jet fuel should contribute to social and economic development in regions of poverty.	Criterion 1: Sustainable alternative jet fuel production shall strive to, in regions of poverty, improve the socioeconomic conditions of the communities affected by the operation.
12. Food security	Principle: Production of sustainable alternative jet fuel should promote food security in food insecure regions.	Criterion 1: Sustainable alternative jet fuel production shall, in food insecure regions, strive to enhance the local food security of directly affected stakeholders.
Guidance on the application of sustainability criteria		
Compliance with Themes 11 and 12 is granted exclusively on the basis of requiring the economic operator to report actions being taken to meet the related criteria, without further judgement of those actions by the Sustainability Certification Scheme (SCS).		
A national attestation of compliance with Themes 8, 9 and 10, and the related criteria, is considered sufficient, and precludes any assessment of those criteria by the SCS.		

CHAPTER 2. EXISTING APPROACHES TO SUSTAINABILITY

2.1 TYPES OF APPROACHES

Ten approaches to sustainability were considered for the development of the 12 CAEP Sustainability Themes and Criteria. They can be grouped as follows:

- **Internationally agreed sustainability approaches**

This category encompasses approaches that were agreed by international forums. However, differently from CORSIA, these approaches do not include a framework for enforcing compliance with their criteria. They include.

- o Food and Agriculture Organization Sustainability Assessment Of Food And Agriculture Systems) (FAO SAFA) (2013) – This approach was developed by the FAO to be an international reference for assessing trade-offs and synergies between all dimensions of sustainability. The target audience of a SAFA assessment is economic operators and stakeholders that participate in crop, livestock, forestry, aquaculture and fishery value chains. However, SAFA is also relevant to governments' strategies, policy and planning.
- o Global Bioenergy Partnership (GBEP) (2011) - developed by 23 countries and 15 international organizations and institutions including nine UN agencies, the GBEP indicators are intended to provide policy-makers and other stakeholders a set of analytical tools that can inform on the development of national bioenergy policies and programmes and monitor the impact of these policies and programmes. That is, GBEP assessments are meant to be applied at a State or regional level, not at the economic-operator-level required by CORSIA.
- o ISO 13065 - Sustainability criteria for bioenergy (2015). The purpose of this International Standard is to provide a framework for considering environmental, social and economic aspects that can be used to facilitate the evaluation and comparability of bioenergy production and products, supply chains and applications. It does not provide threshold values, which can be defined by economic operators and/or other organizations (e.g. governments). Other standards, certification initiatives and government agencies can use this International Standard as a reference for how to provide information regarding sustainability.

- **Regulatory sustainability approaches**

Sustainability approaches adopted at a national level for the sustainability assessment of economic operators. In the case of the EU RED and United States RFS, these regulatory approaches include requirements not only for the economic operators, but also reporting requirements by the responsible governmental agencies. The compliance verification is either done directly by the respective governments (e.g. ISPO) or by third-parties duly recognized to perform such verification (EU RED and US RFS). These approaches are:

- o European Union's Renewable Energy Directive (RED) (2009)
- o Indonesian Sustainable Palm Oil (ISPO) (2015)

- United States’ Renewable Fuel Standard (RFS) Program (2017)

- **Voluntary global sustainability certification schemes**

Certification schemes that are voluntarily adopted by economic operators to certify the sustainability of their products. They include frameworks for verification of compliance, as well as indicators and, in some instances, thresholds.

- Bonsucro (2016)
- International Sustainability and Carbon Certification (ISCC) (2016)
- Roundtable on Sustainable Biomaterials (RSB) (2016)
- Roundtable on Sustainable Palm Oil (RSPO) (2013)

2.2 STRUCTURE OF SUSTAINABILITY APPROACHES

Most of the sustainability approaches considered by CAEP are formatted with three layers of information: Principles, Criteria, and Indicators. These terms are defined by the ISO 13065 as follows:

> ***Principle*** *— aspirational goal that governs decisions or behavior*
>
> ***Criterion*** *— requirement that describes what is to be assessed.*
>
> > *Note 1: A criterion adds meaning and operability to a principle without itself being a direct measure of performance.*
> >
> > *Note 2: A criterion is characterized by a set of related indicators.*
>
> ***Indicator*** *— quantitative, qualitative or binary variable that can be measured or described, in response to a defined criterion.*

Some of the sustainability approaches also include specific guidance on the application of the indicators.

Table 2 provides a summary of these elements in the different sustainability approaches.

Table 2 - Summary of Sustainability Themes, Principles and Indicators in different approaches

Sustainability Approach	Reference document date	Principles	Criteria	Indicators	Guidance provided?	Target audience
CAEP	2017	12	17	0	YES	Economic Operators
FAO SAFA	2013	16	44	116	YES	Economic Operators, States
GBEP	2011	24**	0	46***	YES	States and Regional Organizations
ISO	2015	12	18	62	YES	Government, other standard-setting organizations
EU RED	2009	0*	23	8	NO	Economic operators, government agencies
ISPO	2015	7	45	131	YES	Economic operators
RFS2	2017	0*	15	0	NO	Economic operators, government agencies
BONSUCRO	2016	6	19	55	YES	Economic operators
ISCC	2016	6	96	255	YES	Economic operators
RSB	2016	12	39	156	YES	Economic operators
RSPO	2013	8	46	140	YES	Economic operators

*The EU RED and RFS2 do not explicitly reference sustainability principles or indicators.

**GBEP is based on 24 Indicators that are expressed similarly to the CAEP principles

*** As defined in the GBEP "Indicator Descriptions"

It should be noted that, while being informative, the number of principles, criteria and indicators does not necessarily represent the comprehensiveness of a specific sustainability approach, since the same topic may be covered differently by the different sustainability approaches. For example, CAEP Principle 3 (Water) covers two GBEP Principles (5 – Water use and Efficiency, and 6 – Water Quality).

More details on each of these sustainability approaches are provided in Appendix A.

CHAPTER 3. COMPARATIVE ASSESSMENT OF SUSTAINABILITY APPROACHES

3.1 METHODOLOGY USED

Sustainability aspects are considered in different ways by the existing sustainability approaches, due to their different scopes, objectives, and structures. To overcome those differences, the adherence of the Sustainability Approaches to the Sustainability Themes, Principles and Criteria recommended by CAEP was done in a qualitative manner. This qualitative assessment was performed by identifying which elements of the existing Sustainability Approaches are associated with the Themes, Principles and Criteria recommended by CAEP. In some cases, this methodology required the comparison of elements with different scopes and objectives, for example where there are elements that are included as part of the approach as responsibilities of the implementing organization (e.g., government agency), but are not explicit criteria for economic operator qualification. .

The main objective of such a qualitative assessment is to demonstrate that the list of Sustainability Themes, Principles and Criteria recommended by CAEP builds on existing approaches or combination of approaches to sustainability, including work developed by other UN bodies, fulfilling the ICAO Assembly directive of ensuring the sustainability of aviation fuels. It should not be interpreted as a recommendation or endorsement of any particular sustainability approach for the purposes of CORSIA: the current CORSIA framework includes an approval process by the ICAO Council for SCSs to be recognized under CORSIA. This process will include a detailed assessment of the SCSs by a dedicated ICAO body.

The results of this qualitative assessment are provided in this chapter. More detailed background underlying the assessment is provided in Appendix B.

3.2 ASSESSMENT OF SUSTAINABILITY PRINCIPLES

Table 3 provides an overall assessment of the inclusion of the Principles from the analyzed sustainability approaches, and the 12 Principles recommended by CAEP.

Table 3 - Comparison of Sustainability Principles coverage

	EXISTING APPROACHES TO SUSTAINABILITY									
CAEP-proposed principles	FAO SAFA	GBEP	ISO	EU RED	ISPO	RFS2	Bonsucro	ISCC	RSB	RSPO
3. Water	X	X	X	X	X	X	X	X	X	X
4. Soil	X	X	X	X	X	X	X	X	X	X
5. Air	X	X	X	X	X	X	X	X	X	X
6. Conservation	X	X	X	X	X	X	X	X	X	X
7. Waste and Chemicals	X	X	X	X	X	X	X	X	X	X
8. Human and labour rights	X	X	X	X	X		X	X	X	X
9. Land use rights and land us	X	X	X	X	X		X	X	X	X
10. Water use rights	X		X				X	X	X	X
11. Local and social developm	X	X		X	X	X	X	X	X	X
12. Food security	X	X	X	X		X		X	X	
total principles covered	**10**	**9**	**9**	**9**	**8**	**7**	**9**	**10**	**10**	**9**

3.3 ASSESSMENT OF SUSTAINABILITY CRITERIA

Table 4 provides an overall assessment of the Criteria from the analyzed sustainability approaches, and the 17 Criteria recommended by CAEP.

A detailed assessment of the wording of the different Criteria and detailed references are provided in Appendix B.

Table 4 - Comparison of Sustainability Criteria coverage

	EXISTING APPROACHES TO SUSTAINABILITY									
	FAO SAFA	GBEP	ISO	EU RED	ISPO	RFS2	Bonsucro	ISCC	RSB	RSPO
3.1 Water Quality	x	x	x	x	x	x	x	x	x	x
3.2 Water Use	x	x	x	x	x	x	x	x	x	x
4.1 Soil Health	x	x	x	x	x	x	x	x	x	x
5.1 Air Pollution	x	x	x	x	x	x	x	x	x	x
6.1 Conservation – Use of Protected Areas	x	x	x	x	x	x	x	x	x	x
6.2 Conservation – Invasive Feedstocks	x	x		x		x		x	x	
6.3 Conservation – Effects on Protected Areas	x	x	x	x	x	x	x	x	x	x
7.1 Waste and Chemicals - Use and Disposal	x	x	x	x	x		x	x	x	x
7.2 Waste and Chemicals – Pesticide Use	x				x	x	x	x	x	x
8.1 Human and Labour Rights	x	x	x	x	x		x	x	x	x
9.1 Land use rights and land use	x	x	x	x	x		x	x	x	x
10.1 Water use rights	x		x				x	x	x	x
11.1 Local and social development	x	x		x	x	x	x	x	x	x
12.1 Food security	x	x	x	x		x		x	x	
total criteria covered	**14**	**12**	**11**	**12**	**11**	**10**	**12**	**14**	**14**	**12**

CHAPTER 4. CONCLUSIONS

The need for a common definition of sustainability requirements at the international level applicable to alternative fuels has been an ICAO concern and request since the potential of those fuels to reduce international aviation effects on climate change was identified.

ICAO Assembly resolutions have called to ensure the sustainability of alternative fuels for aviation, and for the harmonization of approaches to sustainability building up on existing approaches or combination of approaches,

In addition to achieving net GHG emissions reductions, the 38th and 39th Assemblies agreed that to be sustainable, aviation alternative fuels should also contribute to local social and economic development, and that competition with food and water should be avoided.

The adoption of ICAO CORSIA SARPs in 2018 established the need to define Sustainability Criteria for the specific purpose of CORSIA compliance for certain fuels to be eligible under the Scheme to reduce offsetting obligations.

Considering these agreements from the Assembly and ICAO Conferences, the Committee on Aviation Environmental Protection (CAEP) developed a list of 12 Sustainability Themes and Principles, and 17 associated Criteria that should be met for an aviation fuel to generate carbon offset reductions under CORSIA. This list was agreed by CAEP during its 2017 Steering Group meeting (Montreal, Canada, 11 to 15 September 2017), and only considered sustainable aviation fuels.

The analysis presented in this report supports the conclusion that the list of 12 Sustainability Themes and Principles, and the 17 associated Criteria recommended by CAEP builds on existing global approaches or combination of approaches to Sustainability, including work developed by other UN bodies, which comprises:

- ✓ Internationally-agreed sustainability approaches developed by: the UN FAO, the Global Bioenergy Partnership (which comprises 52 countries and 28 international organizations including 9 UN bodies) and the International Organization for Standardization (ISO).
- ✓ Regulatory sustainability approaches developed by the EU, Indonesia, and the United States.
- ✓ Voluntary global sustainability certification schemes currently widely used in bioenergy production.

A comparative analysis of the sustainability themes, principles and criteria included on those global approaches show that the recommended list of 12 Sustainability Themes and Principles, and the 17 associated Criteria, for the purpose of its application in CORSIA, fulfil the ICAO Assembly directive of ensuring the sustainability of aviation fuels while building upon a combination of existing global approaches to sustainability. As part of the CORSIA framework, an approval of the ICAO Council is required for the recognition of any sustainability approach under CORSIA.

APPENDIX A – SUSTAINABILITY APPROACHES CONSIDERED BY CAEP

A.1 FAO SAFA

SAFA is a holistic global framework developed by the FAO (Food and Agriculture Organization of the United Nations) for the assessment of sustainability along food and agriculture value chains. SAFA establishes an international reference for assessing trade-offs and synergies between all dimensions of sustainability. It has been prepared so that enterprises, whether companies or small-scale producers, involved with the production, processing, distribution and marketing of goods have a clear understanding of the constituent components of sustainability and how strength, weakness and progress could be tackled. By providing a transparent and aggregated framework for assessing sustainability, SAFA seeks to harmonize sustainability approaches within the food value chain, as well as furthering good practices.

The SAFA provide the protocol for assessing sustainability along 21 themes and 58 sub-themes, and 118 default indicators, which are applicable at the macro level – meaning to all enterprise sizes and types, and in all contexts. Specific guidelines are also provided, together with a computational tool and mobile app that assist users in their implementation.

Reference: http://www.fao.org/nr/sustainability/sustainability-assessments-safa/en/

A.2 GBEP (FAO)

The Global Bioenergy Partnership (GBEP) was created in 2006 with the mission to promote the wider production and use of modern bioenergy, particularly in the developing world where traditional use of biomass is prevalent. GBEP includes 23 Partner countries and 15 Partner international organizations and institutions (9 UN bodies among them), along with 29 countries and 13 international organizations that participate as Observers. It is supported by the GBEP Secretariat, hosted at FAO Headquarters in Rome.

In 2011, GBEP published the first edition of "The Global Bioenergy Partnership Sustainability Indicators for Bioenergy". This report includes 24 sustainability indicators for bioenergy and their methodology sheets, which were intended to provide policy-makers and other stakeholders with a tool that can inform on the development of national bioenergy policies and programmes, monitor the impact of these policies and programmes, as well as interpret and respond to the environmental, social and economic impacts of their bioenergy production and use.

It should be highlighted that GBEP indicators are value-neutral, do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binding. The "GBEP indicators" can be correlated with the "Principles" and "Indicators" from other sustainability approaches. These indicators are intended to inform on policy-making and facilitate the sustainable development of bioenergy.

Although being considered by CAEP, especially for the identification of themes, it should be noted that the GBEP approach is not in line with the CAEP needs for sustainability certification, since its scope is just to evaluate State´s bioenergy policies, and not specific project-scale performance.

References: http://www.fao.org/docrep/016/i2668e/i2668e.pdf

http://www.globalbioenergy.org/programmeofwork/task-force-on-sustainability/gbep-report-on-sustainability-indicators-for-bioenergy/pt/

A.3 ISO 13065

The International Organization for Standardization (ISO) was officially established in 1947 in order to "facilitate the international coordination and unification of industrial standards". The 22,236 International Standards published by ISO to date cover various aspects of technology and manufacturing. As of 2018, ISO includes 783 technical committees and subcommittees, made up of members from 160 States. The organization is supported by the ISO Central Secretariat, based in Geneva, Switzerland.

In 2015, ISO published the first edition of "ISO 13065: Sustainability criteria for bioenergy". This standard includes general requirements and recommendations, 12 sustainability Principles with associated Criteria and Indicators, and informative guidance related to several of the indicators. This Standard provides a framework for considering environmental, social and economic factors, and can be used to evaluate bioenergy production and products, supply chains, and applications. The Standard indicates that it was developed with due consideration to existing relevant sustainability initiatives and International Standards.

Reference: https://www.iso.org/standard/52528.html

A.4 EU RED

The European Union's Renewable Energy Directive (RED) was established by the European Parliament and the Council of the European Union in 2009. This Directive established a policy for the production and promotion of renewable energy throughout the EU. The EU RED mandated that 20% of the EU's total energy needs are to be met with renewables by 2020, and established individual targets for each EU member state. It also mandated that 10% of each EU member state's transport fuels must come from renewable sources by 2020.

The EU RED includes requirements related to 8 of the CAEP-proposed sustainability criteria. These requirements can be found in Article 17, "Sustainability criteria for biofuels and bioliquids" and Article 18, "Verification of compliance with the sustainability criteria for biofuels and bioliquids".

References: https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN

A.5 ISPO

The Indonesian Sustainable Palm Oil (ISPO) policy was established by the Government of Indonesia in the interest of improving the competitiveness of Indonesian palm oil in the global market, while reducing greenhouse gas emissions. The most recent version of the policy was published in 2015. It includes five separate annexes that detail the regulations relevant for various types of producers and manufacturers. The Annexes used for comparison within this document were Annex II, III and IV which apply to plantation companies and mills, while annexes V and VI apply to smallholders. As the regulation is published in the Indonesian language, for the purpose of this work a courtesy translated version provided by the Government was used.

References: http://www.ispo-org.or.id/index.php?lang=en

A.6 US RFS2

The United States' Renewable Fuel Standard (RFS) Program was created by the U.S. Congress in an effort to reduce greenhouse gas emissions while encouraging the development of renewable fuels. The RFS was first created under the Energy Policy Act of 2005. It was largely amended by the Energy Independence and Security Act of 2007 (RFS2). The RFS is implemented by the Environmental Protection Agency (US EPA) in cooperation with the Department of Agriculture and the Department of Energy. The RFS mandates a "volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel, heating oil or jet fuel". Fuel pathways (based on feedstock, production process, and fuel type) are approved for RFS inclusion based on GHG intensity, as well as other sustainability criteria. The applicable regulations are found at 40 CFR Part 80, Subpart M.

References: https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard

A.7 BONSUCRO

Bonsucro is a global multi-stakeholder non-for-profit initiative that provides voluntary sustainability certification for the sugarcane industry. The Bonsucro Production Standard can be applied worldwide to any sugarcane mill and their suppliers. It was first established in 2005 and has since grown to include over 480 members, representing 25% of land used for sugarcane production. The organization is supported by the Bonsucro Secretariat, based in London, England.

The most recent version of the Bonsucro Production Standard is Version 4.2, published in 2016. This version included updates that align Bonsucro with the requirements of EU RED, and covers three pillars of sustainability: economic, social and environmental viability. The document defines "a set of principles, criteria and indicators, along with explanatory notes, for the assessment of the performance of operators against the three pillars of sustainability". It was developed alongside a document titled "Guidance for the Bonsucro Production Standard" which provides further support for compliance with the Bonsucro Production Standard.

References: https://www.bonsucro.com/what-is-bonsucro/

http://www.bonsucro.com/wp-content/uploads/2017/04/Bonsucro-PS-STD-English-2.pdf

A.8 ISCC

The International Sustainability and Carbon Certification (ISCC) is an independent multi-stakeholder organisation providing sustainability certification for various raw materials and products around the world. The ISCC certification system is applicable to entire supply chains, including all feedstock types. The ISCC Association (ISCC e.V.), the governing body of the ISCC, is based in Cologne, Germany.

The ISCC requirements used for comparison with the CAEP-proposed sustainability criteria are those within ISCC Plus. ISCC Plus includes sets of sustainability add-ons, which can be implemented on top of the requirements set in the standard. The latest version of ISCC Plus is ISCC202, "Sustainability Requirements for the Production of Biomass," published in 2016. These requirements include 6 overarching sustainability principles and corresponding detailed criteria for the production of sustainable biomass.

References: https://www.iscc-system.org/about/governance-and-transparency/

https://www.iscc-system.org/process/audit-and-certification-process/iscc-system-documents/

A.9 RSB

The Roundtable on Sustainable Biomaterials (RSB) is an independent multi-stakeholder coalition providing sustainability certification around the world. The RSB has members from 60 organizations, including businesses, NGOs, academics, government and UN organisations. The RSB is supported by its Secretariat, based in Geneva, Switzerland.

The most recent version of the RSB's Principles and Criteria (Version 3.0) was published in 2016. The document includes the RSB's 12 overarching principles for sustainability, which are further elaborated into specific criteria and minimum requirements (e.g. indicators). The RSB has also published a series of standards, procedures and guidance documents, to complement the Principles & Criteria. Together, these documents represent the RSB Standard.

References: https://rsb.org/about/what-we-do/the-rsb-principles/

http://rsb.org/wp-content/uploads/2017/04/RSB-STD-01-001_Principles_and_Criteria-DIGITAL.pdf

A.10 RSPO

The Roundtable on Sustainable Palm Oil (RSPO) is a not-for-profit organization that includes stakeholders from the entire palm oil supply chain. It was formally established in 2004, and has since grown to include over 3,000 members worldwide. RSPO aims to promote the production and use of sustainably derived palm oil. As of 2017, over 19% of the world's palm oil production was certified by the RSPO. The RSPO is supported by the RSPO Secretariat, headquartered in Kuala Lumpur, Malaysia.

The RSPO requirements used for comparison with the CAEP-proposed sustainability criteria are those within RSPO P&C 2013, "Audit Checklist for assessing compliance". This standard includes 8 overarching sustainability principles, which are further elaborated into a series of criteria and indicators. Each indicator has a set of questions included as a checklist, and some indicators include additional guidance information.

References: https://rspo.org/about

https://rspo.org/about/who-we-are

https://www.rspo.org/key-documents/certification/rspo-principles-and-criteria#

APPENDIX B – QUALITATIVE ASSESSMENT OF SUSTAINABILITY CRITERIA

Note. The material contained in Appendix B, "Qualitative Assessment of Sustainability Criteria", of Appendix A, "Report on Sustainability Themes, Principles and Criteria for Sustainable Aviation Fuels," to the CAEP/11 Report on Agenda Item 9, is available at the following link:

http://www.icao.int/environmental-protection/Documents/CAEP11_assessment_of_sustainability_criteria.pdf

APPENDIX C – CAEP REFERENCES

CAEP-AFTF References	
Reference	**Title**
CAEP/11-AFTF/1-WP/03	Task S.5: Sustainability Criteria
CAEP/11-AFTF/1-IP/05	CAEP/10 Scoping Study for Future Work on Sustainability Criteria for Alternative Fuels
CAEP/11-AFTF/1-IP/10	Alternative Jet Fuel Environmental Sustainability Overview
CAEP/11-AFTF/1-IP/15	Supply and Sustainability of Carbon Credits and Alternative Fuels for International Aviation (2020-2035)
CAEP/11-AFTF/1-IP/16	ICSA'S Views on the Work of the Alternative Fuels Task Force
CAEP/11-AFTF/1-IP/18	Extract from CAEP/10 Report
CAEP/10-AFTF/04-FL/08	Sustainability criteria for alternative aviation fuels under the GMBM Scoping study
CAEP/11-AFTF/1-Report	Report of the First Meeting
CAEP/11-AFTF/2-WP/04	Report of the Sustainability Task Group
CAEP/11-AFTF/2-IP/02	Process for Confirming LCA and Sustainability of Alternative Fuels
CAEP/11-AFTF/2-FL/11	AFTF Task S5 Sustainability
CAEP/11-AFTF/2-Report	Report of the Second Meeting
CAEP/11-AFTF/3-WP/06 - Presentation	AFTF Sustainability Task Group WP/6 - Presentation
CAEP/11-AFTF/3-WP/06	Report of the Sustainability Task Group
CAEP/11-AFTF/3-WP/06 – Appendix B	Sustainability Criteria for Alternative Aviation Fuels
CAEP/11-AFTF/3-WP/07 - Presentation	Sustainability Criteria Tracking
CAEP/11-AFTF/3-WP/07	Sustainability Criteria Tracking
CAEP/11-AFTF/3-FL/01	Environmental Themes Principles and Criteria
CAEP/11-AFTF/3-FL/06	Sustainability Criteria for Alternative Aviation Fuels
CAEP/11-AFTF/3-FL/08	Framework for Treating Sustainability Under CORSIA
CAEP/11-AFTF/3-Report	Report of the third Meeting
CAEP/11-AFTF/4-WP/07 - Presentation	Report of the Sustainability Task Group - Presentation
CAEP/11-AFTF/4-WP/07	Report of the Sustainability Task Group
CAEP/11-AFTF/4-WP/08 -	ICAO Sustainability Standard Eligibility Process - Presentation

Presentation	
CAEP/11-AFTF/4-WP/08 rev1	ICAO Sustainability Standard Eligibility Process
CAEP/11-AFTF/4-IP/08 - Presentation	Risk Based Verification of the Protection of No Go Areas for the Production of Sustainable Alternative Jet-Fuels - Presentation
CAEP/11-AFTF/4-IP/08	Risk Based Verification of the Protection of No Go Areas for the Production of Sustainable Alternative Jet-Fuels
CAEP/11-AFTF/04-FL07	Sustainability Criteria Status after AFTF04
CAEP-SG/20153-WP/28	Methodology for the Assessment of Life Cycle Emissions from Alternative Jet Fuels for use in the Global Market Based Measure System
CAEP-SG/20153-WP/48	Further Assessment of Alternative Fuels in a Global Market-Based Measure (MBM)
CAEP-SG/20153-SD/4	Summary of Discussions and Decisions of the Fourth Meeting of the Steering Group
CAEP-SG/20161-WP/21	Report of the Sustainability Task Group
CAEP-SG/20161-SD/3	Summary of Discussions and Decisions of the Third Meeting of the Steering Group
CAEP-SG/20172-WP/6	ICAO CORSIA Package
CAEP-SG/20172-WP/13	Sustainability Themes, Principles and Criteria for Alternative Fuels Under CORSIA
CAEP-SG/20172-SD/2	CAEPSG.20172.SD.2 Agenda Item 4 SD sections (AFTF)
CAEP/9-IP/6	Sustainable Alternative Fuels for Aviation
CAEP/10-WP/42	Scoping Study for Future Work on Sustainability Criteria for Alternative Fuels

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APPENDIX B
(English only)

ICAO DOCUMENT

CORSIA SUSTAINABILITY CRITERIA FOR CORSIA ELIGIBLE FUELS

Theme	Principle	Criteria
1. Greenhouse Gases (GHG)	Principle: CORSIA eligible fuel should generate lower carbon emissions on a life cycle basis.	Criterion 1: CORSIA eligible fuel shall achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis.
2. Carbon stock	Principle: CORSIA eligible fuel should not be made from biomass obtained from land with high carbon stock.	Criterion 1: CORSIA eligible fuel shall not be made from biomass obtained from land converted after 1 January 2008 that was primary forest, wetlands, or peat lands and/or contributes to degradation of the carbon stock in primary forests, wetlands, or peat lands as these lands all have high carbon stocks.
		Criterion 2: In the event of land use conversion after 1 January 2008, as defined based on IPCC land categories, direct land use change (DLUC) emissions shall be calculated. If DLUC greenhouse gas emissions exceed the default induced land use change (ILUC) value, the DLUC value shall replace the default ILUC value.

2.1 Guidance on the application of sustainability criteria

a) *Compliance with Themes 1 and 2 is granted on the basis of independent attestation by CORSIA approved Sustainability Certification Schemes;*
b) *Work on other themes such as Water; Soil; Air; Conservation; Waste and Chemicals; Human and labour rights; Land use rights and land use; Water use rights; Local and social development; and Food security, and related criteria, and on the application of these criteria, is ongoing under the Committee on Aviation Environmental Protection (CAEP) and will be subject to approval by the Council by the end of the pilot phase;*
c) *CORSIA Sustainability Criteria for CORSIA Eligible Fuels does not set a precedent for, or prejudge the outcome of negotiations in other fora.*

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APPENDIX C

(English only)

PROPOSED TERMS OF REFERENCE FOR THE CAEP SCS EVALUATION GROUP (SCSEG)

1. **MANDATE**

1.1 The SCSEG is a subgroup of CAEP mandated with developing technical recommendations to the Council on the eligibility of Sustainability Certification Schemes (SCS).

2. **TASKS**

2.1 In fulfilling this mandate, the CAEP SCSEG is tasked to:

1) undertake the evaluation of Sustainability Certification Schemes (SCS) against the eligibility requirements listed in the ICAO document "CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes";

2) develop technical recommendations based on the above evaluation of SCS applicants for submission to the Council;

3) ensure that SCS around the world can receive advance notice of, and are given ample time to apply for, the evaluation by CAEP SCSEG, and conduct outreach as necessary, with the support of the ICAO Secretariat;

4) collect additional information from SCS and/or economic operators and issue guidance to the SCSs, as required;

5) monitor the compliance of the SCS contained in the ICAO document "CORSIA Approved Sustainability Certification Schemes" with the "CORSIA Eligibility Framework and Requirements for SCSs", and make technical recommendations to Council to decide on the continuity of the SCSs being on the list of eligible SCS;

6) ensure SCS eligibility is re-assessed at least every five years; and

7) raise any technical issues to CAEP for consideration, including issues related to the ICAO document "CORSIA Eligibility Framework and Requirements for SCS".

3. **GOVERNANCE STRUCTURE**

3.1 The SCSEG subject administrative to guidance from CAEP and members are nominated by CAEP Members.

3.2 SCSEG Members are invited to observe the deliberations of CAEP and the CAEP Fuels Task Group (CAEP FTG) but the SCSEG technical work is independent of these bodies.

3.3 The SCSEG's technical recommendations on the eligibility of SCS are contained in a report that is sent to CAEP Members and CAEP Observers who will have 30 days to provide comments on the report prior to the report being forwarded to the Council by CAEP. These comments from CAEP Members and CAEP Observers are reported by CAEP to the Council alongside the report of the CAEP SCSEG.

3.4 Evaluations and reports from the SCSEG following the procedure described above and subsequent reporting to the Council could occur at any time during the CAEP cycle without the need of a formal CAEP meeting.

4. EXPERTISE AND EXPERIENCE REQUIREMENTS

4.1 In order for the CAEP SCSEG to undertake the tasks as outlined in paragraph 2 above, SCSEG members are required to meet at least two of the following five technical expertise and experience requirements, which have to be substantiated at the time of nomination:

a) experience in the development or deployment of fuels for aviation which could fall under the definition of sustainable fuels or lower carbon fuels;

b) experience in the design, development, operation or evaluation of SCS;

c) experience in the development, assessment, or implementation of international standards relevant to aviation fuel, sustainability certification, or sustainable development;

d) experience in fossil-based fuels, biomass, biofuel and/or agriculture value chain sustainability assessments and requirements; and

e) experience in the development, assessment, or oversight of climate change policies and/or sustainable development policies.

4.2 In addition, it would be desirable (though not essential) that CAEP SCSEG members have experience with ICAO processes, in particular those related to CORSIA.

4.3 The collective membership of the CAEP SCSEG should cover all of the areas of expertise provided in Section 4.1.

5. MEMBERSHIP

Nomination of CAEP SCSEG members

5.1 In principle, the size of the SCSEG should be in the order of 14 to 16 experts, nominated by CAEP Members, taking into account the need for balanced geographical representation.

5.2 Nomination is to be made through the submission of a letter (or an email) to the CAEP Secretary, highlighting the areas of expertise and experience of the proposed expert, including a personal conflict of interest declaration and a statement of commitment by the proposed expert to the work of CAEP SCSEG for at least one full CORSIA compliance cycle (i.e., 3 years). Nominations would be considered for approval by CAEP.

Selection of Co-Chairpersons for CAEP SCSEG

5.3 The CAEP SCSEG selects two co-Chairpersons from among its members at its first meeting.

5.4 The co-Chairpersons should not be from the same geographical region.

Replacement of CAEP SCSEG Members during a CORSIA compliance cycle

5.5 The replacement of an existing CAEP SCSEG Member during a compliance cycle of the CORSIA is allowed, if the replacement member is approved by CAEP (through correspondence).

5.6 The replacement must meet the same criteria as outlined in the TOR.

5.7 The outgoing member's nominating CAEP Member should first be allowed to nominate a replacement.

5.7.1 If a replacement is not nominated by that CAEP Member or should CAEP reject the nominated replacement, the CAEP Secretary would then seek nominations from CAEP Members of the outgoing member's geographic region.

5.7.2 If a replacement is not nominated by CAEP Members from that geographical region or should CAEP reject the nominated replacement(s), the CAEP Secretary would then seek nominations from all CAEP Members.

5.7.3 Where possible, the replacement of CAEP SCSEG Members should be staggered over CORSIA compliance cycles to ensure continuity of knowledge and expertise.

6. AVOIDANCE OF CONFLICTS OF INTEREST

6.1 As a part of the nomination process, SCSEG nominees will have to present a personal declaration about potential conflicts of interest assessed/validated by the proposing CAEP Member. SCSEG Members should not benefit materially from decisions made by the SCSEG. This could include employment by or having financial and/or commercial interest in any SCS or an economic actor along the fuel supply chain that would benefit from the expert's appointment. This has to be substantiated at the time of nomination, through a personal declaration.

7. WORKING METHODS

Modality and frequency of SCSEG meetings

7.1 Face-to-face meetings of the CAEP SCSEG are the primary means of organizing its work, making significant decisions and resolving substantive issues.

7.2 The CAEP SCSEG is also expected to conduct business via teleconferences and emails between the face-to-face meetings to progress the work.

7.3 The CAEP SCSEG will discuss and agree on a schedule of meetings, which can be reviewed later as necessary. The number of meetings should be sufficient to achieve its deliverables.

7.4 If changes to the meeting schedule or additional meetings are required, the co-Chairpersons will, after consultations with CAEP SCSEG Members, give notice of any changes in the meeting schedule and/or additional meetings.

Quorum for CAEP SCSEG recommendations

7.5 A majority of CAEP SCSEG Members from at least three geographical regions must be present at its meeting in order to constitute a quorum to make technical recommendations.

Working language for CAEP SCSEG meetings

7.6 The working language of the CAEP SCSEG is English. The recommendations of CAEP SCSEG are translated in all six languages, for consideration by the Council.

Decision process of CAEP SCSEG

7.7 The SCSEG's technical recommendations, including the underlining decisions by the SCSEG, are taken by consensus. If there is no consensus, then the prevailing and alternative conclusions will be described and substantiated, and presented to the Council for decision.

8. PUBLIC INFORMATION, TRANSPARENCY AND COMMUNICATION

8.1 Applications and other information submitted by SCSs will be publicly available on the ICAO CORSIA website, except for materials, which the applicants designate as business confidential.

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APPENDIX D
(English only)

ICAO DOCUMENT

CORSIA ELIGIBILITY FRAMEWORK AND REQUIREMENTS FOR SUSTAINABILITY CERTIFICATION SCHEMES

1. Definitions:

Accreditation bodies: authoritative bodies that perform accreditation (ISO 17011).

Accreditation: a third-party attestation related to a certification body conveying formal demonstration of its competence to carry out specific conformity assessment tasks (adapted from ISO 17011).

Auditors: Auditors plan, conduct and complete audits on behalf of the certification body. Responsibilities include designing risk-based audit and evidence-gathering plans, designing sampling procedures, evaluating the adequacy and sufficiency of evidence of compliance, identifying nonconformities, issuing a recommendation for or against certification and preparing an audit report.

Audits: systematic, independent and documented processes for obtaining audit evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled (adapted from ISO 19011:2011).

Certification bodies: third-party conformity assessment bodies (ISO 17065:2012) making certification decisions and issuing certificates.

Economic operator: Economic operators include feedstock producers, processing facilities, and traders.

Stakeholder: individual or group that has an interest in any decision or activity of an organization (adapted from ISO 26000).

Sustainability Certification Schemes (SCS): organizations that certify economic operators against the sustainability criteria, and ensure that economic operators calculate actual life cycle emissions values (if default values are not applied) using the agreed methodology. SCS define sustainability certification requirements, set requirements for certification bodies, auditors and accreditation bodies, and monitor effectiveness of the assurance mechanism.

2. Eligibility requirements.

SCS meets the requirements specified in Table 1.

Table 1: Requirements for SCS

#	THEME	REQUIREMENT
1)	Documentation management	• SCS has a documentation management system that addresses each of the following elements: o General management system documentation for the SCS CORSIA certification programme (e.g. policies, roles/responsibilities within SCS, etc.). o Control of documents. o Control of records. o Management review of management system. • SCS keeps records for a minimum of 10 years.
2)	Audit competencies	• The SCS documentation describes in sufficient detail the specific audit competencies requirements and how it is ensured that the requirements concerning auditors' competencies (see Table 5, Requirement 6) are met.
3)	SCS Group auditing requirements (where applicable)	• Where the SCS permits group auditing, SCS establishes requirements and provides guidance to certification bodies on: o Risk-based sampling of units within a group audit, including minimum sample size (see Table 5, Requirement 5) and the threshold for non-compliance. o Group management. o Process and conditions to join a group.
4)	Non-compliance with certification requirements	• SCS has documented procedures for addressing when a certified economic operator is found to not comply with the certification requirements. This includes: o Procedures for withdrawing or suspending certificates and the circumstances under which this occurs. o Procedures to ensure that any non-conformities that do not lead to immediate withdrawal or suspension of the certificate are corrected. • SCS makes these procedures available to economic operators.
5)	Monitoring and system review	• SCS has procedures and timelines for reviewing its CORSIA certification programme, including compliance of economic operators, certification bodies and accreditation bodies with the provisions of the programme, to ensure its continuing integrity, adequacy, and effectiveness. • Review of the CORSIA certification programme occurs at planned intervals and after significant changes to the CORSIA requirements as specified by ICAO, as well as in response to complaints received, where necessary. • SCS uses the results of the review to improve its assurance programme where indicated and maintains records of any corrective actions taken.

6)	Transparency	• SCS ensures that the following information is made publicly available on a website: ○ The list of economic operators that are certified under its CORSIA certification programme, including the start and expiry dates of each certificate, and those who no longer participate. Information on the withdrawal or suspension of certificates must be published without delay after the decision has been made. ○ The latest version of SCS CORSIA certification programme requirements. ○ The list of certification bodies that are permitted to conduct audits within the CORSIA certification programme, as well as any certification bodies that are no longer permitted to conduct audits within the programme and those that are temporarily suspended. ○ Publication of contact details for the SCS CORSIA certification programme e.g. telephone number, email address and correspondence address. ○ The names of any other eligible SCS that the subject SCS recognizes within its CORSIA certification programme.
7)	Annual reports	• Recognized SCS submits annually a report to ICAO that includes relevant information • SCS has a procedure in place to collect the information required to fulfil this reporting obligation. • SCS records detailed information about the calculation of actual values within their system and provide this information to ICAO on request, in line with the ICAO document entitled, “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values”.
8)	Risk Management Plan	• SCS has a documented plan for addressing the risks to the integrity of the assurance system.
9)	Accreditation of certification bodies	• SCS uses an accreditation body complying with ISO 17011 to ensure that certification body requirements listed herein are implemented by the certification bodies. • SCS periodically assesses the effectiveness of the accreditation mechanism as part of their system review. • SCS has procedures in place that ensure that the accreditation body has the following competencies: o Knowledge of the 5 ICAO documents that compose the CORSIA Implementation Elements related to CORSIA eligible fuels and the SCS CORSIA certification programme requirements. o Competence to review sampling protocols and practice, where this is undertaken by the Certification Body. o Competence to review assessment of groups under group auditing procedures, where this is permitted by the SCS and undertaken by the Certification Body.
10)	Stakeholder Engagement	• SCS has a process for incorporating stakeholder input relevant to the CORSIA sustainability criteria and adequate to the scope and scale of the operation.
11)	Complaint procedure	• SCS has a documented complaints procedure to respond to complaints received from clients, the public and other stakeholders about its CORSIA certification programme and fraud or potential fraud. • SCS has procedures in place for: o Investigating and responding to relevant complaints, including reporting relevant information, to the oversight body or certification body, as appropriate and in a timely manner. o Reviewing the assurance system and taking corrective actions where necessary (see

		Table 1, Requirement 5). o Documenting all complaints received and actions taken for consideration in the system review. • SCS has procedures in place for responding to requests for information from the ICAO Fuels Advisory Body.
12)	Transparency on GHG reporting and accounting	• SCS will provide any information required by the relevant national authority related to GHG reporting.

SCS ensures that economic operators meet the general requirements specified in Table 2.

Table 2: General requirements set by SCS on Economic Operators

	THEME	REQUIREMENTS
1)	Documentation management	• SCS requires that economic operators: i) have an auditable documentation management system for the evidence related to the claims they make or rely on for certification; ii) keep records for a minimum of 5 years; and iii) accept responsibility for preparing any information related to the auditing of such evidence.
2)	Transparency on other SCS participation by economic operators	• SCS requires all economic operators to declare the names of all SCS under which they are and/or were certified and make available to the auditors all information relevant to those certifications.

3)	CORSIA certification requirements	• SCS requires the economic operator to demonstrate and document that it satisfies all CORSIA requirements specific to the economic operator stated herein, including the following which form the basis for audit objectives:
		o The fuel under review satisfies the CORSIA sustainability criteria specified [ICAO Document “CORSIA Sustainability Criteria for CORSIA Eligible Fuels”].
		o (where applicable) The default GHG LCA value applied by the economic operator matches the value and associated feedstock and conversion process (pathway) specified by ICAO in the ICAO Document “CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels”.
		o (where applicable) The system of the economic operator to calculate GHG emissions for an actual LCA value ensures that:
		  o The CORSIA LCA methodology specified in the ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values” is accurately followed to calculate its actual LCA value.
		  o The LCA value calculation is complete, accurate and transparent.
		o (where applicable) The actual LCA value calculated by the economic operator is accurate and has been calculated in accordance with the CORSIA LCA methodology specified in the ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values” using the most recent data available.
		o (where applicable) The emissions credits used to calculate the actual LCA value by the economic operator are accurate, have been calculated in accordance with the relevant CORSIA emissions credit methodology or methodologies, and satisfy all other requirements for emissions crediting, as specified in the ICAO document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values”,

		Section 6. o In the case of waste or residue feedstocks, the material meets the definition for waste or residues specified by ICAO for CORSIA and can be traced back to the first gathering point [ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values”, Section 4]. o In the case of by-products, the material meets the definition for by-products specified by ICAO for CORSIA and can be traced back to the point of origin [ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values” , Section 4]. o In the case of low LUC risk feedstocks, the feedstocks and / or land use practices meet the criteria specified by ICAO for CORSIA [ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values”, Section 5].

SCS ensures that economic operators meet the traceability requirements specified in Table 3.

Table 3: Traceability requirements set by SCS on Economic Operators

	THEME	REQUIREMENTS
1)	Traceability: Mass balance	• SCS requires economic operators to use a mass balance system that: a) Allows batches of sustainable materials with differing sustainability characteristics to be mixed. b) Requires information about the sustainability characteristics and sizes of the physical quantity (batches) referred to in point (a) to remain assigned to the mixture. c) Provides for the sum of all consignments withdrawn from the mixture to be described as having the same sustainability characteristics, in the same quantities, as the sum of all consignments added to the mixture. d) Demonstrates that the product claims are linked correctly to the feedstock quantities claimed.
2)	Traceability: Mass balance system documentation	• SCS requires each economic operator to include, as part of its documentation management system (see Table 2, Requirement 1), a system for documenting the mass balance. • SCS requires the economic operator to assign a unique reference/identification number to each batch of certified product sold (also known as batch number).
3)	Traceability: Mass balance level of operation	• SCS requires economic operators to operate the mass balance system at a site level. • SCS requires that if more than one legal entity operates on a site then each legal entity that is an economic operator is required to operate its own mass balance.
4)	Traceability: Mass balance timeframe	• SCS requires the economic operator to monitor the balance of material withdrawn from and added to the mass balance system. • SCS requires economic operators to specify a timeframe over which they will ensure that the mass balance is respected. o The operator ensures that the balance is achieved over an appropriate period of time no longer than three months. A deficit is not allowed at the end of the period. • At the end of the reporting period, a positive balance can be forwarded to the next reporting period as long as an equivalent physical stock is available.

SCS ensures that economic operators meet the information transmission requirements specified in Table 4.

Table 4: Information Transmission requirements set by SCS on Economic Operators

	THEME	REQUIREMENT
1)	Transmission of information in the supply chain	• SCS requires the economic operator to transmit relevant information necessary to demonstrate compliance with the CORSIA sustainability criteria throughout the supply chain. The information transmitted includes all of the relevant reporting elements listed in Annex 16. Volume IV, Appendix 5, Table A5-2 for which the economic operator has information. The information is related to a specific physical quantity of material.

SCS ensures that certification bodies meet the requirements specified in Table 5.

Table 5: Requirements set by SCS on Certification Bodies

	THEME	REQUIREMENTS
1)	Accreditation and Auditing Standards	• SCS requires certification bodies to be accredited to ISO standard 17065 by an accreditation body operating in compliance with ISO 17011. • SCS requires that certification bodies are accredited in accordance with Table 1, Requirement 9. • SCS requires certification bodies to inform the SCS immediately if the accreditation is suspended, withdrawn or terminated by the accreditation body. • SCS requires that certification bodies conduct assessments of GHG LCA values in line with ISO 14064-3. • SCS requires that certification bodies conduct audits in line with ISO 19011.
2)	Audits	• The SCS requires that certification bodies being recognized within its CORSIA certification programme, apply the audit objectives to meet CORSIA certification requirements (Table 2, Requirement 3) . • Initial audits should be performed on-site. • SCS may permit remote audits by the certification body under the following conditions: ○ The audit risk as assessed by the certification body is low. ○ The same level of assurance can be achieved with remote audits as with on-site audits. ○ Sufficient traceability (mass balance) records, greenhouse gas data and other forms of appropriate evidence are available. ○ The systems in place for collecting and processing traceability and greenhouse gas data and ensuring data quality are reliable. • It is the responsibility of the certification body to define the size of the sample of mass balance or GHG data to audit in consideration of the audit risk and the required level of assurance (see Table 5, Requirement 7).
3)	Transfer from one SCS to another	• Prior to re-certification of an economic operator that was previously found to be in major non-conformity with any other SCS, the certification body will be required to bring this to the attention of the SCS.

4)	Certificate Issuance	• The SCS requires that certification bodies issue a certificate to an economic operator only after a positive certification decision is reached confirming that the requirements of the SCS CORSIA certification programme have been satisfied.
5)	Group auditing (where applicable)	• Group auditing of economic operators by the certification body is permitted under the following conditions: ○ For the following economic operators: producers of raw material, points of origin in the case of waste and residue supply chains, and warehouses or storage facilities under common management. ○ When confirming compliance with the CORSIA sustainability criteria when the areas concerned are near each other and have similar characteristics. ○ For the purpose of assessing the accuracy of the claimed LCA value when the units have similar production systems and products. ○ A sample of at least the square root of the number of group members is audited individually annually or, for wastes and residues, using a risk-based sampling approach providing the same level of assurance. ○ Self-declarations from economic operators are not accepted by the certification body as sufficient evidence to replace audits supporting a group claim. • A group value for actual GHG LCA would be permitted as long as the SCS sets the guidelines for how this should be determined. • If the conditions for group auditing are not fulfilled, economic operators are audited individually.
6)	Auditor competencies	• SCS requires that certification bodies appoint competent auditor(s), in accordance with the process set out in ISO 19011. • The auditor(s) as a whole, and the independent reviewer, demonstrates knowledge and appropriate necessary skills to conduct audits under the CORSIA eligible fuels framework, in accordance with the audit scope, including: ○ Knowledge of the requirements of the SCS CORSIA certification programme and the ICAO CORSIA Implementation Elements related to CORSIA eligible fuels. ○ Knowledge of and experience with CORSIA or similar sustainability criteria, mass balance systems, traceability, GHG LCA calculations, and data collection and handling. ○ Knowledge of and experience with appropriate sectors (e.g., agriculture, engineering, etc.).
7)	Establishment of a level of assurance	• SCS requires the certification body to conduct all audits to a “reasonable assurance level.” • SCS requires the certification body to apply a materiality threshold of 5% for traceability (volume of sustainable material sold as compliant) and actual GHG LCA value calculations.

Referenced ISO standards

ISO/IEC 17065 Conformity assessment — Requirements for bodies certifying products, processes and services
ISO 19011 Guidelines for auditing management systems
ISO 14064-3 Specification with guidance for the validation and verification of greenhouse gas assertions
ISO/IEC 17011 Conformity assessment — Requirements for accreditation bodies accrediting conformity assessment bodies
NOTE: The most recent version of the standards apply.

3. Eligibility framework.

The approval of SCS will be exclusively carried out centrally by the ICAO Council with the technical assistance of CAEP, which will assess the compliance of the SCS with the eligibility requirements listed in this ICAO Document. Only the SCS that meet all the eligibility requirements will be included in the list of approved SCS.

In case the scope of the certification scheme is limited to part of the CEF supply chain (or specific feedstocks or conversion processes), the assessment mechanism and potential recognition will only apply to the scope of the certification scheme.

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APPENDIX E
(English only)

ICAO DOCUMENT

CORSIA DEFAULT LIFE CYCLE EMISSIONS VALUES FOR CORSIA ELIGIBLE FUELS

1. Acronyms

ATJ =	Alcohol-to-jet
CO_2e =	Carbon dioxide equivalent
FT =	Fischer-Tropsch
HEFA =	Hydroprocessed esters and fatty acids
ILUC =	Induced land use change
LCA =	Life cycle assessment
LS_f =	Life cycle emissions factor for a CORSIA Eligible fuel in gCO_2/MJ
MSW =	Municipal Solid Waste
NBC =	Non-biogenic carbon
SIP =	Synthetic iso-paraffin

2. CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels

Fuel Conversion Process	Region	Fuel Feedstock	Core LCA Value	ILUC LCA Value	LS_f (gCO_2e/MJ)
Fischer-Tropsch (FT)	Global	Agricultural residues	7.7	0.0	7.7
	Global	Forestry residues	8.3		8.3
	Global	Municipal solid waste (MSW), 0% non-biogenic carbon (NBC)	5.2		5.2
	Global	Municipal solid waste (MSW) (NBC given as a percentage of the non-biogenic carbon content)	NBC*170.5 + 5.2		NBC*170.5 + 5.2
	USA	Poplar (short-rotation woody crops)	12.2	-5.2	7.0
	USA	Miscanthus (herbaceous energy crops)	10.4	-32.9	-22.5
	EU	Miscanthus (herbaceous energy crops)	10.4	-22.0	-11.6
	USA	Switchgrass (herbaceous energy crops)	10.4	-3.8	6.6
Hydroprocessed esters and fatty acids (HEFA)	Global	Tallow	22.5	0.0	22.5
	Global	Used cooking oil	13.9		13.9
	Global	Palm fatty acid distillate	20.7		20.7
	Global	Corn oil (from dry mill ethanol plant)	17.2		17.2
	USA	Soybean oil	40.4	24.5	64.9
	Brazil	Soybean oil	40.4	27.0	67.4
	EU	Rapeseed oil	47.4	24.1	71.5
	Malaysia & Indonesia	Palm oil – closed pond	37.4	39.1	76.5
	Malaysia & Indonesia	Palm oil – open pond	60.0	39.1	99.1
Alcohol (isobutanol) to jet (ATJ)	Global	Agricultural residues	29.3	0.0	29.3
	Global	Forestry residues	23.8		23.8
	Brazil	Sugarcane	24.0	7.3	31.3
	USA	Corn grain	55.8	22.1	77.9
	USA	Miscanthus (herbaceous energy crops)	43.4	-54.1	-10.7
	EU	Miscanthus (herbaceous energy crops)	43.4	-31.0	12.4
	USA	Switchgrass (herbaceous energy crops)	43.4	-14.5	28.9
Alcohol (ethanol) to jet (ATJ)	Brazil	Sugarcane	24.1	8.7	32.8
	USA	Corn grain	65.7	25.1	90.8
Synthesized iso-paraffins (SIP)	Brazil	Sugarcane	32.8	11.3	44.1
	EU	Sugar beet	32.4	20.2	52.6

NOTE: The "LCA Methodology Supporting Document" describes the methodologies used by ICAO to calculate these Default Life Cycle Emissions Values, as well as the process for requesting the inclusion of a new conversion process, feedstock, and/or region on this table.

During the pilot phase, negative ILUC values, as shown above, will be provisionally allowed to obtain a negative LS_f. A decision on whether to continue allowing negative LS_f values, due to reductions from negative ILUC, will be made by the end of the pilot phase.

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APPENDIX F
(English only)

ICAO DOCUMENT

CORSIA METHODOLOGY FOR CALCULATING ACTUAL LIFE CYCLE EMISSIONS VALUES

1. Acronyms

CO_2 = Carbon dioxide
CO_2e = Carbon dioxide equivalent
CEF = CORSIA eligible fuel. A CORSIA sustainable aviation fuel or a CORSIA lower carbon aviation fuel, which an operator may use to reduce their offsetting requirements
CH_4 = Methane
GHG = Greenhouse gas
ILUC = Induced land use change
LCA = Life cycle assessment
LEC = Landfill Emissions Credit
LS_f = Life cycle emissions factor for a CORSIA Eligible fuel in gCO_2/MJ
MSW = Municipal Solid Waste
N_2O = Nitrous oxide
REC = Recycling Emissions Credit
SCS = Sustainability Certification Scheme

2. CORSIA Methodology for Calculating Actual Life Cycle Emissions Values

An Aeroplane Operator seeking benefits from the use of CEF in terms of reductions in CORSIA CO_2 offsetting requirements will have to provide documentation to their State on the life cycle emissions values (LS_f) and sustainability. An Aeroplane Operator will need to work with an CEF supplier to obtain this information.

1. An Aeroplane Operator may use an actual core life cycle value – described in paragraphs 3 and 6 – as part of an accepted fuel sustainability certification process if a fuel producer can demonstrate lower core life cycle emissions compared to the default core life cycle values provided in the ICAO Document entitled "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels", or if a fuel producer has defined a new pathway that does not have a default core life cycle value. If the Aeroplane Operator chooses to use an actual core life cycle value, then the Aeroplane Operator shall select an eligible Sustainability Certification Scheme from the ICAO Document entitled "CORSIA Approved Sustainability Certification Schemes" to ensure the analysis is in accordance to the LCA methodology defined below. The results of the actual core life cycle value analysis shall be added to the appropriate ILUC value from the ICAO Document entitled "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels" to calculate the total Life Cycle Emissions Value (LS_f). The SCS shall ensure that the methodology has been applied correctly and that relevant information on GHG emissions is transmitted through the chain of custody. SCS shall record detailed information about the calculation of actual values within their system and provide this information to ICAO on request.

2. If a fuel was produced from a feedstock that is defined as a waste, residue, or by-product according to Section 4, then the actual core LCA value shall be the total LS_f. If the feedstock is not a waste, residue, or by-product, then a default core LCA value and an ILUC value will need to be added to the ICAO Document entitled "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels" before the fuel can be included in CORSIA.

    NOTE: Information on how fuels can be added to the ICAO Document entitled "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels can be found in the "LCA Methodology Supporting Document".

3. The system boundary of the core LCA value calculation shall include the full supply chain of CEF production and use. As such, emissions associated with the following life cycle stages of the CEF supply chain must be accounted for: (1) production at source (e.g., feedstock cultivation); (2) conditioning at source (e.g., feedstock harvesting, collection, and recovery); (3) feedstock processing and extraction; (4) feedstock transportation to processing and fuel production facilities; (5) feedstock-to-fuel conversion processes; (6) fuel transportation and distribution to the blend point; and (7) fuel combustion in an aircraft engine.

4. For life cycle stages 1-6 described in Paragraph 3, carbon dioxide equivalent (CO_2e) emissions of CH_4, N_2O and non-biogenic CO_2 from these activities shall be calculated on the basis of 100-year global warming potential (GWP). CO_2e values for CH_4 and N_2O shall be based on the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (28 and 265, respectively). Only non-biogenic CO_2 emissions from fuel combustion shall be included in the calculation of CO_2e emissions.

5. The functional unit for final LS_f results shall be grams of CO_2e per megajoule of fuel produced and combusted in an aircraft engine, in terms of lower heating value (gCO_2e/MJ).

6. The calculated LS_f values shall include emissions generated during on-going operational

activities (e.g., operation of a fuel production facility, feedstock cultivation), as well as emissions associated with the material and utility inputs to operational activities, such as processing chemicals, electricity, and natural gas. Emissions generated during one-time construction or manufacturing activities (e.g., fuel production facility construction, equipment manufacturing) shall not be included.

7. In many cases, the CEF supply chain of interest will result in the co-production of multiple commodities. These co-products may include non-CEF liquid fuels, chemicals, electricity, steam, hydrogen, and/or animal feed. Energy allocation shall be used to assign emissions burdens to all co-products in proportion to their contribution to the total energy content (measured as lower heating value) of the products and co-products. CO_2e emissions shall not be allocated to waste, residues and by-products that result from the CEF supply chain of interest.

8. CEF feedstocks can be broadly categorized into three groups - primary or co-products, by-products, and wastes and residues. Further information on how feedstocks are categorized into these group for the purposes of CORSIA can be found in Section 4.

9. Feedstocks that are "low risk" for land use change have been identified and assigned as having zero emissions from land use change. The low land use change risk feedstock list includes: (1) feedstocks that do not result in expansion of global agricultural land use for their production; (2) wastes, residues, and by-products (see Section 4); and (3) feedstocks that have yields per surface unit significantly higher than terrestrial crops (~ one order of magnitude higher) such as some algal feedstocks. The feedstocks in these three categories shall all receive an ILUC value of zero in the fourth column of the table in the ICAO Document "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels".

10. Aeroplane Operators may choose to capture the benefits of utilizing land use change-risk mitigation practices, (e.g., land management practices) to avoid ILUC emissions as part of an accepted fuel sustainability certification process (see the ICAO Document "CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes"). Mitigation practices that avoid ILUC emissions and the requirements that shall be met to obtain these reductions can be found in Section 5. The ILUC value of zero shall be used in place of the default ILUC value to calculate total LSf. If the Aeroplane Operator chooses to claim emissions reductions from the implementation of land use change-risk mitigation practices, then the Aeroplane Operator shall select an eligible Sustainability Certification Scheme from the ICAO document "CORSIA Approved Sustainability Certification Schemes" to provide documentation that the fuel was produced using land use change-risk mitigation practices according to Section 5.

11. Waste, residue, and by-product feedstocks are assumed to incur zero emissions during the feedstock production step of the lifecycle. Emissions generated during the collection, recovery, extraction, and processing of these wastes, residues, and by-products, however, shall be included (life cycle stages 2-7 described in paragraph 3).

12. The production of SAF from wastes and residues, as defined in Section 4 (Feedstock Categories section of the CORSIA Methodology for Calculating Actual Life Cycle Emissions Values), may generate emission credits that can be subtracted from the actual LCA values to calculate total LS_f. If the Aeroplane Operator chooses to use a SAF that would generate such an emission credit, then the Aeroplane Operator shall select an eligible Sustainability Certification Scheme from the CORSIA ICAO Document "CORSIA Approved Sustainability Certification Schemes" to ensure the calculation of emission credits is in accordance with the specific methodologies

defined in this document, as follows.

- Avoided Landfill Emissions Credit (LEC) for SAF derived from Municipal Solid Waste (MSW) – Section 6.1
- Recycling Emissions Credit (REC) for SAF derived from Municipal Solid Waste (MSW) – Section 6.2

The analysis to calculate these emission credits values shall be documented in a technical report citing fully the data sources, such that the results are replicable and use the most recent data available. The technical report must also demonstrate that the emission credits claimed are permanent; directly attributable to the SAF production; exceed any emissions reductions required by law, regulation or legally binding mandate; avoid double counting (including double issuance[3] or double claiming[4]) of such credits; and exceed emissions reductions that would otherwise occur in a business-as-usual scenario.

During the pilot phase of CORSIA, and until additional requirements and guidance have been developed to (a) ensure that emission credits for SAF generated under CORSIA are of an equivalent quality and quantity to emission units and (b) resolve concerns regarding double counting, after the subtraction of the LEC and/or REC applicable to a SAF, the total LS_f value cannot be smaller than 0 gCO_{2e}/MJ.

3. Technical Report Requirements

3.1 Reporting Requirements

The SCS will require economic operators to document all relevant data appropriately in a Technical Report, which is verified by an accredited certification body. Upon request, the economic operator will submit the technical report to the SCS and on request, the SCS will submit the report to ICAO.

Relevant data include:

a) GHG emissions by life cycle step within the scope of certification, broken out by GHG emission species and aggregated in CO_2e (100 year GWP). With regard to the life cycle steps, Section 2, Paragraph 3 of the ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values” states: “The system boundary of the core LCA value calculation shall include the full supply chain of SAF production and use. As such, emissions associated with the following life cycle stages of the SAF supply chain must be accounted for: (1) production at source (e.g., feedstock cultivation); (2) conditioning at source (e.g., feedstock harvesting, collection, and recovery); (3) feedstock processing and extraction; (4) feedstock transportation to processing and fuel production facilities; (5) feedstock-to-fuel conversion processes; (6) fuel transportation and distribution to the blend point; and (7) fuel combustion in an aircraft engine.”

b) The LCA inventory data by life cycle step within the scope of certification, including all energy and material inputs. For life cycle steps 1-4, the inventory data are to be

[3] In this instance, double issuance occurs when two or more credits or units are being issued for the same reduction.
[4] In this instance, double claiming occurs when the same unit was used by multiple entities

provided per mass of feedstock, for the other steps per total fuel energy yield (MJ of fuel).

c) Emission factors used for calculating GHG emissions associated with energy and material inputs, including information about the source for the emission factors.

d) All relevant feedstock characteristics within the scope of certification, such as, for example, agricultural yield, lower heating value, moisture content, the content of sugar, starch, cellulose, hemicellulose, lignin, vegetable oil, or any other energy carrier (as applicable to feedstock of interest).

e) Quantities for all final and intermediate products, per total energy yield.

f) If Municipal Solid Waste is being used as a feedstock, then all relevant data required for the calculation of landfill emissions credits and recycling emissions credit will be disclosed according to the MSW crediting methodology in Section 6 on "Emissions Credits."

g) In case a low LUC risk practice is being used, all relevant data required for the calculation and certification will be disclosed according to the Low LUC Risk Practices methodology.

The SCS will report evidence that the certification body has verified that the economic operator has accurately followed the methodology specified in the ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values” to calculate its actual LCA value using the most recent and scientifically rigorous data available, and that the LCA value calculation is complete, accurate and transparent.

The SCS will report information on chain of custody system employed.

Data will be recorded and reported to ICAO upon request in a format conducive to re-calculation and verification, for example as a spreadsheet in .csv or .txt file format.

3.2 **Flow Of Information Along The Supply Chain For Actual LCA Values**

Each economic operator along the supply chain will implement a robust and transparent system to track the flow of data outlined in Section 2, Paragraph 3 of the ICAO Document “CORSIA Methodology for Calculating Actual Life Cycle Emissions Values” along the supply chain (“chain of custody system”).

Tracking will occur each time the feedstock or fuel passes through an internal processing step or changes ownership along the supply chain.

The SCS will implement procedures that allow verification that the economic operator has used an appropriate chain of custody system.

4. **Feedstock Categories**

Primary and co- products are the main products of a production process. These products have significant economic value and elastic supply, (i.e., there is evidence that there is a causal link between feedstock prices and the quantity of feedstock being produced).

By-products are secondary products with inelastic supply and economic value.

Wastes are materials with inelastic supply and no economic value. A waste is any substance or object which the holder discards or intends or is required to discard. Raw materials or substances that have been intentionally modified or contaminated to meet this definition are not covered by this definition.

Residues are secondary materials with inelastic supply and little economic value. Residues include:

a) Agricultural, aquaculture, fisheries and forestry residues: Residues directly deriving from or generated by agriculture, aquaculture, fisheries and forestry.

b) Processing residues: A substance that is not the end product that a production process directly seeks to produce; the production of the residue or substance is not the primary aim of the production process and the process has not been deliberately modified to produce it.

The positive list provided in Table 1 includes feedstocks that have been classified as by-product, wastes and residues. It has been arrived at considering a broad range of publicly-available regulatory and voluntary approaches.

The positive list is non-exhaustive. It includes materials currently in use or in discussion to be used for sustainable aviation fuel.

The classification of specific feedstocks as by-products is subject to later revisions as part of the regular CORSIA review process in case there is strong scientific evidence showing that significant indirect effects could be associated to these feedstocks.

Residues
Agricultural residues:
- Bagasse
- Cobs
- Stover
- Husks
- Manure
- Nut shells
- Stalks
- Straw
Forestry residues:
- Bark
- Branches
- Cutter shavings
- Leaves
- Needles
- Pre- commercial thinnings
- Slash
- Tree tops
Processing residues:
- Crude glycerine

-	Forestry processing residues
-	Empty palm fruit bunches
-	Palm oil mill effluent
-	Sewage sludge
-	Crude Tall Oil
-	Tall oil pitch
Wastes	
-	Municipal solid waste
-	Used cooking oil
By-products	
-	Palm Fatty Acid Distillate
-	Tallow
-	Technical corn oil

Table 1: Positive lists of materials classified as residues, wastes or by-products

The positive list is an open list. The ICAO Council can add materials to it, according to the definitions of feedstocks above and using the process shown in Figure 1 as a guide:

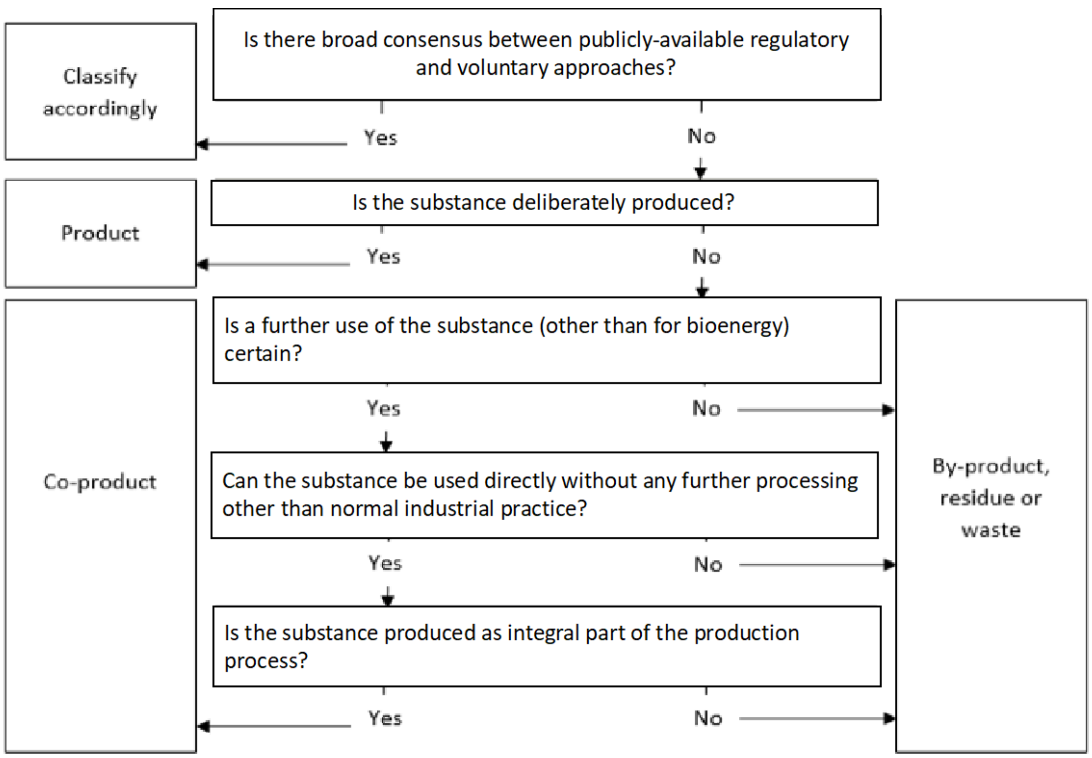

Figure 1: Guidance for inclusion of additional materials in positive list

5. **Low LUC Risk Practices**

For the purposes of CORSIA, using certain types of land, land management practices (LMP), and the incorporation of innovative agricultural practices could all be considered as contributing to low risk for land use change and therefore receive a value of zero for ILUC. The implementation of these low LUC risk practices for a project should avoid market mediated responses that lead to changes in land use, and lead to additional SAF feedstock available relative to a baseline, without increasing land requirements.

SCS with a methodology consistent with the principles and criteria listed below could be authorized by the ICAO Council to assess the implementation of low LUC risk practices and certify their low LUC risk status on a case-by-case, project-specific basis. The methodology must be open, documented, and publicly communicated. Feedstocks designated under the Low LUC Risk Practices approach during the CORSIA pilot phase are designated as such until 2030, subject to periodic audits to ensure ongoing compliance with the original requirements when the feedstocks were certified by the SCS.

In all cases, this methodology should consider that, for a specific project to be eligible for recognition as a low LUC risk practice, the practice must be verified as a net enhancement in SAF feedstock available per unit of land.

There are two approaches for low LUC risk SAF feedstock production:

a) Yield Increase Approach.

b) Unused Land Approach.

Low LUC risk practices implemented on or after 1 January 2016 could be eligible. The feedstock producer needs to provide credible and verifiable evidence of the nature of the new land management practice, timing of its implementation and level of additional feedstock production. Exceptionally, practices implemented between 1 January 2013 to 31 December 2015 may be accepted where it can be demonstrated that low LUC risk practices were implemented primarily as a result of demand for biofuels. This would have to be demonstrated on a project-specific basis.

This methodology is applicable during the pilot phase of CORSIA only.

5.1 **Yield Increase Approach**

Eligible land management practices for the yield increase approach could include, among others, sequential cropping where more than one crop is planted per year, cover crops, the use of fallow land in a prescribed crop rotation, significant post-harvest loss reduction, and significant project level productivity increases due to the introduction of good practices and technology.

The Yield Increase approach applies to any situation where feedstock producers are able to increase the amount of available feedstock out of a fixed area of land (i.e. without expanding the surface of the land). An increase in the harvested feedstock may be the result of:

a) An improvement in agricultural practices, (practices that increase yields through means such as increased organic matter content, reduced soil compaction/erosion, decreased pests, post-harvest loss reduction, etc.);

b) Intercropping, (i.e. the combination of two or more crops that grow simultaneously, for example as hedges or through an agroforestry system);

c) Sequential cropping, (i.e. the combination of two or more crops that grow at different periods of the year); and/or

d) Improvements in post-harvest losses, (i.e. losses that occur at cultivation and transport up to but not including the first conversion unit in the supply chain).

If there is a decrease of the available feedstock for the food or feed market at the project level resulting from the LMP (e.g., reduced yield from the main crop) this should be accounted for in calculating the volume of low LUC risk SAF feedstock (i.e., the volume of low LUC risk SAF feedstock represents the net increase in feedstock after accounting for any reduction in production of the primary food/feed crop that had been grown historically).

Measurements of yield increases and post-harvest loss reduction relative to a baseline are calculated based on historical practices using the annual yield per unit of land based on data from the preceding 5 years before the LMP measure takes effect from similar producers within the same region for the duration of the LMP measure. The low LUC risk feedstock thus represents additional feedstock obtained as a consequence of the improvement relative to the baseline.

The amount of additional feedstock available and considered eligible for low LUC risk feedstock is calculated as follows:

1) The average amount of feedstock available historically, from similar producers within the same region, is calculated based on actual net feedstock production (i.e., amount harvested less post- harvest losses) in the five years before the LMP measure takes effect. Similar producers can be defined as producers growing the same (or equivalent) crops and using a similar management model (e.g., smallholder, small or large scale plantation).

2) The amount of feedstock available as a consequence of the LMP is calculated based on the current/new net feedstock production (amount harvested less post-harvest losses) that is attributable to the adoption of the new LMP measure.

3) The additional low LUC risk feedstock represents the difference between the values calculated via the two previous steps.

5.2 **Unused Land Approach:**

Eligible lands for the unused land approach could include, among others, marginal lands, underused lands, unused lands, degraded pasture lands, and lands in need of remediation.

For a land to be eligible for the unused land approach, it needs to meet one of the following criteria:

a) Land was not considered to be arable land or used for crop production during the five years preceding the reference date.

b) Land is identified as severely degraded land or undergoing a severe degradation process for at least three years, according to criteria proposed by a Sustainability Certification Scheme recognized under CORSIA, where the criteria are based on scientific literature.

For a land to be eligible for the unused land approach, it also needs to have little risk for displacement of services from that land onto different and equivalent amounts of land elsewhere. *Note: services refer to products obtained from ecosystems such as food, animal feed, or bioenergy feedstocks.*

The amount of feedstock considered eligible for low LUC risk feedstock is equal to the amount of feedstock harvested for SAF production.

6. Emissions Credits

6.1 Methodology for Calculation of Landfill Emissions Credits

SAF produced from Municipal Solid Waste (MSW) feedstocks may generate an avoided Landfill Emissions Credit (LEC). The value of the LEC shall be calculated as follows:

Step 1 – Estimate the proportional shares of each of the following four waste categories (*j*) that make up the MSW diverted from landfilling: paper/textiles; wood/straw; other (non-food) organic putrescible/garden and park waste; and food waste/sewage sludge. These shares should be expressed in terms of the dry mass of each waste category (*j*) per dry mass of MSW diverted from landfilling (before additional sorting and recycling, if applicable) (eg. $W_{paper/textiles}$ = 0.4 dry tonne per dry tonne of MSW).

Step 2 – Select the degradable organic carbon content (DOC) and the fraction of carbon dissimilated (DOC_F) values from Table 2 that best represent each waste category (*j*) in the MSW. Use weighted averages to generate DOC and DOC_F values that accurately represent each of the four waste categories of the MSW feedstock of interest.

Table 2: DOC and DOC_F

Material	DOC[5] (% of dry matter)	DOC_F (%)
Corrugated containers	47%	45%
Newspaper	49%	16%
Office paper	32%	88%
Coated paper	34%	26%
Food waste	50%	84%
Grass	45%	46%
Leaves	46%	15%
Branches	49%	23%
Gypsum board	5%	45%
Dimensional lumber	49%	12%
Medium-density fiberboard	44%	16%
Wood flooring	46%	5%

Step 3 – Select the methane correction factor (MCF) from Table 3 that most accurately represents the conditions of the landfill in question.

[5] EPA, "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM). Management Practices Chapters." 2016. EPA Office of Resource Conservation and Recovery (ORCR). https://www.epa.gov/sites/production/files/2016-03/documents/warm_v14_management_practices.pdf

Table 3: Methane correction factor (MCF)[6]

Landfill conditions	MCF
Anaerobic managed solid waste disposal site	1.0
Unmanaged solid waste disposal site – deep	0.8
Semi-aerobic managed solid waste disposal site	0.5
Unmanaged solid waste disposal site - shallow	0.4

Step 4 – Use Equation 1 to calculate total CH_4 generation, Q, from each waste category, j, per dry tonne of diverted MSW.

Equation 1: Total CH_4 generation from waste category j, per dry tonne of diverted MSW [g CH_4 / t dry diverted MSW]

$$Q_j = W_j \times DOC_j \times DOC_{F\_j} \times F \times MCF \times (16/12) \times 10^6$$

where:

Q_j	= total CH_4 generation over a 100-year period from waste category j
W_j	= dry mass of waste category j per dry mass of MSW diverted from landfilling [%]
DOC	= degradable organic carbon content from Table 2 [%]
DOC_F	= fraction of degradable organic carbon dissimilated from Table 2 [%]
F	= CH_4 concentration in LFG, 50%
MCF	= Methane correction factor from Table 3
$16/12$	= CH_4 to carbon ratio
10^6	= grams per tonne conversion [g / t]

Step 5 – Select the lifetime LFG collection efficiency (*LFGCE*) that most accurately represents the landfill-specific conditions in Table 4, for each waste category of the organic MSW diverted from the landfill. If the landfill in question is not managed, and LFG is not collected, use a value of 0%. Note that in this case, it would be inappropriate to also select a MCF value of 1.0 which corresponds to an anaerobic managed solid waste disposal site.

[6] Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC guidelines for national greenhouse gas inventories. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

Table 4: Landfill gas collection efficiency (LFGCE)[7]

Climate zone		Boreal and temperate (MAT ≤ 20°C)						Tropical (MAT > 20°C)					
		Dry (MAP/PET < 1)			Wet (MAP/PET >1)			Dry (MAP < 1000 mm)			Moist and wet (MAP >1000 mm)		
Waste category, *j* / LFG collection		Active[a]	Moderate[b]	Minimal[c]	Active[a]	Moderate[b]	Minimal[c]	Active[a]	Moderate[b]	Minimal[c]	Active[a]	Moderate[b]	Minimal[c]
Slowly degrading waste	Paper/textiles waste	78%	70%	56%	82%	71%	56%	79%	70%	56%	83%	71%	56%
	Wood/straw waste	68%	63%	51%	74%	67%	54%	71%	65%	53%	76%	68%	55%
Moderately degrading waste	Other (non-food) organic putrescible/garden and park waste	80%	71%	56%	83%	69%	54%	83%	71%	56%	80%	61%	55%
Rapidly degrading waste	Food waste/Sewage sludge	82%	71%	56%	79%	59%	49%	84%	70%	55%	72%	46%	43%

MAT – Mean annual temperature; MAP – Mean annual precipitation; PET – Potential evapotranspiration.
[a] Active: Typically, the landfill operator is using horizontal LFG collectors from the early stage of cell development while still accepting MSW (less than a year after cells' first waste disposal), and vertical collectors once cells are capped.
[b] Moderate: Horizontal collectors are installed to capture LFG 1-3 years after cells' first waste disposal, and vertical collectors are used once cells are capped.
[c] Minimal: LFG is not collected during waste acceptance, but vertical collectors are used once cells are capped.

Step 6 – Select the oxidation rate that best represents the landfill conditions: 10% should be used for modern, sanitary, and well-managed landfills; 0% should be used in all other cases.[2]

Step 7 – Calculate non-captured CH_4 emissions, CH_4^n, per dry tonne of diverted MSW using Equation 2. Note that Q_j and $LFGCE_j$ are defined for each waste category, *j*.

Equation 2: Non-captured CH_4 emissions (CH_4^n) [g CH_4 / t dry MSW]

$$CH_4^n = \sum_j \left[Q_j \times \left(1 - LFGCE_j\right) \times (1 - oxidation\ rate) \right]$$

[7] Nine landfills were interviewed, and three landfills that represent active, moderate, and minimal LFG collection were selected and simulated based on the method provided in Lee et al. (2018) with phased collection efficiency specified in Barlaz et al. (2009).

Lee, U., Han, J. and Wang, M., 2017. Evaluation of landfill gas emissions from municipal solid waste landfills for the life-cycle analysis of waste-to-energy pathways. Journal of Cleaner Production, 166, pp.335-342.

Barlaz, M.A., Chanton, J.P., Green, R.B., 2009. Controls on landfill gas collection efficiency: instantaneous and lifetime performance. J. Air Waste Manag. Assoc. 59, 1399–1404.

Step 8 – Calculate biogenic CO_2 in non-captured CH_4 emissions, CO_2^n, and biogenic CO_2 that remains as carbon in the landfill, CO_2^s, using Equation 3.

Equation 3: CO_2^n and CO_2^s [g CO_2e / t dry MSW]

$$CO_2^n = CH_4^n \times 44/16$$

$$CO_2^s = \sum_j \left[W_j \times DOC \times (1 - DOC_F) \times (44/12) \times 10^6 \right]$$

Step 9 – In the case that the project of interest diverts MSW from a landfill where collected CH_4 is used for electricity generation instead of flaring, calculate the avoided electricity credit using Equation 4.

Equation 4: Avoided electricity credit [g CO_2e / t dry MSW]

$$Avoided\ electricity\ credit\ = LHV_{CH4} \times \boldsymbol{\eta} \times CF \times [\Sigma_j(Q_j \times LFGCE_j)] \times CI_{elec} \times 10^{-3}$$

where:

LHV_{CH4}	= lower heating value of CH_4, 0.0139 MWh / kg
η	= net electricity generation efficiency (eg. 30%, dependent on landfill of interest)
CF	= capacity factor including downtime (eg. 85%, dependent on landfill of interest)
Q_j	= total CH_4 generation from waste category j from Equation 1[g CO2e / t dry MSW]
$LFGCE_n$	= landfill gas collection efficiency selected from Table 3 [%]
CI_{elec}	= average carbon intensity of grid electricity in the region where the landfill generating electricity is located (use the highest spatial resolution regional-level CI published by a relevant national entity) [gCO_2e / MWh]
10^{-3}	= kilogram per gram conversion [kg / g]

Step 10 – Calculate the final LEC of the SAF production process, as shown in Equation 5. This landfill- and waste-specific LEC value is to be subtracted from the core LCA value (g CO_2e/MJ) of MSW-derived SAF.

Equation 5: Final LEC calculation [g CO_2e/MJ]

$$LEC = \frac{CH_4^n \times (GWP_{CH4}) - CO_2^n - CO_2^s - [avoided\ electricity\ credit]}{Y}$$

where:

CH_4^n	= non-captured CH_4 emission [g CH_4 / t dry MSW]
GWP_{CH4}	= 100-year global warming potential of CH_4, 28 g CO_2e / g CH_4
CO_2^n	= Biogenic CO_2 in non-captured CH_4 emissions [g CO_2e / t dry MSW]
CO_2^s	= Biogenic CO_2 that remains as carbon in the landfill [g CO_2e / t dry MSW]
[avoided electricity credit]	= Emissions offset by replacing grid electricity with electricity from captured CH_4 [g CO_2e / t dry MSW]
Y	= Total energy yield (liquid fuels, other fuel and energy co-products and non-energy co-products) from MSW [MJ/ t dry MSW]. Note that this is calculated on the basis of MSW diverted from the landfill, before any additional sorting or recycling takes place.

6.2 **Methodology for Calculation of Recycling Emissions Credits**

SAF produced from Municipal Solid Waste (MSW) feedstocks may generate a Recycling Emissions Credit (REC), due to additional recyclable material being recovered and sorted during feedstock preparation. The emissions avoided for additional recycling of plastics and metals, calculated separately, are summed to generate a total REC value. REC shall be calculated as follows:

1. Plastics

Step 1a. – Select the energy consumption factors for virgin plastic production and recycling from Table 5, for the plastic types recovered from the MSW feedstock in question.

Table 5: Energy factors for virgin plastic production and recycling[8]

Material	Specific electricity consumption for virgin plastic production (SEC_{bl})	Specific fossil fuel consumption for the production of virgin plastic (SFC)	Specific electricity consumption for plastic recycling (SEC_{rec})
	[MWh / t]	*[GJ / t]*	*[MWh / t]*
PET	1.11	15.0	0.83
HDPE	0.83	15.0	0.83
LDPE	1.67	15.0	0.83
PP	0.56	11.6	0.83

Step 1b. – Select appropriate emission factors for electricity, and direct fossil fuels use, for virgin plastic production, that accurately represent the specific project in question.

CI_{elec}	*= average carbon intensity of grid electricity in the region where the virgin plastic production is being offset (use the highest spatial resolution regional-level CI published by a relevant national entity) [gCO$_2$e / MWh]*
CI_{ff}	*= carbon intensity of fossil fuel used in the virgin plastic production process [g CO$_{2e}$ / GJ]. The life cycle CIs of coal, natural gas, fuel oil, and diesel, used as stationary fuels in US industrial processes, are 100.7, 69.4, 95.6, and 93.4 g CO$_2$e/MJ, respectively. Note that more regionally or context appropriate data should be substituted for the values given here, if available.*

Step 1c. – Estimate the emissions avoided by using recycled plastics to reduce virgin plastic production, per tonne of diverted MSW feedstock. This calculation should be carried out for each plastic type, and summed up, as shown in Equation 6.

Equation 6: REC associated with additional recycled plastic [g CO2e / t dry MSW]

$$REC_{plastic} = \sum_i q_i \times \left[L_i \times \left(SEC_{bl,i} \times CI_{elec} + SFC_i \times CI_{ff}\right) - \left(SEC_{rec,i} \times CI_{elec}\right)\right]$$

where:

q_i	*= quantity of plastic i recycled [t / dry t MSW]. This is on the basis of per tonne of dry MSW diverted from the landfill, before additional recycling takes place.*
i	*= type of plastic recycled (eg. PET, HDPE, LDPE, or PP)*
L_i	*= adjustment factor for degradation in material quality and loss when using the recycled material, 0.75*
$SEC_{bl,i}$	*= specific electricity consumption for virgin material production for plastic i [MWh / t plastic]*
$SEC_{rec,i}$	*= specific electricity consumption for recycling of plastic i [MWh / t plastic]*
SFC_i	*= specific fossil fuel consumption for virgin material production of plastic i [GJ / t plastic]*

[8] United Nations Framework Convention on Climate Change (UNFCCC). 2018. *AMS-III.AJ.: Recovery and recycling of materials from solid wastes --- Version 7.0. Clean Development Mechanism.* Valid from August 2018.

2. Metals

Step 2a. – Select the energy consumption factors for virgin metal production and recycling from Table 6, for the metal types recovered from the MSW feedstock in question.

Table 6: Emissions and energy factors for virgin metal production recycling[9]

Material	Emission factor for virgin metal production (*CI*)	Specific electricity consumption for metal recycling (SEC_{rec})
	[g $CO_{2e}e$ / t]	*[GJ / t]*
Aluminium	8.40×10^6	0.66
Steel	1.27×10^6	0.9

Step 2b. – Select an appropriate emission factor for electricity use in virgin metal production that accurately represents the specific project in question.

CI_{elec} = *average carbon intensity of grid electricity in the region where virgin metal production is being offset (use the highest spatial resolution regional-level CI published by a relevant national entity) [gCO_2e / MWh]*

Step 2c. – Estimate the emissions avoided by using recycled metals to reduce virgin metal production, per tonne of diverted MSW feedstock. This calculation should be carried out for each metal type, and summed up, as shown in Equation 7.

Equation 7: REC associated with additional recycled metal [g CO2e / t dry MSW]

$$REC_{metal} = \sum_i q_i \times \left[L_i \times (CI_i) - \left(SEC_{rec,i} \times CI_{elec}\right)\right]$$

where:

q_i = *quantity of metal i recycled [t / dry t MSW]. This is on the basis of per tonne of dry MSW diverted from the landfill, before additional recycling takes place.*

i = *type of metal recycled (eg. steel, or aluminum)*

CI_i = *emission factor for virgin production of metal i [g CO_2e / t metal]*

L_i = *adjustment factor for degradation in material quality and loss when using the recycled material, 0.75*

$SEC_{rec,i}$ = *specific electricity consumption for recycling of metal i [MWh / t plastic]*

Step 3 – Sum up emissions credits from plastics and metals, and convert to a basis of per MJ of fuel, as shown in Equation 8.

Equation 8: Final REC calculation [g CO2e / MJ]

$$REC = \frac{REC_{plastic} + REC_{metal}}{Y}$$

where:

Y = *Total energy yield (liquid fuels, other fuel and energy co-products and non-energy co-products) from MSW [MJ/ t dry MSW]. Note that this is calculated on the basis of MSW diverted from the landfill, before any additional sorting or recycling takes place.*

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[9] United Nations Framework Convention on Climate Change (UNFCCC). 2018. *AMS-III.AJ.: Recovery and recycling of materials from solid wastes --- Version 7.0. Clean Development Mechanism.* Valid from August 2018.

议程项目 10：航空器噪声和排放的科学现状

10.1 更新政府间气候变化专门委员会 1999 年航空和全球大气特别报告

10.1.1 国际民航组织秘书处介绍了为更新载于政府间气候变化专门委员会（IPCC）关于航空和全球大气的 1999 年特别报告中的信息所作的工作。为更新载于政府间气候变化专门委员会（IPCC）1999 年报告的信息确定了八个主题领域：1)飞机排放和环境，2)排放情景，3)航空对气候的影响，4)航空带来的潜在气候变化，5)航空器技术，6)航空运输业务，7)缓解途径和监管措施，以及 8)未来情景。具体而言，关于项目 4，一个自我组建的科学家小组一直在评估航空可能带来的气候变化，这应包括修改对辐射强迫气候效应的估算。秘书处着重指出，无法为任何其它工作找到进一步的资源和资金，以对政府间气候变化专门委员会 1999 年报告中的其余大多数信息进行彻底更新。因此，国际民航组织秘书处集中力量从国际民航组织通过航空环境保护委员会和其他机构进行的工作作出更新，并在国际民航组织网站发布这项信息。

讨论和结论

10.1.2 在一位成员提出关于秘书处开展的工作与政府间气候变化专门委员会未来更新之间关系的问题之后，有人指出，所提交的工作无意取代政府间气候变化专门委员会作出的任何更新，它只会以可得的信息补充政府间气候变化专门委员会的 1999 年报告，指出根据政府间气候变化专门委员会的正式程序，政府间气候变化专门委员会未来作出的任何更新都是一项重大任务并将是对政府间气候变化专门委员会 1999 年开展的工作的完全更新。

10.1.3 会议同意使用秘书处建议的材料来补充政府间气候变化专门委员会 1999 年报告，同意在国际民航组织网站上公布这些材料。

10.2 影响与科学小组的报告

10.2.1 影响和科学小组（ISG）共同报告员概述了影响和科学小组在 CAEP/11 周期进行的活动。影响和科学小组与第 1 工作组和第 2 工作组密切协调，拟定和举办了影响和科学小组航空噪声影响研讨会，目的是收集有关航空噪声影响的最新共识科学信息，为影响和科学小组编制“航空噪声影响白皮书”做准备。这份白皮书涵盖了许多不同航空器产生的噪音影响，包括社区噪音烦扰、睡眠搅扰、健康影响、儿童学习、直升机噪音、超音速航空器的航路噪音、城市空中运输噪音和无人机系统噪音以及航空噪声产生的经济成本。

讨论和结论

10.2.2 会议同意影响和科学小组已经完成它在 CAEP/11 周期的任务，国际民航组织应发布影响和科学小组提供的“航空噪声影响白皮书”并附上适当的注意事项和注明相关的作者。会议确认，可以通过国际民航组织的环境报告发布这份白皮书。

10.2.3 一位成员指出，“航空噪声影响白皮书”中使用了大量技术术语，因此，愿意与秘书处合作在白皮书发表之前编制一份词汇表。

10.2.4 一位观察员表示了他对“航空噪声影响白皮书”的结论的看法，在轻型民用航空器中，对固定翼航空器和旋翼航空器的反应没有明显差异，他着重指出，这与一些国际民航组织成员国的一些当地指导意见相反。

10.2.5 会议讨论了如何将“航空噪声影响白皮书”与世界卫生组织最近公布的噪声指南联系在一起（会议开始时曾经讨论），指出这两项工作尽管都使用了最新的科学证据，但“航空噪声影响白皮书”没有提出政策建议。一位观察员具体评论了世卫组织的指南和建议的科学有效性，指出世界卫生组织的建议是在没有适当的技术和科学专业知识、成本效益和影响分析的情况下提出的，因此作出了不合理的政策建议。另一位观察员指出，世卫组织的指南主要影响到欧洲国家，因此应由这些国家考虑如何以及是否实施这些建议，而不是国际民航组织。

10.2.6 **建议**

10.2.6.1 在随后的讨论中，会议同意发布“航空噪声影响白皮书”的建议如下：

建议 10/1 — 航空噪声影响白皮书

国际民航组织应发布本议程项目的报告附件所载的航空噪声影响白皮书。

10.3 **制定国际航空排放的长期理想目标**

10.3.1 影响和科学小组共同报告员根据政府间气候变化专门委员会（IPCC）最近公布的全球变暖 1.5°C 特别报告，介绍了国际航空排放长期目标（LTG）的工作。决策者摘要（SPM）根据对全球变暖 1.5° C 相关的现有科学、技术和社会经济文献的评估以及比工业化前全球变暖 1.5°C 和 2°C 的比较，介绍了这份特别报告的主要结论。政府间气候变化专门委员会（IPCC）报告的数据以及国际民航组织的环境趋势数据可作为进行一项分析的基础，而这项分析可用来支撑制定长期理想目标。

10.3.2 一位观察员认为，国际民航组织应作为紧急事项设定一个长期目标，显示该部门将如何为实现净零排放和 1.5°C 温度目标所需的总体努力作出公平的贡献。该观察员建议航空环境保护委员会使用简化的碳预算方法制定长期目标（LTG）分析草案，以便在国际民航组织大会第 40 届会议作出介绍。

讨论和结论

10.3.3 若干成员认识到了解航空长期预测和战略工作的重要性，敦促在制定长期目标（LTG）时要谨慎进行。这些成员指出，任何工作都应突出国际民航组织及其成员国为减少航空对全球气候的影响所做的努力，包括碳中和增长的理想目标和一揽子措施。他们敦促在《巴黎协定》背景下直接开展这项工作时要谨慎进行，建议如果要使用政府间气候变化专门委员会（IPCC）的 1.5°C 情景，那么应该非常小心。

10.3.4 其他几位成员和观察员指出推进长期目标的工作有多么重要，认为这项工作不仅应考虑航空能对 1.5°C 温度目标作出的贡献，还应考虑航空应做出何种贡献。成员对国际民航组织大会提出的要求和如何因应国际民航组织理事会继续探索国际航空长期全球理想目标的可行性的要求提出看法，其方式是进行详细研究，评估任何提出的目标的可实现性和影响，包括对所有国家特别是对发展中国家的增长和成本产生的影响，并将这项工作的进展情况提交国际民航组织大会第 40 届会议。对长期目标的评估应包括成员国对其实现中期目标的经验的信息（参见 A39-2 号决议）。

10.3.5 会议同意，责成影响和科学小组在支持 A39-2 号决议第 9 段所载要求方面的工作将首先侧重于自下而上的方法来分析航空部门对气候变化作出的努力，包括实施国际民航组织的“一揽子措施”并将通过首先关注二氧化碳的分阶段方法进行，承认进一步扩展以整合短期气候污染物将需要更详细的气候建模，并指出这项任务不应该是全球碳预算的一部分；并向 2019 年 CAEP 指导小组会议提交进度报告。

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APPENDIX

AVIATION NOISE IMPACTS WHITE PAPER

STATE OF THE SCIENCE 2019: AVIATION NOISE IMPACTS

V. Sparrow, Pennsylvania State University, Pennsylvania, United States
T. Gjestland, SINTEF, Norway
R. Guski, Ruhr-Universität Bochum, Germany
I. Richard, ENVIRONNONS, France
M. Basner, University of Pennsylvania, Pennsylvania, United States
A. Hansell, University of Leicester, United Kingdom
Y. de Kluizenaar, The Netherlands Organization for applied scientific research (TNO), The Netherlands
C. Clark, ARUP, United Kingdom
S. Janssen, The Netherlands Organization for applied scientific research (TNO), The Netherlands
V. Mestre, Landrum & Brown, California, United States
A. Loubeau, NASA Langley Research Center, Virginia, United States
A. Bristow, University of Surrey, United Kingdom
S. Thanos, University of Manchester, United Kingdom
M. Vigeant, Pennsylvania State University, Pennsylvania, United States
R. Cointin, Federal Aviation Administration, Washington, DC, United States

SUMMARY

This paper provides an overview of the state of the science regarding aviation noise impacts as of early 2019. It contains information on impacts including community noise annoyance, sleep disturbance, health impacts, children's learning, helicopter noise, supersonic aircraft, urban air mobility and unmanned aerial systems. The paper also considers the economic costs of aviation noise. This information was collected during an ICAO/CAEP Aviation Noise Impacts Workshop in November 2017 and in subsequent follow-on discussions.

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CHAPTER 1. INTRODUCTION

The purpose of this document is to provide an overview of the state of the science in the area of aviation noise impacts. As part of its work programme CAEP's Impacts and Science Group (ISG) was tasked with providing an updated white paper on the topic of aviation noise impacts. A white paper on aviation noise impacts was provided at the CAEP/10 meeting as WP/54-Appendix G, and was later published in 2017 as an open access journal article[1], but it did not address some emerging areas in aviation. So instead of merely providing an update, the course taken was to extend the review to the above mentioned topics. An Aviation Noise Impacts Workshop was held for invited scientists and other observers and guests in Montreal, Canada November 1-3, 2017. The purpose of this workshop was to lay the foundation for this white paper, and over 50 attendees participated. One specific topic requested by the CAEP Steering Group (CAEP SG.20161.SD.4) was for ISG to address the non-technical environmental aspects of the public acceptability for supersonic aircraft noise, and ISG began to explore this topic. In addition, the authors found much material on supersonics that had not previously been summarized for CAEP, and these details are provided in an appendix. Subsequent follow-up discussions led to additions to this white paper beyond those discussed at the workshop, and this includes urban air mobility (UAM) and unmanned aerial systems (UAS) noise. The basic of metrics for aircraft noise were defined in an appendix to WP/54-Appendix G and the open access journal article[1], and those will not be repeated here.

CHAPTER 2. COMMUNITY NOISE ANNOYANCE

2.1 Definition

Community noise annoyance refers to the average evaluation of the annoying aspects of a noise situation by a "community" or group of people. Annoyance, in this context, comprises a response that reflects negative experiences or feelings such as dissatisfaction, anger, disappointment, etc. due to interference with activities (e.g., communication or sleep) or simply an expression of being bothered by the noise.
To facilitate inter-study comparisons standardized annoyance questions and response scales have been introduced by the International Commission on Biological Effects of Noise, ICBEN.[2] These recommendations have been adopted by the International Standards Organization[3], ISO TS 15666, and translated into a number of new languages, following a standard protocol.[4]

2.2 Exposure-response relationships

Over the years, many attempts have been made to relate the percentage of respondents highly annoyed by a specific noise source to the day-night average noise exposure level, L_{dn}, or a similar indicator, e.g. day-evening-night average noise exposure level, L_{den}.[5,6] The standard ISO 1996: 2016 has tables with % HA as a function of L_{dn} and L_{den} for various transportation noise sources.[7] A review by Gelderblom et al.[8] confirms these data for aircraft noise. Another review suggests different relationships, particularly for aircraft noise annoyance.[9]

2.3 Generalized versus local exposure-response relationships

While exposure-response relationships have been recommended for assessing the expected annoyance response in a certain noise situation, they are not applicable to assess the effects of a change in the noise climate. Existing survey results reveal a higher annoyance response in situations with a high rate of change, for instance, where a new runway is opened.[10,11,12] Such heightened annoyance response seems to prevail.

Since airports and communities may differ greatly with respect to acoustic and non-acoustic variables, local exposure–response relationships, if available, may be preferred for predicting annoyance and describing the noise situation with desired accuracy. Still, generalized exposure–response relationships are desirable to allow assessment across communities and to establish recommended limit values for levels of aircraft noise.

2.4 Moderating variables

Analyses show that the common noise exposure variables *per se* explain about one third of the variance of individual annoyance responses. The annoyance response is moderated by a series of other factors, both acoustic and non-acoustic. Acoustic factors can be maximum levels, number of flights, fleet composition, and their respective distribution over time. Non-acoustic factors are for instance, personal noise sensitivity and attitude towards the noise source. In the aviation industry all "non- L_{dn} factors" are commonly referred to as "non-acoustic".

Two old meta-analyses on the influence of non-acoustic factors on annoyance[13,14] showed the factors of fear of danger of aircraft operations, followed by noise sensitivity and age, had the largest effects. More recent results indicate that fear is no longer a dominating modifying factor. Other important modifying factors may be distrust in authorities and expectations of property devaluation.[15] Guski et al. suggested[9] that the rate of change at an airport with respect to noise and operational procedures could be an important moderating factor. They defined two types: LRC and HRC, low/high rate of change airport. Gelderblom et al. have shown that the average difference in the annoyance response between these two types of airports, LRC and HRC, corresponds to a 9-dB-difference (9 dB ± 4 dB) in the noise exposure.[17] Guski et al. reported a similar, but smaller difference, about 6 dB.[9] The difference between the two studies is likely due to different selections and weighting of survey samples.

An important non-acoustic factor seems to be the attitude towards the noise source and/or its owner. Contrary to common beliefs, people that benefit from the air traffic are not more tolerant to aircraft noise.[18] A lack of trust in the authorities, misfeasance, and a feeling of not being fairly treated will increase the annoyance.[15] People may adapt different coping strategies, i.e. to master, minimize or tolerate the noise situation. Noise sensitive people have more difficulties coping with noise than others.[19]
If the respondents in a survey are selected according to proper random procedures, and the number of respondents is large enough to be an accurate representation of the population, individual factors will have the same effect in all surveys. However, other factors are location specific, for instance number of aircraft movements, prevalence of night time operations, LRC/HRC categorization, etc. The survey results from different airports will therefore vary unless these location specific factors are the same, or that they are accounted for statistically. Hence the search for a common exposure-response function, a "one curve fits all" solution, may not be applicable for all purposes.

2.5 Temporal trends in aircraft noise annoyance

Systematic surveys on aircraft noise annoyance have been conducted regularly over a good half century. Analyses by some researchers indicate that there has been an increase in aircraft noise annoyance over the past decades.[20,21] These authors state that at equal noise exposure levels, people today seem to be more annoyed by aircraft noise than they were 30-40 years ago.

Other researchers, however, claim that they can observe no change provided that the comparisons comprise similar and comparable noise situations.[17] Gelderblom et al. point out that the trend observations made by others can be explained by variations in non-acoustic factors, such as the fact that the prevalence of HRC airports are higher among recent surveys than among older ones. When LRC and HRC airports are analyzed separately they claim that there has been no change in the annoyance response over the past 50 years. Guski et al. on the other hand, claim that even at LRC airports the prevalence of highly annoyed people is higher for all exposure levels compared to older studies.[9]

Survey results from different airports show a large variation in the annoyance response. The result of a trend analysis based on a limited sample of surveys is therefore highly dependent on the selection criteria.

2.6 Noise mitigation strategies

Annoyance due to aircraft noise has been recognized by authorities and policy makers as a harmful effect that should be reduced or prevented. Priority is given to noise reduction at the source (e.g., engine noise, aerodynamic noise) and reducing noise impact by adjusting operational procedures and take-off and landing trajectories. Attempts to modify the noise spectrum to produce a more agreeable "sound" were made in the EU-funded COSMA project.[22] Such changes gave little or no effect. Sound insulation of dwellings is often applied, but such measures have no consequences for the outdoor experience of aircraft noise. The observed influence on annoyance of personal non-acoustic factors such as perceived control, and trust in authorities suggests that communication strategies addressing these issues could contribute to the reduction of annoyance, alongside or even in the absence of a noise reduction.

2.7 Conclusions

There is substantial evidence that there is an increase in annoyance as a function of noise level, e.g. L_{dn} or L_{den}. The noise level alone, however, accounts for only a part of the annoyance. Location and/or situation specific acoustic and non-acoustic factors play a significant role and must be taken into account.

There is conflicting evidence that there has been a change in the annoyance response in recent years. Under equal conditions, people today are not more annoyed at a given noise level than they were 30-40 years ago. However, due to changes in both acoustic and non-acoustic factors (more HRC airports, higher number of aircraft movements, etc.), the average prevalence of highly annoyed people at a given noise level (L_{dn} or L_{den}) seems to be increasing. Existing exposure-response functions should be updated and diversified to account for various acoustic and non-acoustic factors. The difference between a high rate change and a low rate change situation seems to be particularly important.

CHAPTER 3. SLEEP DISTURBANCE

3.1 Sleep And Its Importance For Health

Sleep is a biological imperative and a very active process that serves several vital functions. Undisturbed sleep of sufficient length is essential for daytime alertness and performance, quality of life, and health.23,24 The epidemiologic evidence that chronically disturbed or curtailed sleep is associated with negative health outcomes (like obesity, diabetes, and high blood pressure) is overwhelming. For these reasons, noise-induced sleep disturbance is considered one of the most important non-auditory effects of environmental noise exposure.

3.2 Aircraft noise effects on sleep

The auditory system has a watchman function and constantly scans the environment for potential threats. Humans perceive, evaluate and react to environmental sounds while asleep.[25] At the same sound pressure level (SPL), meaningful or potentially harmful noise events are more likely to cause arousals from sleep than less meaningful events. As aircraft noise is intermittent noise, its effects on sleep are primarily determined by the number and acoustical properties (e.g., maximum SPL, spectral composition) of single noise events. However, whether or not noise will disturb sleep also depends on situational (e.g., sleep depth[26]) and individual (e.g., noise sensitivity) moderators.[25]

Sensitivity to nocturnal noise exposure varies considerably between individuals. The elderly, children, shift-workers, and those in ill health are considered at risk for noise-induced sleep disturbance.[24] Children are in a sensitive developmental stage and often sleep during the shoulder hours of the day with high air traffic volumes. Likewise, shift-workers often sleep during the day when their circadian rhythm is promoting wakefulness and when traffic volume is high. Sleep depth decreases with age, which is why the elderly are often more easily aroused from sleep by noise than younger subjects.

Repeated noise-induced arousals impair sleep quality through changes in sleep structure including delayed sleep onset and early awakenings, less deep (slow wave) and rapid eye movement (REM) sleep, and more time spent awake and in superficial sleep stages.[26,27] Deep and REM sleep have been shown to be important for sleep recuperation in general and memory consolidation specifically. Non-acoustic factors (e.g., high temperature, nightmares) can also disturb sleep and complicate the unequivocal attribution of arousals to noise.28 Field studies in the vicinity of airports have shown that most arousals cannot be attributed to aircraft noise, and noise-induced sleep-disturbance is in general less severe than that observed in clinical sleep disorders like obstructive sleep apnea.[29,30] However, noise-induced arousals are not part of the physiologic sleep process, and may therefore be more consequential for sleep recuperation.132 Short-term effects of noise-induced sleep disturbance include impaired mood, subjectively and objectively increased daytime sleepiness, and impaired cognitive performance.[31,32] It is hypothesized that noise-induced sleep disturbance contributes to the increased risk of cardiovascular disease if individuals are exposed to relevant noise levels over years. Recent epidemiologic studies indicate that nocturnal noise exposure may be more relevant for long-term health consequences than daytime noise exposure, probably also because people are at home more consistently during the night.[16,33]

3.3 Noise effects assessment

Exposure-response functions relating a noise indicator (e.g., maximum SPL) to a sleep outcome (e.g. awakening probability) can be used for health impact assessments and inform political decision making. Subjects exposed to noise typically habituate, and exposure-response functions derived in the field (where subjects have often been exposed to the noise for many years) are much shallower than those derived in unfamiliar laboratory settings.[34,35] Unfortunately, sample sizes and response rates of the studies that are the basis for exposure-response relationships were usually low, which restricts generalizability.

Exposure-response functions are typically sigmoidal (s-shaped) and show monotonically increasing effects. Maximum SPLs as low as 33 dB(A) induce physiological reactions during sleep, i.e., once the organism is able to differentiate a noise event from the background, physiologic reactions can be expected (albeit with a low probability at low noise levels).[34] This reaction threshold should not be confused with limit values used in legislative and policy settings, which are usually considerably higher. At the same maximum SPL, aircraft noise has been shown to be less likely to disturb sleep compared to road and rail traffic noise, which was partly explained by the frequency distribution, duration, and rise time of the noise events.[27,36] At the same time, the percent highly sleep disturbed assessed via self-reports is typically higher for aircraft noise compared to road and rail traffic noise at the same L_{night} level.[37]

Although equivalent noise levels are correlated with sleep disturbance, there is general agreement that the number and acoustical properties of noise events better reflect the degree of sleep disturbance (especially for intermittent aircraft noise). As exposure-response functions are typically without a clearly discernible sudden increase in sleep disturbance at a specific noise level, defining limit values is not straight forward and remains a political decision weighing the negative consequences of aircraft noise on sleep with the economic and societal benefits of air traffic. Accordingly, night-time noise legislation differs between Contracting States.

3.4 Noise mitigation

Mitigating the effects of aircraft noise on sleep is a three-tiered approach. Noise reduction at the source has highest priority. However, as it will take years for new aircraft with reduced noise emissions to penetrate the market (and will thus not solve the problem in the near future), additional immediate measures are needed. For example, noise-reducing take-off and landing procedures can often be more easily implemented during the low-traffic night-time. Land-use planning can be used to reduce the number of relevantly exposed subjects. Passive sound insulation (including ventilation) represent mitigation measures that can be effective in reducing sleep disturbance, as subjects usually spend their nights indoors. At some airports, nocturnal traffic curfews have been imposed by regulation. It is important to line up the curfew period with the (internationally varying) sleep patterns of the population.

3.5 Recent evidence review

For sleep disturbance, a systematic evidence review based on studies published in or after the year 2000 was recently published.[37] According to GRADE[38] criteria, the quality of the evidence was found to be moderate for cortical awakenings and self-reported sleep disturbance (for questions that referred to noise) induced by aircraft noise, low for motility measures of aircraft noise induced sleep disturbance, and very low for all other investigated sleep outcomes. Significant exposure-response functions were found for aircraft noise for (a) sleep stage changes to wake or superficial stage S1 (unadjusted OR 1.35, 95% CI 1.22-1.50 per 10 dB increase in $L_{AS,max}$; based on N=61 subjects of a single study) and (b) percent highly sleep disturbed for questions mentioning the noise source (OR 1.94, 95% CI 1.61-2.33 for a 10 dBA increase in L_{night}; based on N=6 studies including > 6,000 respondents). For percent highly sleep disturbed, heterogeneity between studies was found to be high (I^2=84%).

CHAPTER 4. HEALTH IMPACTS

4.1 Introduction

There is good biological plausibility for health impacts of environmental noise, with potential mechanisms involving sleep disturbance, 'fight and flight' physiological response and annoyance.[39,40] The number of epidemiological studies investigating impacts of environmental noise on disease risk and risk factors has increased greatly since the previous ICAO white paper[1] and these have been used to define exposure-response relationships. Some variability is expected between epidemiological studies due to differences in populations, methodology, exposures and study design. Therefore, a combined estimate from a meta-analysis of studies with a low risk of bias is used to provide a state of the art estimate of the exposure-response relationship.

This section highlights main findings from the systematic literature reviews and meta-analyses published in 2017-2018. These reviews reference the noise and health literature up to August 2015 for cardiovascular outcomes[41] and December 2016 for birth outcomes.[42] This section also considers new publications up to end July 2018, including from the NORAH (http://www.laermstudie.de/en/norah-study/) and SIRENE (http://www.sirene-studie.ch/) studies in Germany and Switzerland respectively. Almost all studies available were conducted in European and North American populations.

4.2 Aircraft noise and cardiovascular impacts

The systematic review on cardiovascular and metabolic effects of environmental noise was performed by van Kempen et al.[41] and described in detail in an RIVM (Dutch National Institute for Public Health and the Environment) report.[46] The authors reviewed studies on the association between environmental noise (different source types) and hypertension in adults (none were identified focusing on children), ischaemic heart disease, stroke and obesity published up to August 2015. Findings for aircraft noise were reported to be consistent with findings for road traffic noise, where there are more studies available.

For hypertension: the van Kempen et al.[41] meta-analysis included nine cross-sectional studies and provided an estimated increased risk of 5% (95% confidence intervals -5% to +17%) per 10 dB (L_{den}) aircraft noise (comprising 60,121 residents, including 9487 cases of hypertension). The one cohort study identified[50] (4721 residents and 1346 cases in Sweden published in 2010) did not show an overall association with hypertension incidence, but there were significant associations in subgroup analyses of males and of those annoyed by aircraft noise. The authors of the review ranked the quality of the evidence for noise from air traffic as "low" using the GRADE ranking system, meaning that further research is considered very likely to have both an important impact on confidence in the estimate of effect and to change the size of the estimate. Subsequent to the systematic review, a large case-control study (137,577 cases and 355,591 controls) from the NORAH study[51] found no associations overall for aircraft noise with hypertension, but an increased risk for the subgroup of those who went on to develop hypertension-related heart disease, i.e. more severe cases. A subsequent publication from a small cohort (N=420) with up to 9 years follow-up in Athens who formed part of the original HYENA (Hypertension and Exposure to Noise

Near Airports) study found a 2.6-fold increased risk of hypertension in association with a 10 dB increase in night-time aircraft noise.[52]

Hypertension shows a positive but non-statistically significant association overall reflecting inconsistency between studies. This can be a difficult outcome to define precisely – the PURE multi-country study published in 2013 found nearly half of all cases of hypertension were unrecognised.[198] There are various issues about defining hypertension by medication use, and recognised issues about measuring blood pressure in individuals. Also, hypertension may not be the only or most important mechanism contributing to potential impacts of noise on the heart – inflammation, small blood vessel function and sleep disturbance also need to be considered.[196,197]

For ischaemic heart disease (IHD) and heart failure, findings were more consistent than for hypertension: the van Kempen et al. systematic review[41] reported a statistically significant increased risk of new cases of ischaemic heart disease of +9% (95% confidence intervals +4% to +15%) per 10 dB L_{den}, derived from a meta-analysis of two very large registry-based studies of 9.6 million participants and 158,977 cases. Taking into account evidence relating to existing as well as new cases and to mortality, the authors of the systematic review concluded “Overall, we rate the quality of the evidence supporting an association between air traffic noise and IHD as ‘low’” [using the GRADE ranking system] “indicating that further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate”. Subsequent published analyses from the SIRENE project using data from the Swiss National Cohort covering 4.4 million people[53], reported associations between aircraft noise and myocardial infarction mortality with increased risk of +2.6% (95% confidence intervals +0.4% to +4.8%) per 10 dB L_{den}. Highest associations between noise and IHD were seen with intermittent night-time exposures.[54] A large case-control study in Germany (19,632 cases and 834,734 controls) forming part of the NORAH study found associations of aircraft noise with diagnosis of myocardial infarction at higher noise levels (>55 dB) in the early morning hours, although not for 24 hour average noise levels. A further large NORAH study analysis[55] found a statistically significant linear exposure-response relationship with aircraft noise for heart failure or hypertensive heart disease of +1.6% per 10 dB increase in 24 hour continuous noise level (analysis based on 104,145 cases and 654,172 controls).

For stroke: the van Kempen et al. systematic review[41] considered seven studies of different designs including one cohort study (the Swiss National Cohort). Findings were mixed but the meta-analysis did not show statistically significant associations of aircraft noise with stroke outcomes. This result is consistent with subsequently published SIRENE study findings on stroke mortality also using the Swiss National Cohort but with improved noise exposure estimates.[53]

Comparisons with findings for road traffic noise: findings for aircraft noise and the cardiovascular disease outcomes presented above are consistent with those for road traffic noise as reported in the van Kempen et al systematic review.[41] In particular, for ischaemic heart disease, the systematic review rated the quality of the evidence supporting an association between road traffic noise and new cases of ischaemic heart disease to be high, providing an increased risk of +8% (+1% to +15%) per 10 dB L_{den} road traffic noise (as compared with findings for aircraft noise for this outcome of +9% (+4% to +15%) as noted above). Analogy with road traffic noise is meaningful, because, as well as impacts on annoyance, noise also functions as a non-specific stressor with non-auditory impacts on the autonomic nervous system and endocrine system. These stressor effects are seen with noise from different sources and result in adverse effects on oxidative stress and vascular function in experimental studies.[196,197]

4.3 Aircraft noise and metabolic effects (diabetes, obesity, waist circumference, metabolic biomarkers)

The van Kempen et al. systematic review[41] identified one Swedish cohort study considering aircraft noise,[56] which found a significant association between aircraft noise exposure and increased waist circumference over 8-10 years follow-up, but not for Body Mass Index (BMI) or type 2 diabetes. The authors of the systematic review concluded that further research would be likely to have an important impact on both size and statistical confidence in the estimate of effect. Three more recent publications also report some associations of aircraft noise with metabolic disturbance.[57-59] A 2017 Swiss cohort study analysis forming part of the SIRENE project suggested an approximate doubling of diabetes incidence per 12 dB L_{den} increase in aircraft noise exposure[57] and positive although non-significant associations of aircraft noise exposure with glycosylated haemoglobin, a measure of glucose control over the past three months and a predictor of diabetes.[58] A 2017 study in Korea of 18,165 pregnant women identified through health insurance records,[59] found an association between night-time but not daytime aircraft noise exposure during the first trimester of pregnancy and risk of gestational diabetes mellitus.

Findings are consistent with a hypothesis that noise exposure is related to stress-hormone-mediated deposition of fat centrally and other impacts on metabolic functioning and/or adverse effects of disturbed sleep on metabolic and endocrine function, also with results from a small number of studies considering road traffic noise that also found associations with diabetes, but more studies are needed to strengthen the evidence base for this outcome.

4.4 Aircraft noise and birth outcomes

A systematic review by Nieuwenhuijsen, et al.[42] published in 2017 considered literature published up to December 2016. Six aircraft noise studies were included, but there were too few studies to conduct a meta-analysis. Four studies (published 1973-2001) considered birth weight and all studies found associations with aircraft noise exposure, but noise exposure levels in these studies were high (> 75 dB, various metrics). A further two studies conducted in the 1970s considered birth defects, of which one found significant associations – again, noise levels considered were high. Evidence was considered such that any estimate of effect is very uncertain. The authors commented that “there may be some suggestive evidence for an association between environmental noise exposure and birth outcomes” with some support for this from studies of occupational noise exposure (which were higher than most current environmental aircraft noise exposures), but that further and high quality studies were needed. No further studies relating birth outcomes to aircraft noise have been published to date.

4.5 Aircraft noise and mental health

There remain very few studies of aircraft noise exposure in relation to wellbeing, quality of life, and psychological ill-health. Since the previous ICAO paper and publication[1] in 2017, there has been one major German analysis[60] published from the NORAH study, which found a significant association with depression as recorded in health insurance claims. Risk estimates increased with increasing noise levels to a maximum Odds Ratio (OR) of 1.23 (95% CI=1.19-1.28) at 50-55 dB (24 hour average), but decreased at higher exposure categories. The reason for this is unclear but it may potentially be due to uncertainties related to very small numbers of exposed and cases at higher noise levels. A cohort study following 1185 German school children[61] from age 5-6 to 9-10 years did not find associations of aircraft noise exposure with mental health problems (such as emotional symptoms, hyperactivity and conduct problems), but as the study used parental noise annoyance at place of residence as the measure of exposure as opposed to objectively assessed (modelled or measured) quantitative exposure levels, it is difficult to draw firm conclusions.

4.6 Conclusions

There has been a large increase in studies in recent years examining associations of noise exposure with health outcomes. The best epidemiological evidence relates to cardiovascular disease, which includes analyses from population-based studies covering millions of individuals, in particular for new cases of ischaemic heart disease. Findings for aircraft noise are consistent with those for road traffic noise (for which more studies have been conducted and where the quality of evidence is rated as high). Results from epidemiological studies are also supported by evidence from human and animal field and laboratory experimental studie[45-49] showing biological effects of noise on mechanistic pathways relating to risk factors for cardiovascular disease. This experimental evidence, together with consistency with findings for road traffic noise, supports the likelihood that associations for aircraft noise with heart disease observed in epidemiological studies are causal. However, the exact magnitude of the exposure-response estimate for heart disease varies between studies and best estimates (obtained by combining results from good quality studies in a systematic review) are likely to change as further studies add to the evidence base.

There are important gaps in the evidence base for other outcomes. Perhaps surprisingly, few studies have been conducted in relation to impact of aircraft noise on mental health. There are also few studies relating to maternal health and birth outcomes including birth weight.

Generally, health studies to date have used L_{den}, L_{day} and L_{night} metrics, most likely as these were available and had been extensively validated in annoyance studies. There is a need to examine other noise metrics that may be more relevant to health endpoints – some of the more recent studies are starting to include other metrics, including intermittency ratio,[43] maximum noise level and to examine specific time periods,[44] especially for night-time exposures. These new metrics should be additional, but not replace the standard equivalent metrics (L_{Aeq}, L_{den}) to allow for comparability of results, at least at present while the evidence base is being compiled.

CHAPTER 5. CHILDREN'S LEARNING

5.1 Chronic aircraft noise exposure and children's learning

Several studies have found effects of aircraft noise exposure at school or at home on children's reading comprehension or memory skills[62] or standardized test scores.[63,64] The RANCH study (Road traffic and Aircraft Noise and children's Cognition & Health) of 2844 9-10 year old children from 89 schools around London Heathrow, Amsterdam Schiphol, and Madrid Barajas airports found exposure-response associations between aircraft noise and poorer reading comprehension and poorer recognition memory, after taking social position and road traffic noise exposure, into account.[65] A 5 dB increase in aircraft noise exposure was associated with a two month delay in reading age in the UK, and a one month delay in the Netherlands.[66] These associations were not explained by co-occurring air pollution.[67] Night-time aircraft noise at the child's home was also associated with impaired reading comprehension and recognition memory, but night-noise did not have an additional effect to that of daytime noise exposure on reading comprehension or recognition memory.[68] The recent NORAH study of 1242 children aged 8 years from 29 primary schools around Frankfurt airport in Germany found that a 10 dB (L_{Aeq} 08.00am-14.00pm) increase in aircraft noise was associated with a one-month delay in terms of reading age. The RANCH and NORAH studies examine the effect of aircraft noise on children's reading comprehension starting from a very low level of exposure. This enables the studies to adequately assess where effects of aircraft begin (i.e. identify thresholds): we should not be concerned by the inclusion of the examination of such low levels of aircraft noise exposure as both the RANCH and the NORAH study adjust the results for other noise exposures (e.g. road noise in RANCH and road and rail noise in NORAH) making the assessment meaningful in terms of considering other noise exposures and ambient noise exposure per se. Effects of aircraft noise on children's learning have been demonstrated across a range of aircraft noise metrics including L_{Aeq}, L_{max}, number of events above a threshold, and time above a threshold. [64]

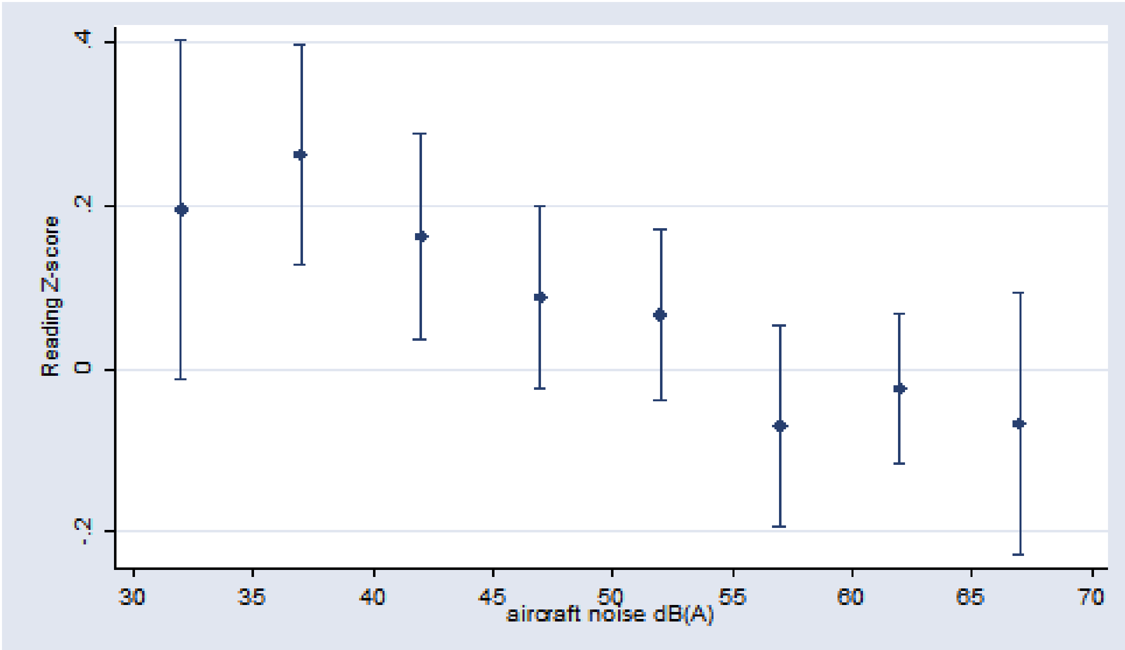

Figure 1. Exposure-effect relationship between aircraft noise exposure at school and reading comprehension in the RANCH study. The vertical axis shows the adjusted mean reading z scores and 95% confidence intervals for 5-dB(A) bands of aircraft noise at school (adjusted for age, gender, and country).[66]

Data from the RANCH study and the NORAH study enable the exposure-effect association between aircraft noise exposure and children's reading comprehension to be estimated[69,70] (see Figures 1 and 2). Both studies suggest that the relationship between aircraft noise and reading comprehension is linear, so reducing exposure at any level should lead to improvements in reading comprehension. In the RANCH study, reading comprehension began to fall below average at exposures greater than 55 dB L_{Aeq} 16 hour at school.

It is possible that children may be exposed to aircraft noise for many of their childhood years, but few studies have assessed the consequences of long-term noise exposure at school on learning or cognitive outcomes. Whilst it is plausible that aircraft noise exposure across a child's education may be detrimental for learning, evidence to support this position is lacking. A six-year follow-up of the UK sample of the RANCH study, when the children were aged 15-16 years of age, failed to find a statistically significant association but did suggest a trend between higher aircraft noise exposure at primary school and poorer reading comprehension at follow-up,[71] as well as a trend between higher aircraft noise exposure at secondary school and poorer reading comprehension at secondary school. This study was limited by its small sample size, which may be why it detects trends rather than significant associations. There remains an urgent need to evaluate the impact of aircraft noise exposure throughout a child's education on cognitive skills, academic outcomes and life chances.

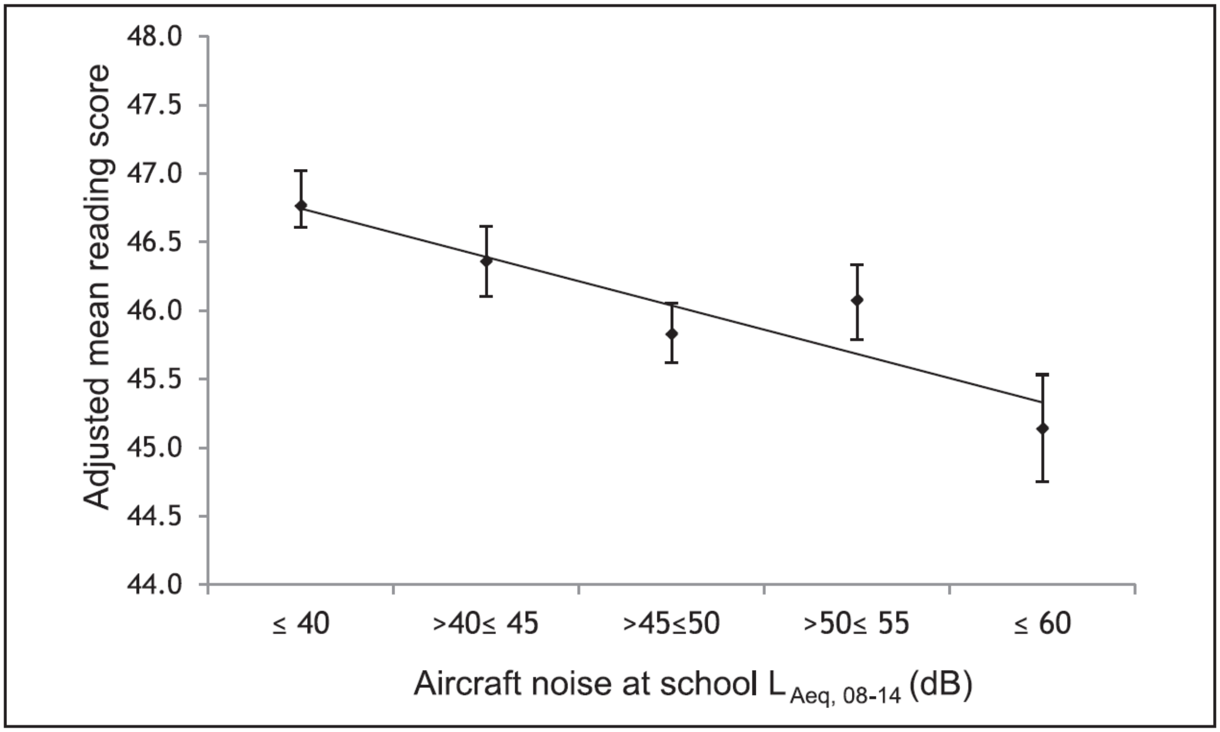

Figure 2. Exposure-response function between aircraft noise exposure at school and reading comprehension in the NORAH study.[70]

5.2 How might chronic aircraft noise exposure cause learning deficits?

Aircraft noise may directly affect the development of cognitive skills relevant for learning such as reading and memory. A range of other plausible pathways and mechanisms for the effects have also been proposed. Communication difficulties might also account for the effects: teacher behavior is influenced by fluctuations in external noise, with a recent observational study finding associations between aircraft noise events and teacher voice-masking (when the teacher's voice is distorted or drowned out by noise) and teacher's raising their voice).[72] Effects might also be accounted for by teacher and pupil frustration, reduced morale, impaired attention, increased arousal – which influences task performance, and sleep disturbance from home exposure which might cause performance effects the next day.[73,74] Noise causes annoyance, particularly if an individual feels their activities are being disturbed or if it causes difficulties with communication. In some individuals, annoyance responses may result in physiological and psychological stress responses, which might explain poorer learning outcomes.

5.3 Interventions to reduce aircraft noise exposure at school

Studies have shown that interventions to reduce aircraft noise exposure at school do improve children's learning outcomes. The longitudinal Munich Airport study[75] found that prior to the relocation of the airport in Munich, high noise exposure was associated with poorer long-term memory and reading comprehension in children aged 10 years. Two years after the airport closed these cognitive impairments were no longer present, suggesting that the effects of aircraft noise on cognitive performance may be reversible if the noise stops. In the cohort of children living near the newly opened Munich airport impairments in memory and reading developed over the first two-year period following the opening of the new airport. A recent study of 6,000 schools exposed between the years 2000-2009 at the top 46 United States airports (exposed to Day-Night-Average Sound Level of 55 dB or higher) found significant associations between aircraft noise and standardized tests of mathematics and reading, after taking demographic and school factors into account.[64] In a sub-sample of 119 schools, they found that the effect of aircraft noise on children's learning disappeared once the school had sound insulation installed. These studies evidence the effectiveness of the insulation of schools that may be exposed to high levels of aircraft noise.

Sound-field systems, which ensure even distributions of sound from the teacher across the classroom, could provide a solution to improving children's learning in situations of aircraft noise. However, an evaluation of these systems in schools in the UK, which were not exposed to aircraft noise, found that whilst the systems improved children's performance on tests of understanding of spoken language they did not influence academic attainment in terms of test of numeracy, reading or spelling.[76] Whether such systems may be an effective intervention for children attending schools with high levels of aircraft noise exposure remains to be evaluated.

5.4 Conclusions

There is robust evidence for an effect of aircraft noise exposure on children's cognitive skills such as reading and memory, as well as on standardized academic test scores. Evidence is also emerging to support the insulation of schools that may be exposed to high levels of aircraft noise. Whilst a range of plausible mechanisms have been proposed to account for aircraft noise effects on children's learning, future research needs to test these pathways, to further inform decision-making concerning the design of physical, educational and psychological interventions for children exposed to high levels of aircraft noise. Further knowledge about exposure-effect relationships in different contexts, using either individually collected cognitive performance data or standardized school test data, would also further inform decision-making. It would also be productive to derive relationships for a range of additional noise exposure metrics, such as the number of noise events. To date, few studies have evaluated the effects of persistent aircraft noise exposure throughout the child's education and there remains a need for longitudinal lifecourse studies of aircraft noise exposure at school and cognitive skills, educational outcomes and life chances.

CHAPTER 6. HELICOPTER NOISE

6.1 Exposure-response relationships

Exposure-response relationships derived for annoyance by aircraft noise were viewed as not necessarily valid for specific sources such as helicopters, low-flying military aircraft or aircraft ground noise.[6] Although relatively little is known on annoyance induced by helicopter noise, some surveys performed in the past have shown that helicopter noise is more often reported as annoying than fixed-wing aircraft noise, at similar or even lower A-weighted outdoor noise levels.[78-82] This was found for heavy military helicopters as well as for lighter civilian helicopters. A more recent survey[83] was done in three residential areas under or adjacent to helicopter corridors that were used by light civilian helicopters. The study was limited to only three surveys, but it was clear that for light civilian aircraft there was not a pronounced difference between response to fixed wing and rotary wing aircraft. The study did show that there was a residual annoyance associated with helicopter operations that was not associated with noise exposure level.

6.2 Role of non-acoustic factors

Some field studies[81,84] have shown that helicopter noise annoyance is heightened by certain non-acoustic factors, in particular fear of a crash, lack of information on the reason of the flights, and low perceived necessity of the helicopter flights themselves (such as when the helicopter is viewed as ‘rich person’s toy’) or of the noise that is produced by them (for instance when it is felt that the pilot or operator could reduce the disturbance by choosing a different flight pattern).

A more recent study[83] also found that for three surveys completed under or near light civil helicopter routes there was ‘residual annoyance,’ not a function of noise exposure level, an annoyance that was constant for all noise exposures with no evident tendency to approach zero at even very low noise levels. This lack of correlation between noise exposure level; and annoyance was associated with the strong influence of non-acoustic factors. These and earlier findings suggest that observed differences in annoyance between helicopters and fixed-wing aircraft may heavily depend on non-acoustic factors.

6.3 Role of impulse noise

Several laboratory studies have explored whether the degree of impulsiveness of the helicopter noise may contribute to annoyance.[85-89] No consistent differences in annoyance were found between helicopter and aircraft noise, again suggesting that observed differences in the field were partly due to non-acoustic factors, nor did annoyance depend on the degree of impulsiveness. Therefore, the overall consensus is that there is no evidence to justify the application of an impulse correction to the noise level of helicopters with impulsive characteristics.[90-91]

6.4 Role of rattle noise and vibrations

There is evidence that helicopter noise characterized by large low frequency components may impact the building and produce rattle (i.e. sounds of rattling objects or windows within the dwelling) or vibration (the perception of vibrating building elements or furniture), which in turn may lead to increased annoyance by the helicopter noise.[92] While rattle noise and vibration may also be induced by the low-frequency components of ground noise during aircraft landing and take-off,[93,94] it is only sporadically induced by overflying fixed-wing aircraft.[95] In a large field study in the United States[96] it was found that noise from helicopters flying over was rated by subjects (seated in a wooden frame building) as more annoying than a control stimulus, but only when the helicopter induced rattle noise or vibration within the building. The results suggest a decibel offset of at least 10 dB to account for the extra annoyance when rattle or vibration were induced by the helicopter noise (i.e. the control stimulus had to be at least 10 dB higher to induce equal annoyance). An extension of this study suggested similar offset values of 10 and 8 dB for two helicopter types inducing rattle and vibration.[80] A recent study in the Netherlands suggests a lower offset, around 5-6 dB, for helicopter noise in combination with rattle noise induced within the building.[97] This conclusion is not supported for light civil helicopter surveys[83] where survey respondents did not report vibration or rattle as a source of annoyance. The relatively small degree of low frequency energy associated with light civil helicopters as compared to heavy lift helicopters is not expected to produce rattle noise, which is the most plausible explanation for the difference.

CHAPTER 7. EN-ROUTE NOISE FROM SUPERSONIC AIRCRAFT

7.1 Introduction

Sonic booms are the unique sounds produced by supersonic aircraft. This section summarizes many of the properties and impacts of sonic booms, as we know them today. Additional detail about sonic boom noise impacts is provided in an Appendix to this white paper, for readers interested in those specifics. Detailed references are given in that Appendix.[98-164]

Conventional sonic booms are widely considered to be loud, and this forms the basis of current regulations in many countries that prohibit supersonic overland flight. However, new research has enabled aeronautical engineers the tools to develop quiet “low-boom” aircraft designs that may be available in 5 to 10 years. Hence, sonic boom research needs to clearly distinguish whether the sonic booms are the conventional N-wave sounds, so called because of their letter N pressure versus time shape, or the new low-booms which are considerably smoothed. The low-booms, or “sonic thumps”, can be as much as 35 dB quieter than conventional booms.

7.2 Human response studies

Studies have shown that sonic booms can be reproduced quite accurately in the laboratory, and this makes it possible to perform subjective experiments under controlled conditions. Although no supersonic aircraft has produced a low-boom signature yet, a similar surrogate sound can be created using a special aircraft dive manoeuver. This makes it possible to conduct tests with real aircraft outdoors for either N-waves or low-booms, complementing the laboratory tests.

A number of subjective tests have been conducted. One trend seen in studies from both the U.S. and Japan is that annoyance to sonic boom noise is greater indoors compared to outdoors. The findings show that indoor annoyance can be estimated based on the outdoor sonic boom exposure. There has been recent work to establish that both rattle and vibration contribute to indoor annoyance of sonic booms. One interesting point is that although conventional N-waves can be accompanied by a startle response, it turns out that low-booms are of low enough amplitude that they don’t induce a consistent physiological startle response.

There has been substantial work in recent years to establish metrics to assess sonic boom noise. Out of a list of 70 possible metrics, a group of 6 metrics has been identified for the purposes of use in certification standards and in developing dose-response curves for future community response studies. Clearly the low-booms are much quieter than the conventional N-wave booms, but additional community studies with a low-boom aircraft need to be conducted to assess public response.

7.3 Non-technical aspects of public acceptability for sonic boom

An additional aspect that should be considered for sonic booms includes the non-technical aspects of acceptability. The CAEP Steering Group specifically requested that ISG look into this topic. A preliminary discussion has revealed a strong resemblance to the non-acoustical factors of subsonic aircraft noise, previously mentioned in Section 2 “Community Noise Annoyance” of this white paper. There are currently no peer-reviewed studies on the topic of non-acoustical factors for sonic boom noise, but it seems plausible that the knowledge of subsonic aircraft non-acoustical factors could be extended for application to sonic boom noise non-technical aspects.

7.4 Impacts of sonic boom on animals

Recently there has been renewed interest regarding the impacts of sonic boom noise on animals. Fortunately there is an extensive literature extending from before the days of Concorde to recent years, mostly for conventional N-wave aircraft. The details of the many studies are available in the Appendix to this white paper.

There have been substantial studies for both livestock and other domesticated animals, and detailed studies of some wildlife species. For conventional sonic booms the animals usually show no reactions or minimal reactions, although occasionally they may startle just as humans do. There are no reported problems of developing fish eggs or of avian eggs due to sonic boom exposures. NASA conducted a number of studies in the late 1990s and early 2000s to assess the impact of overwater sonic booms on marine mammals. There is a good bit of knowledge as to how much sonic boom noise transitions from air into water, and fortunately, very little of the sound gets into the water. For the California sea lion, elephant seals, and harbor seals, careful lab experiments showed no temporary hearing shifts in those species.

In 1997 and 1998 a study of a colony of seals exposed to Concorde booms on a regular basis showed that the booms didn’t substantially affect the breeding behavior of gray or harbor seals. It instead seems that these animals substantially habituated to hearing these N-wave sonic booms on a routine basis.

Most of what is known about noise impacts on animals comes from the literature of the effects of subsonic aircraft and other anthropogenic noise sources, not sonic booms, on animals. It is well known that human activities can interfere with animal communication, for example.

There have not been many specific studies on the effects of sonic boom noise on animals in recent years. Some species with good low-frequency hearing, such as elephants, have never been evaluated regarding sonic boom noise. But it makes sense that if the already tested animals were not negatively affected by sonic boom noise from conventional N-waves, that they will likely not be affected by the proposed low-booms of the future. Long-term effects of sonic boom exposure on animals seem unlikely.

7.5 Conclusions

Much progress has been made to model and mitigate the effect of sonic booms from supersonic flight. Ongoing research to assess the impact on the public indicate that new supersonic aircraft designs will create quieter sonic thumps that are much less annoying than conventional sonic booms. Upcoming community tests with a low-boom demonstrator aircraft will collect the data needed on noise exposure and resulting public reactions.

CHAPTER 8. UAM/UAS noise

8.1 Current status

New aircraft technologies for increased mobility are likely to lead to new sources of community noise. Urban Air Mobility (UAM) refers to a range of vehicle concepts and missions operating in a community, from small Unmanned Aerial Systems (sUAS) to vehicles large enough for several passengers. The sUAS are envisioned for package delivery, surveillance, agriculture, surveying, and other similar applications that can benefit from use of a small and agile autonomous system, while the larger vehicles are envisioned for on-demand urban passenger transportation.[165] Electric propulsion is seen as a key technology that could enable these kinds of systems, across the range of vehicle types and sizes.[165]

UAM vehicles have the potential to alter the community soundscape due to their noise characteristics that are qualitatively different from traditional aircraft.[166-168] In addition, similar to sonic booms from supersonic aircraft en route, the noise may not be concentrated around traditional airports. There is very little scientific research on the human impacts of noise from UAM aircraft, although there have been increased efforts to measure and model the noise generated by them and their components.[167,169-172] Two psychoacoustic studies are briefly described here.

A study[166] was conducted by NASA to evaluate human annoyance to sUAS noise, including the effect of variation in operational factors and a comparison of annoyance to noise from road vehicles. The noise from four commercially available sUAS and four road vehicles, ranging in size from a passenger car to a step van, were recorded and presented to test subjects in a specialized simulation facility. For this limited set of noise sources, a systematic offset was found that indicates the noise of sUAS is more annoying than noise from road vehicles when presented at the same loudness.

Another NASA psychoacoustic study[168] concentrated on annoyance to noise from a simulated distributed electric propulsion (DEP) aircraft. Using auralizations from noise predictions of spatially-distributed, isolated propeller noise sources, the subjective study in a specialized psychoacoustic facility found that the number of propellers and inclusion of time-varying effects were significant factors in annoyance, while variation of the relative revolutions-per-minute (RPM) between propellers was not significant. The study also developed an annoyance model based on loudness, roughness, and tonality for predicting annoyance to these DEP sounds. Despite the limitations in prediction methods and simplifications, the study identified the relevant parameters and metrics that should be studied further.

8.2 Conclusions

Growing interest in UAM aircraft has been observed from different sectors, such as hobbyists, commercial entities, the military, government agencies, and scientists.[165] There is preliminary evidence that the public may be concerned with these new noise sources intended for transportation and package delivery.[173] Although there is only a very limited amount of research on subjective reaction to noise from these new aircraft types, indications that the noise characteristics differ from traditional aircraft warrant further research to understand and predict human perception of these sounds.

CHAPTER 9. ECONOMIC COST OF AVIATION NOISE / MONETIZATION

9.1 Introduction

Sleep disturbance, myocardial infarction, annoyance, stroke, dementia, and other health effects are increasingly recognized as economic costs of noise.[174] Recent studies estimating annual noise costs around specific major world airports are useful in considering the scale of the challenge and include: Taipei Songshan Airport €33 million[175] and Heathrow £80.3 million.[176] An unpublished student thesis by Kish (2008) suggests annual costs for aviation noise at 181 airports worldwide in excess of $1 billion, which is not out of line with the individual airport estimates.[177] It is clear that noise can be a key factor when airport expansion is considered. Values of disturbance from aircraft noise are used in analysis and planning decisions affecting airport development and operations. Their main application is in estimating the costs or benefits arising from changes in noise levels and/or exposure. It is therefore important to look at the evidence that underpins these value estimates. There are three main approaches for monetizing noise costs, two of which value the nuisance according to individual preferences: revealed preference, usually hedonic pricing, and stated preference methods, which include contingent valuation and stated choice. The third type of approach, the impact pathway, links health effects of noise nuisance to monetary values from reducing morbidity risks that are typically derived from elsewhere. These are discussed in turn below.

9.2 Hedonic Pricing (HP)

The main method using revealed preference is hedonic pricing whereby the market for an existing good or service, in this case housing, is used to derive the value for components of that good, in this case the noise environment. House price in HP is modelled as a function of property characteristics that should include all social, spatial, and environmental factors. HP then provides the percentage change in house prices resulting from a 1 dB change in noise levels.[178,179] The method has been extensively applied to the problem of aircraft noise, especially in North America. Individual studies yield a wide range of price changes from 0% to 2.3% per dB.[180] Thus a key challenge is to derive values that are applicable or transferable in different contexts.

Meta-analyses have sought to estimate consensus values based on pooled evidence from individual studies.[181-183] These meta-analyses are based on a reasonably small number of, US dominated studies, observations of 30, 29 and 53 respectively. Nelson (2004) and Wadud (2013) converge on 0.5 to 0.6% house price fall in response to a 1 dB increase in aviation noise, with caveats concerning the broad range of estimates and a dearth of studies in less developed countries. Using data on income, Kish (2008) carried out a meta-analysis on US based HP evidence, estimating a model with a low but reasonable fit, which he found did not transfer well to UK data. He et al. (2014) built on this work[184] but their model fit was poor. The evidence from these studies also suggests that values in Canada are higher[182,183] or more generically that values outside the US are higher.[184] Interestingly, Kopsch (2016) reports a meta-analysis including air and road noise, finding that aviation noise increases the NDI by 0.4 to 0.6% relative to road.[185] To conclude, the best available evidence from the HP is that house prices fall by 0.5 to 0.6%, on average, per 1 dBA increase in aircraft noise, and there is also some support for country specific effects.[182,183]

9.3 Stated Preference (SP)

Stated preference approaches have been increasingly applied to value noise nuisance especially in Europe. These involve either direct questioning on value, contingent valuation, or trade-off approaches, stated choice or ranking. As with HP, individual studies exhibit a wide range in values per unit of noise. A data set of 258 values of transportation noise derived from SP studies, adjusted to 2009 prices, yielded an average value per decibel change per household per annum of $141.59, 95% Confidence Interval (CI) +/- $30.24 with a range from $0 to $3,407.67. However the aviation noise values within this data, 69, exhibit less variation with a mean of $292.24 and a CI of +/- $23.10 and smaller range of $15.05 to $1097.83. Such variation in values may reflect genuine variations in preferences, the impact of contextual variables, variations in approach, systematic study or country effects, and changing preferences over time or some combination of these effects.[186] Again, meta-analysis can assist in explaining some of this variation. Only one meta-analysis has been conducted on studies of transportation noise, utilising 258 values derived from 49 studies across 23 countries conducted over a 40-year period.[186] As might be expected, the value of noise reduction or the cost of noise increases were found to be dependent on level of annoyance and income. The income elasticity was close to one, suggesting that the value placed on reduced noise increases broadly in line with income; this is higher than estimates from cross sectional studies. There were no country effects found in this meta-analysis, suggesting that the model and values derived from it are transferable. Additionally, aviation noise was found to have a higher cost per dBA than road and rail noise. A result that is consistent both with studies of annoyance,[6] and HP meta-analysis.[185] Furthermore, comparison with the then HP-based approach applied by the UK Department for Transport at the time (2014) indicated that the values from the SP meta-analysis and the HP-based approach were broadly comparable. [186] This is also supported by the primary research of Thanos *et al.* (2015), applying SP and HP in the same context.[195]

9.4 Impact pathway

The third approach is rather different by exploring the impact pathway (IP) for noise effects on human health, and expressing those endpoints in terms of Disability Adjusted Life Years (DALYs) or Quality Adjusted Life Years QALYs) to quantify healthy life years lost. The World Health Organization adopted this approach[174] and identified disability weights (DW) for cardiovascular disease, sleep disturbance, tinnitus and annoyance resulting from environmental noise. The evidence on the health impacts in all areas has been growing over the years. However, the evidence base underpinning the DWs for sleep disturbance and annoyance is extremely sparse, with a high degree of uncertainty.[180] This is reflected in the WHO (2011, p: 93) weight on annoyance where “a tentative DW of 0.02 is proposed with a relatively large uncertainty interval (0.01-0.12)”. This DW is only applicable those who are “highly annoyed”, so any individuals experiencing annoyance who are not highly annoyed are assigned a value of zero.

There is uncertainty around the value of a healthy life year lost, which is combined with the DW weights to derive monetary values. In practice, value of life has been derived from stated preference studies of traffic fatalities in the UK,[188] or reduced mortality risk based on stated preference studies in Europe.[189] As these values do not stem from analysing the health risks of noise nuisance, there is an added element of uncertainty regarding transferability of values from diverse contexts. Furthermore, the impact pathway approach has many steps each with potential to add error and uncertainty to the value/cost estimates. As Freeman et al., (2014, p: 441) put it, "significant work is needed to improve and update the values of reducing risks that lead to morbidity and/or mortality."[190] Nevertheless, the method has been adopted into policy analysis by the UK Department of Transport[191] in assessing transport schemes and by the European Commission in evaluating the environmental noise directive.[192]

9.5 The abatement and mitigation costs of dealing with noise

The costs imposed by noise lead to efforts to measure, manage and mitigate. Airports can bear substantial costs, for example at the high end of the scale, Amsterdam Schiphol spent approximately €644.6m largely on insulation between 1984 and 2005.[193] Nevertheless this only amounted to €0.58 per passenger. Whilst manufacturers have produced quieter aircraft, there is a trade-off between achieving energy efficiency and quieter design and operation. The benefits of any mitigation activity should outweigh the costs. The costs of mitigation are relatively straightforward to estimate, as they have a market price of implementation and maintenance, in the case of noise insulation or barriers, or of estimating forgone benefits, for instance, of noise curfews. It is also rational to compare the costs of different routes to achieving a noise reduction target, for example through regulation or market incentives. Once both the costs of noise and any additional costs of mitigation are established; cost benefit analysis (CBA) can be used to guide towards solutions with the highest net benefits.

9.6 Conclusions

Economic valuation of noise nuisance and health effects is necessary and robust values are available. Most importantly, these values are applied and used in decision making. Meta-analysis of both hedonic pricing and stated preference studies suggests that these approaches, when properly applied, deliver robust values of noise nuisance. These preference-based approaches do not capture the health effects of noise that are not perceived by the exposed population. The impact pathway approach provides non-market values for these health effects. However, IP does not value annoyance at levels less than "highly annoyed", has a less well developed evidence base than HP and SP, and requires more steps that have the potential to introduce more error. Furthermore, HP and SP meta-analyses have improved the transferability of values providing confidence intervals for their variation, whereas there is no robust evidence on value transferability for the IP approach. This approach should be viewed with caution in the absence of a well-developed evidence base, and especially in the case of annoyance effects perceived by the exposed populations, for which robust values of noise nuisance can be delivered by tested methods.

CHAPTER 10. OVERALL CONCLUSIONS AND FUTURE WORK

This paper has provided an overview of the many different aircraft noise impacts. There is substantial evidence that increases in noise levels lead to increases in community annoyance, but there are other non-acoustical contributors to annoyance. In future work, existing exposure-response functions should be updated and diversified to account for various acoustic and non-acoustic factors. The difference between a high rate change and a low rate change situation seems to be particularly important.

Undisturbed sleep is a prerequisite for high daytime performance, well-being and health. Aircraft noise can disturb sleep and impair sleep recuperation. Further research is needed to (a) derive reliable exposure-response relationships between aircraft noise exposure and sleep disturbance, (b) explore the link between noise-induced sleep disturbance and long-term health consequences, (c) investigate vulnerable populations, and (d) demonstrate the effectiveness of noise mitigation strategies. This research will inform political decision making and help mitigate the effects of aircraft noise on sleep.

Epidemiological evidence from a systematic review published in 2018 covering studies up to 2016 and subsequent published studies involving several million participants show associations of aircraft noise with ischaemic heart disease. This is consistent with the evidence for road traffic noise, with larger numbers of studies. There is biological plausibility for impacts of noise on health and experimental evidence of effects of noise on the mechanistic pathways relating to cardiovascular disease, supporting the likelihood that associations are causal. Associations between aircraft noise and hypertension or stroke are less consistent across epidemiological studies, but other biological mechanisms than hypertension are available to explain associations with heart disease. However, the evidence base for aircraft noise remains limited and further research may result in changes to exposure-response relationships with cardiovascular disease, such as those derived from the systematic review of studies published in 2018. The evidence base is limited for non-cardiovascular outcomes; further research is particularly needed on diabetes and obesity, mental health, and pregnancy and birth outcomes. Further research is also needed using additional noise metrics, including those that better characterise air traffic events than average sound level (e.g. number of events above a certain noise threshold) and that consider time period (e.g. late evening and early morning).

There is robust evidence for an effect of aircraft noise exposure on children’s cognitive skills such as reading and memory, as well as on standardized academic test scores. Future research needs to test the different mechanisms and to inform key individuals who can intervene on the behalf of exposed children. Longitudinal studies over the lifecourse need to be conducted.

While some surveys suggest a higher response to helicopter noise than to noise from fixed-wing aircraft, any observed differences in annoyance seem to heavily depend on non-acoustic factors. Overall, there is no evidence for a pronounced difference between response to fixed-wing and to rotary wing aircraft at equal noise levels that would justify a stricter evaluation of helicopter noise. Only when the helicopter noise is characterized by a large degree of low-frequency energy, which may produce rattle noise or vibration in buildings, there is evidence that annoyance is markedly increased. Further research should consider the consequences of rattle noise to the evaluation of helicopter noise, as well as the important role of non-acoustic factors.

Using laboratory simulators and testing in the field with special aircraft manoeuvers, progress has been made on understanding and predicting human response to sonic boom noise from overflight of new proposed quiet supersonic aircraft. To confirm these results and extend the applicability of derived models, a new low boom flight demonstrator aircraft is being built to conduct sonic boom community response studies. Plans are underway for designing these experiments to develop exposure-response models for this new kind of quiet supersonic aircraft. Several aspects of human response to low-boom supersonic flight still remain to be researched. Subjective studies have not fully investigated perception of focus booms, booms from other parts of the trajectory outside the cruise portion, noise in the shadow zone beyond lateral cut-off, Mach cut-off booms, and secondary booms. In addition, sleep disturbance relating to low-boom supersonic cruise flight or any of these other conditions has not been studied. Finally, community studies are needed using quiet supersonic aircraft in areas where people are not accustomed to hearing sonic booms, in order to develop a dose-response relationship for this new sector of commercial transportation. Regarding the non-technical aspects of public acceptability for supersonic aircraft noise, there is nothing in the literature that directly applies. However, it may be possible in the future to draw from the existing literature on the topic of non-acoustical factors for subsonic aircraft noise. We are fortunate that there already have been many studies on how animals react to conventional sonic booms, and current thinking is that the new low-boom aircraft would even have less of an impact. It is still unknown if large animals with good low-frequency hearing such as elephants will respond any differently compared to the medium and small sized animals that have already been studied.

There is preliminary evidence that the public may be concerned with the new UAM noise sources intended for transportation and package delivery. Although there is only a very limited amount of research on subjective reaction to noise from these new aircraft types, indications that the noise characteristics differ from traditional aircraft warrant further research to understand and predict human perception of these sounds.

Evidence from hedonic pricing and stated preference studies suggests that these approaches, when properly applied, deliver robust monetary values of noise nuisance. Although the impact pathway approach additionally provides non-market values for health effects, it should be viewed with caution especially in the absence of a well-developed evidence base and evidence on value transferability. There remains a need for further research to improve the robustness of the impact pathway approach and comparisons with other approaches. A further issue is that of evidence for lower income countries which is very sparse.

Comparisons between aircraft noise impacts and other noise source impacts, such as rail, road, and industrial noise, are beyond the scope of this current white paper. Others have already pointed out some of the similarities and differences in impacts between different types of noise sources, so much of that information is currently available.[194]

CHAPTER 11. ACKNOWLEDGMENTS

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APPENDIX A - Sonic Boom Noise Impact, Additional Detail And References

A1. Sonic boom impacts on humans

A.1.1 Unique qualities of sonic booms

There are several unique aspects of sonic booms that require different treatment from subsonic aircraft noise. The transient nature of the sonic boom and large amount of low-frequency energy in the signal result in a sound character that is perceived much differently than conventional aircraft. While subsonic aircraft noise is a concern near airports, the sonic booms from supersonic aircraft are created along the entire supersonic route and could potentially affect large segments of the population. Thus the existing methods and noise metrics for measuring and regulating aviation noise impacts cannot be used for supersonic aircraft.

With advances in aircraft shaping techniques, modern supersonic aircraft designs are predicted to create shaped, low-amplitude sonic booms heard on the ground that are much quieter than conventional sonic booms from military aircraft or the Concorde. The significant reduction in waveform amplitude and increase in rise time lead to a reduction in sound pressure level spectra, particularly at higher frequencies where the reduction can reach 60 dB. Accordingly, the loudness spectra are also reduced, by over a factor of 10 in sones over most of the frequency range critical to human hearing.

Historically, the maximum overpressure of the front shock of the waveform was used to describe the level of conventional N-wave sonic booms. Years of research using outdoor sonic boom simulators, however, resulted in identification of Perceived Level (PL) as a noise metric[98,99] that works best for a variety of signature shapes.[100] Annoyance to sonic booms as experienced indoors presents additional factors to consider that are related to the building environment.

A.1.2 Sonic boom noise generation for subjective studies

Laboratory simulators have been used effectively to study human annoyance to a broad range of sonic boom signals under controlled conditions.[101] Simulators can reproduce measured booms as well as booms predicted for aircraft designs. They can also be used to study other boom-like waveforms to study human response to different parameters and interactions. The majority of simulators reproduce sonic booms as they would be experienced outdoors, although filtered outdoor waveforms or recordings of indoor waveforms have also been presented to estimate the indoor environment. These simulators, however, lack indoor realism because there is an absence of space and reverberation, secondary rattle and vibration, and overall aesthetic composition.

Most outdoor sonic boom simulators in existence today consist of an airtight, small rigid-walled booth. The cavity is driven with subwoofer loudspeakers to reproduce the low frequencies characteristic of sonic booms, while mid-range loudspeakers fill in the rest of the pertinent spectrum. Another simulator design consists of a mobile trailer that creates a traveling wave using an array of loudspeakers, a folded horn, and an anechoic termination.[102]

High-quality headphones or earphones are also used to reproduce the audible content of sonic booms and secondary rattle noises typically encountered in indoor environments. Binaural signals have been used to approximate the auditory experience of sonic boom and rattle exposure in different-sized rooms, through the use of models and filtering.[103,104] Some limitations of this playback equipment are the absence of experiencing the sounds in a real space with natural reverberation, the absence of tactile vibration, and decreased realism due to limited very low-frequency reproduction. High-quality systems of amplifiers and headphones have mitigated this last point somewhat, but the systems are still more limited than subwoofer systems for reproducing the full frequency content of the sonic booms.

Lastly, newer simulators allow for more realistic indoor soundscapes for investigating causes of elevated annoyance to sonic booms experienced indoors. One configuration[105] consists of a small booth that can be configured for indoor listening using a partition with a window. Another installation[106] called the Interior Effects Room (IER) at NASA Langley Research Center consists of a small room configured as a living room with loudspeaker playback over arrays adjacent to two exterior walls of the simulator. The realistic indoor soundscape and environment, augmented with the ability to control secondary rattle noises and vibration, have enabled systematic studies of the factors contributing to human annoyance to sonic booms.

Sonic boom subjective studies have also been conducted with real supersonic overflight of an aircraft. In the past, these studies were limited to assessing response to very loud booms, usually produced with military aircraft. However, a special flight manoeuver called a low-boom dive has been developed[107] to mimic the lower amplitudes at the ground that would be expected from supersonic overflight of future aircraft. By adjusting the location of the dive, the ground sonic boom can be varied in level over a small geographic area. This manoeuver has been used successfully in several field studies to create a variety of boom loudness levels that would otherwise not be possible with today's aircraft in steady, level flight.

A.1.3 Human response studies

Human response to outdoor booms

Many human response tests were performed in NASA's outdoor sonic boom simulator[100] in the 1990s. These laboratory studies were designed to investigate a wide range of shaped sonic boom signatures and to gather human perception of loudness and annoyance to these sounds. Several noise metrics were evaluated for their ability to predict the subjective response. Shaped booms were rated less loud than symmetric N-waves, and PL was found to be the best noise metric for describing subjective effects both outdoors and indoors. The metric PL has hence been used widely to design and assess sonic boom characteristics of supersonic aircraft. Conclusions on the indoor environment are limited because the waveforms were created by pre-filtering booms based on frequency-dependent noise reduction for transmission of sound into a typical house.
An evaluation of the realism of outdoor boom simulation was conducted between three simulators and real booms from overflight of a supersonic aircraft.[108] PL values were found to be highly correlated

between field recordings and simulator reproduction, and results increased confidence in the use of simulators for human response testing. It was noted that very low frequency energy (less than 7 Hz) was not found to be significant for assessing realism to booms experienced in an outdoor environment.

Outdoor vs. indoor response

Some studies have been conducted to compare perception of sonic booms heard in indoor and outdoor environments. A field study conducted by NASA compared ratings from test subjects seated inside and outside a house overflown by a supersonic airplane, using the low-boom dive maneuver.[109] Although the annoyance ratings showed that indoor and outdoor annoyance were the same for the same noise exposure, a post-test questionnaire highlighted an increase in annoyance indoors. This inconsistency could possibly be attributed to the methodology chosen or to the presence of a rattle indoors.

A series of subjective tests with playback of measured low-amplitude sonic booms was conducted[110,111] to further explore the inconsistency discovered by Sullivan et al.[109] Three different listening environments were explored, including headphones indoors, headphones outdoors, and an outdoor simulator,[102] and the same set of signatures were used in each case. Indoor signatures were found to be more annoying than outdoor signatures regardless of listening environment, and signatures experienced indoors were considered more annoying.

A series of tests was also conducted by JAXA[105] to evaluate both loudness and annoyance ratings of N-waves with different amplitudes and rise times, using both indoor and outdoor configurations of their simulator. Different Japanese adjectives were evaluated for correspondence with the English words of loudness and annoyance. Most of the noise metrics investigated exhibited a high correlation with response, with indoor response being higher than outdoor response for the same loudness.

Given the evidence from older community studies[101,112] and these more recent studies, it is expected that indoor annoyance will be higher than outdoor annoyance, due to several factors discussed in the following section.

Human response to indoor booms

In recent years, sonic boom subjective research has shifted to exploring perception of booms experienced indoors.[104, 113-126] Initial studies in NASA's IER simulator found that boom amplitude and rise time persist as important factors for indoor response.[113,114] Overall, the longer rise times of low booms result in decreased annoyance.

A later study evaluated indoor annoyance to sonic booms predicted for sub-scale and full-scale supersonic aircraft, which have different low-frequency energy, even for the same overall loudness value.[115,116] The test was conducted using shaped, low-amplitude booms for four classes of aircraft size from sub-scale demonstrator to full-sized airliner. For a given exterior PL, the annoyance to sub-scale aircraft booms was not significantly different than that for full-scale aircraft booms. This finding confirmed that exterior PL can be used to evaluate supersonic aircraft designs, regardless of size. These results help justify plans for use of a sub-scale demonstrator for community studies. However, results were limited to isolated booms with no rattle.

In order to address the concern from community studies that rattle is important to perception of sonic booms indoors, a series of tests was conducted to investigate human response to rattle and to combined boom and rattle.[104] Using binaural recordings of rattle played back over headphones, the study found differences in annoyance between rattle sounds of the same PL. Rattle sounds from structural elements such as windows, walls, and doors were judged more annoying than rattle from smaller objects. Most combinations of boom and rattle were more annoying than the boom alone at equal PL, giving a rattle penalty of 3-9 dB, depending on the rattle type. This result confirms the elevated annoyance indoors when rattle is present. Lastly, standard loudness and sound quality metrics were found to be poor predictors of annoyance to rattle sounds and boom/rattle combinations, but hybrid models incorporating multiple metrics resulted in higher correlations with subjective data.

Rattle studies conducted in NASA's IER facility using a more realistic sonic boom playback and indoor environment[117-119] found that rattle increased indoor annoyance. Window rattle sounds reproduced for a variety of window types demonstrated that the average increase in annoyance due to rattle was equivalent to an increase in exterior boom PL of 4 dB, confirming the headphone test rattle penalty of 3-9 dB.

Two vibration studies were also conducted in the IER to investigate the effect of vibration on annoyance to sonic booms.[120-123] The vibration condition was varied using vibration isolators on the test chair legs and in the second study, shakers attached to the seat bottom. The shaker signals were determined through structural modeling for an ensemble of approximately 6000 houses with varied physical properties, and the levels from the 84th and 99th percentile of the predicted peak acceleration distribution were chosen.[124] Between the two studies, vibration penalties up to 10 dB were observed, indicating that vibration also plays a role in indoor perception of sonic booms.

Another possible factor in human response to sonic booms is the startle experienced due to the transient nature of the boom. Earphone studies examined annoyance, startle, and loudness ratings for impulsive sounds including sonic booms.[125,126] The startle ratings were strongly correlated with annoyance, and the importance of the abruptness of the initial shock and resulting high-frequency energy were highlighted. Subjective judgments of startle were then compared to physiological responses using measured skin conductance, heart rate, and electrical activity of three neck muscles. Subject-to-subject and day-to-day variability in the physiological responses were observed, and their association with startle were rare. It was concluded that low booms are below the threshold of consistent physiological startle responses using the current measurement techniques.

Community studies

A community study was conducted of the response of 100 Edwards Air Force Base (EAFB, USA) residents to sonic booms, ranging from low amplitude using the low-boom dive manoeuver to higher amplitude from conventional overflight.[127,128] Although the study was primarily a methodological test in preparation for future studies with a low-boom demonstration aircraft, the daily annoyance results are remarkably similar to those from the 1960s Oklahoma City test.[129] Lessons learned from this test are being used to develop follow-on risk reduction studies in preparation for community testing with a low-boom flight demonstrator aircraft.

A.1.4 Sonic boom metrics evaluation

Since no international standard exists for defining a sonic boom metric, there is a need to identify noise metrics to quantify the noise exposure dose in dose-response curves of community test data. A study was conducted to combine results from several years of laboratory testing into a meta-analysis to evaluate candidate noise metrics, with the objective of identifying the best subset of metrics.[130] A meta-analysis was chosen because there was no clear preferred metric. Some metrics performed relatively better than other metrics in some studies, while the metrics ranking was very different for other studies. Some studies showed low or high correlations of metrics with human response in general for all metrics, compared to other studies.

An exhaustive list of approximately 70 metrics was compiled from standards and literature; expert judgment, including consideration of non-acoustic factors, resulted in 25 metrics being chosen for quantitative analysis. Different metrics treat lower frequencies differently, which is critical for describing sonic boom noise. The candidates were grouped into three categories: engineering metrics that describe aspects of the sound, loudness metrics that attempt to account for human perception of sound, and “hybrid” metrics that combine several metrics. Using three laboratory studies of human response to isolated outdoor and indoor booms, eight metrics were retained.[130] Additional analysis with two more laboratory studies on rattle and vibration effects reduced the number to six metrics: ASEL, BSEL, DSEL, ESEL (A-, B-, D-, and E-weighted sound exposure levels, respectively), PL, and ISBAP (indoor sonic boom annoyance predictor).[131] This set of six metrics will be used by NASA in development of dose-response curves from future studies of community response to sonic booms.

A.1.5 Conclusions

Sonic boom simulators and special aircraft manoeuvers have been used to investigate human annoyance to sonic booms in outdoor and indoor environments. The most important factors have been studied separately to shed light on the role they each play in human perception. Studies have confirmed the viability of using an outdoor metric to predict human response indoors, despite differences in noise dose indoors. Results indicate that low-amplitude shaped sonic booms are much less annoying than conventional sonic booms, although annoyance levels need to be confirmed with community testing.

Laboratory test results have been used in meta-analyses to evaluate candidate noise metrics, and six metrics are recommended for further study. This subset of metrics will be used by NASA in future dose-response curve analyses of community field studies using a purpose-built low-boom flight demonstrator.

Other factors not considered in the subjective studies to date include: focus boom, booms from other parts of the trajectory outside the cruise design point, secondary booms, noise in the shadow zone beyond lateral cut-off, Mach cut-off booms, and sleep disturbance relating to any of these conditions.

A2. Non-technical aspects of public acceptability for sonic boom

As most people are not yet familiar with the concept of quiet supersonic civilian flight that may be developed in the future, it is likely that some individuals will assume future supersonic flights will be very much like those of Concorde or today's military aircraft, each creating loud sounds both on take-off and approach to landing as well as during supersonic cruise. In contrast, some members of the population could very well not be aware of noise concerns regarding supersonic flight from years ago, and hence, would be more open to this new transportation option. Therefore, it seems likely that, from the start, the public will have mixed reactions to future supersonic aircraft, without even having heard them.

The CAEP Steering Group requested that its Impacts and Science Group (ISG) investigate the "non-technical aspects of public acceptability" for the noise of future supersonic civilian aircraft. There is no peer-reviewed literature available to easily address this topic. At the Aviation Noise Impacts Workshop held in Montreal, forming the basis of the present white paper, an open discussion was held on the topic by the attending scientific experts. It became clear during the discussion that there were some parallels between the "non-technical aspects of public acceptability" and the area known as "non-acoustical factors" of noise annoyance research, previously described in this paper for subsonic aircraft.

Currently there are no studies available to compare attitudes and/or reactions of the public between subsonic and supersonic aircraft noise. Referring back to the section of this white paper on community annoyance briefly, the population usually does not think of the benefits of air travel when assessing their tolerance to aircraft-generated noise, and there is no reason to think there will be differences in these tolerances between subsonic and supersonic aircraft. There is also no reason to believe that a lack of trust in and/or sensitivity to fair treatment by politicians, airports, airlines, and manufacturers would be any different between subsonic and supersonic travel. So much of the knowledge regarding "non-acoustical factors" of annoyance may well also apply to the "non-technical aspects of public acceptability." Hence, the applicability of our knowledge of "non-acoustical factors" to the issues of "non-technical aspects of public acceptability" should be explored in the future. ISG will continue to study this issue, but it is unlikely that our knowledge, based in science, will change in the next few years regarding public acceptability to new supersonic noise sources.

A3. Impacts of sonic booms on animals

Animals can be affected by aviation operations, and the impact of supersonic aircraft noise (sonic boom) has been a topic of discussion since the 1960s when the Concorde and the U.S. SST programs were initiated. There is a sizable existing literature regarding effects of sonic boom noise on animals, both wild and domesticated. It should be noted that all past studies were primarily concerned with N-wave sonic booms with amplitudes determined by civilian and military supersonic aircraft. No studies have been conducted thus far examining the effects of low-boom supersonic aircraft, now on the drawing board, on animals.

During the 1960s and 1970s the emphasis was on farm animals and potential adverse effects of sonic booms and their economic consequences. The concern was that operators of supersonic aircraft might have to pay damages via court orders. For either low-altitude flights or accidental incidents of high-amplitude focused sonic booms, military supersonic aircraft can cause breaking of windows or cracking of plaster in buildings, resulting in damages that must be compensated. Clearly, the developers of supersonic passenger aircraft and the regulatory authorities wanted to avoid such situations. Some of the primary references for the studies of the time are (Runyan & Kane, 1973; Bell, 1972; Cottereau, 1972; and Bond, 1971).[133-136]

Bell notes that during the period 1961 to 1970, the U.S. Air Force received claims of almost 900,000 USD but paid out about 128,000 USD in awards. Over 100,000 USD of those awards were for mink, a type of animal used to make warm coats. Because of their monetary value, there were several controlled experiments conducted in which mink were exposed to real and simulated sonic booms. It was noted that female kits may be alerted, pause in activity, and look around for sources of the sound. Sleeping females may awaken and mating pairs may show momentary alertness, but the mating ritual is not disturbed. No wounding, killing, carrying or burying of kits in the nests of females were observed. One study observed that the reactions of mink to barking dogs, truck noises, or mine blasting were similar to their reactions to sonic booms. Bell noted that domestic or pet animals may react to sonic booms, and simple startle is the most common response. Occasionally reactions such as trampling, moving, raising the head, stampeding, jumping, or running may be observed due to sonic boom. Avian species occasionally will run, fly, or crowd. It was noted that these reactions are similar to those due to subsonic airplane or helicopter flights, barking dogs, or other sudden noises. Regarding studies of wild animals and to animals in zoos, it was reported that observations of deer, reindeer, and some zoo animals showed no reaction or only minimal and momentary reactions such as raising the head, pricking the ears, or scenting the air. The Federal Aviation Administration funded a study on the effects of sonic boom on fish.[137] The conclusion of the study was that sonic booms have no effects on developing fish eggs or fish. It was suggested that the pressure of a sonic boom was akin to the pressure of a pebble, stone, or boulder being dropped into water, and that this should be investigated in future studies. No follow-up studies are in the literature.

Later in the 1980s and early 1990s the emphasis switched to the studies on the hatchability of eggs and to studies conducted by the United States Air Force. The Air Force program with interest in this topic was NSBIT ADPO, the Noise and Sonic Boom Impact Technology Aerospace-Medical Division Program Office. The program director during 1989-1994 was Robert Kull, and he at the time chaired the “Noise and Animals” team of ICBEN. That team no longer exists. The two large detailed literature reviews of the time were (Kull and Fisher, 1987; and Manci, *et al.*, 1988).[138-139] In one of his unpublished overview presentations of the time Kull noted that it was difficult to observe animals in their natural environment, it's difficult to measure the noise exposure at the animal's position, the species of concern are usually low in population size and laws and/or regulations restrict access to those animals, there are thousands of species, the animals cannot be interviewed, the animals seem to habituate quickly, and terrestrial animals are usually not exposed for long periods or high levels. Each of these points make it a challenge to get the same types of impacts data for animals that we can get for the human population.

There were a number of studies examining the possibility that chicken or other avian eggs might not hatch or might be cracked by sonic booms. In 1972 Bell reported on a number of studies in the 1960s where egg hatchability was not affected by sonic booms. A later study in 1994 by Bowles et al. showed similar results.[140] However, there was one report from 1970 that a mass hatching failure of Sooty Tern eggs might have been caused by sonic booms.[141] This prompted additional research, and subsequent detailed studies[142,143] that showed this mass hatching failure was very likely not caused by sonic booms. It was suggested that it was much more likely that a predator, weather, lack of food, or insects caused the incident. Another study from this period noted that nesting peregrine falcons and other raptors were often minimally affected by mid to high- altitude sonic booms, showing no effects on their production of offspring. Overall, it was reported that adult birds would sometimes be alerted or would flee their nests in response to a loud boom, but no productivity-limiting responses were detected.[144]

Another species studied in the 1990s was the Desert Tortoise (Gopherus Agassizii). Bowles et al. reported in 1999 that simulated carpet sonic booms "did not stimulate any significant changes in behavior other than brief bouts of looking." Overall, it was concluded that the Desert Tortoise does not have an acoustic startle response.[145] It should be noted that this was a very complete study where the animals' hearing, metabolic rate, heart rate, oxygen consumption, etc. were very carefully monitored throughout the testing. During the 1990s and early 2000s NASA undertook a number of studies to assess the impact of overwater N-wave sonic booms on marine mammals, including both pinnipeds and whales. NASA's aim was to ensure that N-wave booms would be compliant with existing U.S. regulations such as the Marine Mammal Protection Act (MMPA). Physics tells us that when a sonic boom traveling through air impinges on the water that the pressure just above the air/water interface must be the same as the pressure just below the air/water interface, i.e. the boundary condition is matched. This is true for any aircraft traveling at a speed of Mach 3 or less. Also there is a large density change, a factor of about 800, between air and water. This and the sound speed difference between air and water means that almost zero acoustic energy is transferred between the air and water. Thus although there is a pressure created in the water due to sonic booms in air, there is no propagating wave into the water. So the pressure disturbance in the water hugs the surface, and the sound pressure decays exponentially with depth. High frequencies (hundreds of hertz or higher) die off very fast with depth, but some very low frequencies penetrate to distances of about 50 m. Hence whales, which come up to breath air at the surface, would likely hear sounds created by sonic booms when they are very near the surface. They will hear nothing if they are diving to deep depths. In 2001 Rochat and Sparrow conducted a computational study to see if swell on the ocean surface could focus this sound energy and create acoustic hot spots, but this focusing was very small and had little effect.[146]

The theory to predict N-wave sonic boom penetration into the ocean was developed in the 1960s, and this theory was updated by Sparrow and Ferguson in 1997 to handle arbitrary sonic boom signatures.[147] The theory was tested in the field with hydrophones (underwater microphones) deployed by boats with a supersonic aircraft overhead by Sohn *et al.* in 2000.[148] The acquired field data closely matched the simulation predictions, and these theories and results were summarized in a review paper by Sparrow in 2002.[149] It should be noted that the sonic boom sounds that might be heard underwater are at levels much less than if a sound source is making sound IN the water. In that case, there is no mismatch between the density and speed of sound as in the case of sonic booms, and the sound will propagate very effectively. This has been seen for other types of anthropogenic underwater noise such as active sonar from military operations, underwater explosions, and pile driving. Such high amplitude underwater noises are known to create problems for underwater marine life and their habitats. So there are good physical reasons why sonic booms are not in the same category and will not cause similar problems for marine life.

For the case of pinnipeds such as walrus, sea lions, seals, etc., NASA sponsored studies to measure the hearing thresholds of animals such as harbour seals, elephant seals, and the California sea lion. The results in the lab showed that after exposure to N-wave booms, that there was no evidence of temporary hearing loss for these animals.[150,151] An additional field study of a colony of seals regularly exposed to Concorde sonic booms sheds additional light.[152] Gray and harbour seals located on Sable Island, 163 km off the coast of Nova Scotia, Canada, were regularly exposed to sonic booms from Concorde flights during the 1990s. A team from the National Zoo of the United States travelled to the island and observed the seals during 3 weeks in January 1997 and during 3 additional weeks in June 1998. The team and the seals heard Concorde booms about 3 times per day during these periods. It was noted[152] that "No significant differences in the behaviour or beach counts following sonic booms, regardless of the season" and that the booms "do not substantially affect the breeding behaviour of gray or harbour seals." The takeaway from this study is that over time the animals very likely habituated to the N-wave Concorde booms, and the animals showed no adverse effects whatsoever due to regular exposure to the N-wave booms.

During the later 2000s and in the last few years there has been little new research on supersonic aircraft noise effects on animals, but a number of studies have been conducted on subsonic aviation and other transportation noise and their effects on wildlife. Some of this research has been funded by the United States National Park Service. A short overview of some of this recent research is now provided, and some review articles are now summarized.

Hanson in 2008 noted that high speed train noise with high levels can cause effects on wildlife and livestock.[153] Barber, Crooks, and Fristrup in their extensive 2010 review on chronic noise exposure for terrestrial organisms stated that there is a "preponderance" of "suggestive but inconclusive evidence" that noise "masking is substantially altering ecosystems."[154] A further extensive review by Shannon *et al.* in 2016 noted that anthropogenic "noise is detrimental."[155]

A number of recent papers found no adverse effects on animals from aircraft noise.[156-159] Other papers found that high levels of noise could cause effects. Barber *et al.* in 2011 cited studies of clear negative relationships between traffic noise on roads and birds nesting near the roads.[160] Bunkley *et al.* in 2017 showed that high levels of compressor noise could be impactful.[161] In a laboratory study in 2014 Schmidt *et al.* described that male cricket calls were not heard by females when noise was present.[162]

In 2017 Damsky and Gall noted that anthropogenic noise can affect the behaviour of songbirds.[163] In cases where the noises under study were relatively continuous there is a distinct possibility of interference with communication between members of a species and disruption of auditory cues that are part of predator/prey relationships.

In summary an extensive literature is available for N-wave sonic booms and their effects on a range of animals. Some animals such as the Desert Tortoise do not startle at all, but many animals react to sudden noises the same way that humans do. It is likely that hearing an isolated N-wave sonic boom would cause momentary startle in some animals. As there are many species of animals, there are many that have not been studied. These include large animals such as elephants and rhinoceroses that have good low-frequency hearing. Such animals can communicate over many kilometres of distance because of this low-frequency hearing capability.[164] For other sound sources, there is a body of literature showing that louder and continuous sources have effects on animal communication. And it is well established that underwater sound sources with high sound levels such as active sonar, pile driving, etc. can have detrimental effects on marine life.

The issue of startle and habituation due to sonic boom is still an open research question. However, the Perry *et al.* 2002 study clearly points to the likelihood that some animals will habituate to hearing N-wave sonic booms on a regular basis.[152] Based on the known hearing characteristics of many animal species, there is little reason to expect hearing damage from exposure to infrequent sonic booms from aircraft at cruise altitudes. Other adverse long-term effects due to sonic boom exposure also seem unlikely, but such long-term studies have not been conducted.

For overall conclusions regarding en-route supersonic aircraft noise, see Sections 7 and 10 of this white paper.

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议程项目 11： 理事会有关航空环境保护委员会的职权范围（TOR）、结构、成员组成和工作方法的决定以及选举主席和副主席

11.1 主席介绍了航空环境保护委员会的订正职权范围和修订的航空环境保护委员会指令。根据航空环境保护委员会指令第 8.1.2 段，主席请航空环境保护委员会从其成员中选出一名主席和两名副主席。

11.2 在选举主席时，阿根廷成员提出动议和在沙特阿拉伯成员附议下，提名加拿大航空环境保护委员会成员 Gilles Bourgeois 先生为航空环境保护委员会主席；他被会议一致选为航空环境保护委员会主席。

11.3 关于两位副主席的选举，美国成员提出动议并在埃及附议下，提名新加坡航空环境保护委员会成员 Tan Kah Han 先生为航空环境保护委员会副主席之一，澳大利亚航空环境保护委员会成员提出动议并在巴西航空环境保护委员会成员的附议下，提名瑞士航空环境保护委员会成员 Urs Ziegler 先生为另一位副主席，两位副主席被会议一致选任。

11.4 会议讨论了经修订的航空环境保护委员会指令第 6.6 段和第 7.5 段，其中规定航空环境保护委员会、航空环境保护委员会各指导小组和航空环境保护委员会各个小组应尽可能在加拿大蒙特利尔举行会议，但这不排除在各个地区举行一些会议，以促进地区的参与。若干成员和观察员表示关切的是，在蒙特利尔召开所有航空环境保护委员会会议将对某些地区的航空环境保护委员会参与者造成不成比例的影响，而且这种程序不符合使发展中国家更多参与的意图。会议强调指出，在航空环境保护委员会代表性不足的地区的国家举行会议可以鼓励更多的参与并促进该地区的信息流动。一位成员和一位观察员强调，在蒙特利尔以外地点举行会议也有助于进行技术访问，这对于使航空环保委员会的工作具有意义非常重要。一些成员指出，优先在蒙特利尔举行会议有助于派驻国际民航组织驻地代表团的国家的参与。

11.5 会议同意，大家普遍支持在蒙特利尔以外地点举行一些会议，但指出考虑到各国和秘书处的预算，应设法取得平衡。会议同意，已经计划在蒙特利尔以外地点举行会议的工作组应保持目前计划，因为作出适当调整为时已晚。会议同意航空环境保护委员会应努力为会议订定长期计划，以便会员和观察员能获得适当预算。主席通知会议，他将把这些关切提交给理事会。

11.6 一位成员根据向国际民航组织驻地国代表团和其他成员国提供的访问权，对获得访问航空环境保护委员会加密门户网站的用户协议的现况提出问题。航空环境保护委员会秘书指出，更新后的航空环境保护委员会指令并未改变航空环境保护委员会成员和观察员访问国际民航组织安全门户网站的管理程序。

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议程项目 12：今后的工作

12.1 航空环境保护委员会的结构和 CAEP/12 的工作方案

12.1.1 秘书处介绍了目前各工作组和工作队提出的 CAEP/12 可能工作项目汇编。这些信息已由航空环境保护委员会指导小组 2018 年会议作出修改，后来再由最后一组 CAEP/11 工作组和工作队会议作出修订。国际民航组织秘书处还提出了供航空环境保护委员会审议的其他工作项目。

12.1.2 一位成员对与国际航空碳抵消和减排计划和通信有关的未来工作安排提出了意见。该成员支持设立一个工作组，为国际航空碳抵消和减排计划提供持续支持，包括维护附件 16 第 IV 卷和《环境技术手册（ETM）》第 IV 卷以及大多数实施要素（如二氧化碳估算和报告工具的持续开发）。该成员还认为代用燃料工作队（AFTF）应根据修订后的职权范围予以保留，并由新的国际航空碳抵消和减排计划工作组进行有关国际航空碳抵消和减排计划合格燃料问题的一些未来工作。该成员建议在航空环境保护委员会内设立一个通信小组，将航空环境保护委员会的各种相关信息汇总在一起，以便提供航空环境保护委员会任务的内容、原因和方式，使理事会成员和航空当局能及时了解航空环境保护委员会的目前和即将开展的工作。

12.1.3 一位成员建议对超音速飞机进行严格度分析并制定着陆和起飞噪声标准和建议措施；支持对附件 16 第 I 至第 IV 卷及其相关《环境技术手册》的持续维护；支持更新和改进现有模型和数据库的工作；支持审查新的建模功能，使航空环境保护委员会处于进行未来评估的更好地位。关于航空环境保护委员会在 CAEP/12 之前的结构，该成员认为全球基于市场措施技术工作队（GMTF）和代用燃料工作队（AFTF）应发展成为航空环境保护委员会的两个常设小组。

讨论和结论

12.1.4 会议讨论了设立一个通信小组的提案，虽然会议认识到需要适当传达航空环境保护委员会的结果，但它指出，航空环境保护委员会的结果并不完全代表在国际民航组织秘书处下进行的航空环境保护委员会的全部环境工作。一位成员着重指出，国际民航组织有专门用于通信的结构，包括各个地区办事处，目前尚不清楚航空环境保护委员会的通信小组将如何与这一结构进行互动。会议认识到航空环境保护委员会专家对国际民航组织秘书处的外联和能力建设工作作出进一步贡献的重要性。

12.1.5 会议讨论了航空环境保护委员会处理国际航空碳抵消和减排计划未来工作的结构。一位成员指出，现在附件 16 第 IV 卷的第一版已经通过，可以通过类似第 1 工作组和第 3 工作组的治理结构进行维护，而不需要航空环境保护委员会成员组成的一个“监护小组”。会议同意第 4 工作组不再需要以前在全球基于市场措施技术工作队中使用的“监护小组”。会议同意将全球基于市场措施技术工作队和代用燃料工作队分别发展成为航空环境保护委员会的常设小组 — 第 4 工作组和燃料任务组（FTG）。会议认为，与燃料相关的运行、政策和监督活动应成为燃料任务组（FTG）工作方案的一部分，因为将这些活动纳入第 4 工作组将导致丧失执行这些活动的专业知识。会议同意航空环境保护委员会在 CAEP/11 会议之前的结构以及每个小组的共同报告员。这项信息在本议程项目报告的附录 A 中提供。

第 1 工作组的工作方案

12.1.6　关于第 1 工作组的工作方案，增加了一项新任务以反映关于“超音速航空器探索性研究”的协议，详见议程项目 4 报告第 4.3.29 至 4.3.31。这项任务取代了第 1 工作组最初提出的关于制定超音速运输机标准（亚音速机制）的任务。类似的任务也列入建模和数据库小组、预测和经济分析支持小组、第 3 工作组和影响和科学小组的工作方案。议程项目 4 下的先前协议也反映在与制定超音速运输机标准（超音速机制）相关的任务中，并且从第 1 工作组的工作方案删除了与全球航空环境计划（GAEP）相关的任务，以反映会议的结论。

12.1.7　在与第 2 工作组合作的情况下，会议讨论了第 1 工作组的任务，提议对可能的侵占指标进行调查。第 2 工作组共同报告员着重指出，侵占是一个全球性问题，因此，支持调查历史上曾经发生过并可能在未来还会发生的侵占行为的工作。一位观察员认为，只有在地方层面才能对侵占进行有意义的评估和理解，强调除了影响机场附近人口变化的土地使用规划政策和立法之外，还有其他各种因素，目前尚不清楚这将如何在研究中得到审议和反映。最后，该观察员指出，各国对噪声等值线使用不同的指标，他对这种差异意味着在全球范围得出不正确的结论表示关切。会议同意委托第 2 工作组对该提案进行范围研究，并将在 CAEP 指导小组 2019 年会议提交。

12.1.8　在讨论了若干成员和观察员的一项提案后，会议同意增加一项任务，要求第 1 工作组审查和分析亚音速喷气式飞机和重型螺旋桨飞机的审定合格噪音水平。

第 2 工作组的工作方案

12.1.9　一位观察员提议进行范围界定研究，以评估建立全球数据库的可能性，其中包含用于管理全世界机场运行对环境影响的方法的详细信息，并将此作为 CAEP/12 第 2 工作组工作方案的一部分。

12.1.10　尽管一位观察员对建立和维护此类数据库所需的资源数量表示担忧，但会议同意委托第 2 工作组编制一份可行性报告，评估建立一个关于管理噪声和排放举措的机场数据库的可能性。

12.1.11　会议审议了国际民航组织秘书处、成员和观察员提出的其他第 2 工作组任务。在这些提议中，会议对无人驾驶航空器结合到空中交通管理系统所产生的环境影响的范围界定报告感到兴趣。关于拟议的循环经济任务，虽然会议未批准这项任务，但它对从国际民航组织秘书处定期收到关于这个议题的最新报告感到兴趣。

12.1.12　若干航空环境保护委员会成员和观察员提出进行一项关于超音速飞行运行产生的环境影响及其结合到空中交通管理系统和机场的影响的研究。一位成员指出，这项拟议的任务不会对以前就超音速进行探索性研究的协议产生问题。该成员认为，及早评估超音速飞行运行产生的任何环境影响可以提供将环境目标纳入空中交通管理设计阶段的机会，而不需要追溯到航空器何时投入使用的问题。一位成员对这项提案提出他的看法，他指出，目前对超音速航空器进行探索性研究的妥协应受到保护，并且会议同意不再讨论这个问题，因此，这项拟议任务不应列入 CAEP/12 的工作方案。

第 3 工作组的工作方案

12.1.13 三名观察员支持第 3 工作组未来更新排放建模指导材料的工作，包括更新 NOx、nvPM 和挥发性微粒物质的建模方法，这些方法将导致更新国际民航组织 Doc 9889 号文件。第 3 工作组共同报告员注意到未来的工作项目 E.16“更新和审查 Doc 9889 号文件”已经反映了观察员的这些建议。

12.1.14 会议讨论了第 3 工作组未来有关发动机排放的工作，商定了一系列反映议程项目 3 的成果的新任务，包括继续开展有关 nvPM 相关项目的工作。

12.1.15 若干成员和观察员提出未来新的关于监测和审查 CO_2 的审定合格和项目飞机数据的工作项目以及进行进一步分析以预测更多有关新技术信息，并根据研究结果，提供信息以决定是否在 CAEP/13 期间审查目前的附件 16 第 III 卷的监管水平。一位成员尽管支持监测 CO_2 信息，但认为现在审查 CO_2 标准似乎太早。会议同意，任务将是监测 CO_2 信息，指出这项主题可能需要在 2019 年 CAEP 指导小组会议期间提供额外投入。

建模和数据库小组和预测和经济分析支持小组的工作方案

12.1.16 两位成员和一位观察员建议调整建模和数据库小组和预测和经济分析支持小组的未来工作项目，以涵盖新型严格度建模、标准成本、分析协调、不确定性和当地空气质量建模等领域。

12.1.17 由于与机场容量数据的国际可比性相关的问题，一位观察员对未来的工作项目 F.04“机场容量限制对全球空中交通的影响”表示关切。观察员强调指出，在国际一级，经济合作与发展组织（OECD）已为全世界 100 个最忙碌的机场制定模型作出投资，建议航空环境保护委员会在进行分析之前，与航空数据和分析专家组（ADAP）协调审议这项工作。他还对分享敏感和保密的机场数据表示关切，因此，建议在地区一级汇总数据。

12.1.18 应建模和数据库小组共同报告员的要求，会议支持成立一个由第 1 工作组、第 3 工作组、建模和数据库小组、预测和经济分析支持小组和影响和科学小组组成的协调小组，为进行超音速飞机的探索性研究提供支持。根据一位成员提出的建议，会议同意应制定这个小组的职权范围，并以支持制定 CO_2 标准的 WMF 协调小组的职权范围为基础。

影响和科学小组的工作方案

12.1.19 一位观察员建议影响和科学小组编写一份关于非声学因素的白皮书，这些因素约占 70%与航空器有关的社区烦躁。会议讨论了这项提案，同意进行这项任务，它将侧重于对非声学因素进行文献审查。有人强调，大部分的审查工作可能已由影响和科学小组完成，成为编制“航空噪声影响白皮书”的一部分，因此影响和科学小组应该表明是否需要对这项工作作出任何补充。

12.1.20 会议同意影响和科学小组提出的工作方案，其中作出适当调整，以便考虑到会议对超音速和长期目标的讨论结果。

第 4 工作组的工作方案

12.1.21 全球基于市场措施技术工作队（GMTF）共同报告员介绍了未来预备将由第 4 工作组进行的关于国际航空碳抵消和减排计划的工作。根据议程项目 6、7 和 8 项下的讨论，全球基于市场措施技术工作队向会议提交的未来工作提案将成为 CAEP/12 周期期间国际航空碳抵消和减排计划工作的基础。会议注意到，一些成员和观察员提出的未来工作提案已经包含在全球基于市场措施技术工作队提出的提案中，其中增加了两个项目（支持理事会编制国际航空碳抵消和减排计划的定期审查报告和继续开展与实施国际航空碳抵消和减排计划相关的技术分析有关的工作）以及需要修改全球基于市场措施技术工作队关于任务“管理排放单位标准”的提案，以便纳入未来重复计算的工作。对于后者，一位成员提出了得到会议同意的具体措辞提案。一位观察员提出一项建议，包括盘点所有国家实施附件 16 第 IV 卷的情况，重点是第 II 部分第 1 章和第 2 章，以便为理事会筹备进行国际航空碳抵消和减排计划定期审查提供支持；会议注意到该项提案，其中同意进行盘点的具体方式将由新的第 4 工作组决定。

燃料任务组和可持续性审定合格机制评估小组的工作方案

12.1.22 燃料任务组共同报告员根据代用燃料工作队（AFTF）制定的初步提案描述了燃料任务组的拟议工作方案，其中包含了反映会议结论的修订案文。可持续性审定合格机制评估小组（SCSEG）的工作方案也提供给了会议，航空环境保护委员会同意了拟议的方案。

航空碳计算器支助小组（ACCS）的工作方案

12.1.23 航空碳计算器支助小组（ACCS）报告员介绍了航空碳计算器支助小组的拟议工作方案，它获得会议的同意。

航空环境保护委员会第十二次会议（CAEP/12）的最后工作方案

12.1.24 作为会议讨论的结果，航空环境保护委员会核准的各小组工作方案载于本议程项目报告附录 B。

12.1.25 **建议**

12.1.25.1 鉴于前述讨论，会议拟定了以下建议：

建议 12/1 — 航空环境保护委员会第十二次会议（CAEP/12）的工作方案

理事会核准本议程项目的报告附录 B 所载的航空环境保护委员会订正工作方案。

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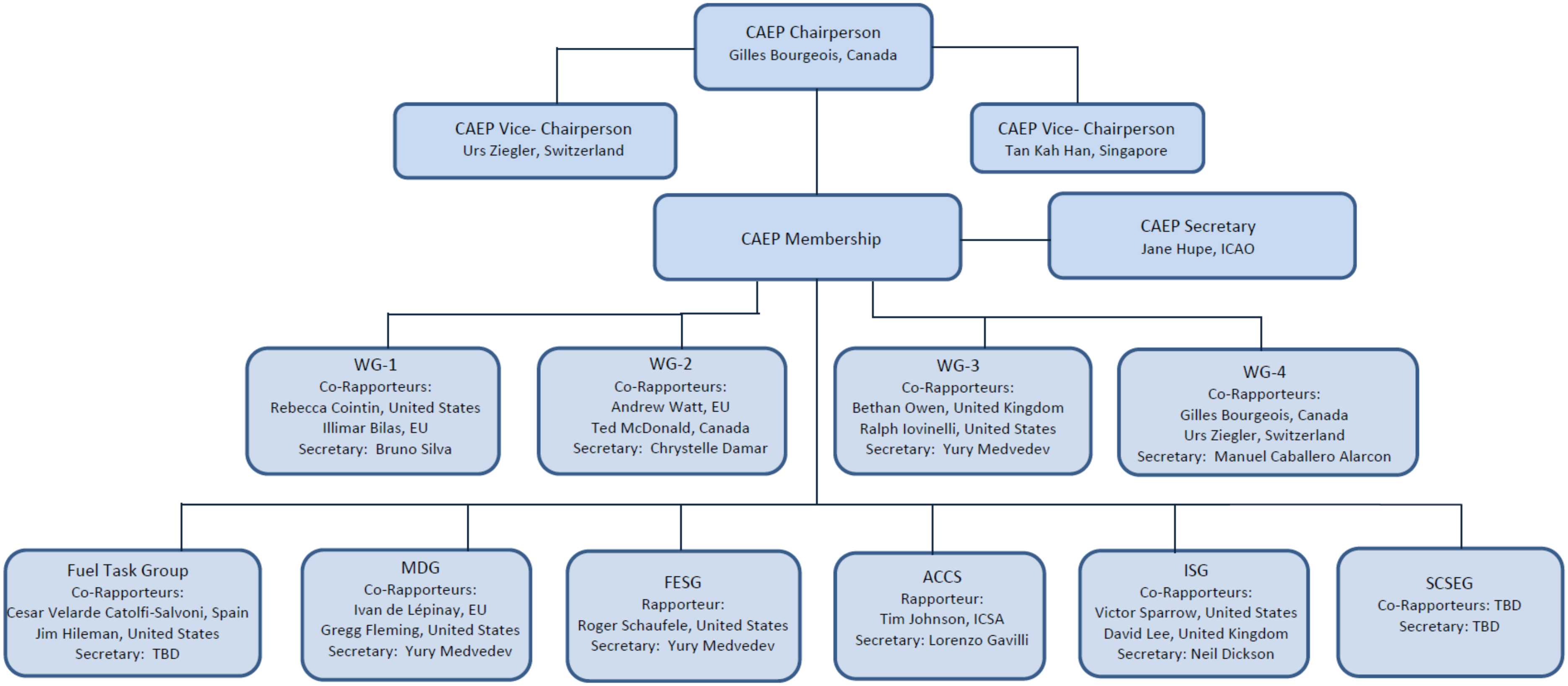
APPENDIX A
(English only)

CAEP STRUCTURE LEADING UP TO CAEP/12



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APPENDIX B
(English only)

CAEP/12 WORK PROGRAMME

CAEP/12 Working Group 1 – Noise Technical – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
N.01	Coordination	Coordinate with other working group Rapporteurs on + interdependencies related to technology, operational issues, and goals as well as harmonizing the goal setting process. + interdependencies related to management and update of noise and emissions databases + interdependencies related to environmental impacts, including stringency + programmes for development of both noise and emissions SARPs for future supersonic aeroplanes	Coordination	Ongoing
N.02	Annex and ETM maintenance	Maintain and update Annex 16, Vol. I and ETM, Vol. I.	Updates to ETM Updates to Annex 16	SG2021 CAEP/12
N.03	NoisedB	Ensure process integrity and data currency of the ICAO noise certification database.	Up-to-date ICAO NoisedB	Ongoing
N.04	Monitor research and development	Monitor and report on the various national and international research programme goals and milestones. Review data on emerging technologies as it becomes available.	Report	CAEP/12
N.05.01	Monitoring SST research	Monitor and report on research to characterize, quantify and measure (including metric) climb and en route noise from supersonic flight, including Mach cut-off conditions, and its acceptability while also assisting in promoting and defining such research.	Report	CAEP/12

CAEP/12 Working Group 1 – Noise Technical – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
N.05.02	SST Standard development (supersonic regime)	Continue to work on a new scheme for en route noise/sonic boom certification for supersonic flight, as informed by developments under N.05.01. Continue to gather data on which “other factors” need to be considered for SARPs development. These may include boom at “off design” Mach numbers, boom from accelerations and turns, secondary sonic booms, restricting N-wave booms over water, sleep and booms at night, effects on animals, and avalanches.	Progress report	CAEP/12
N.05.03	SST coordination	Update Air Navigation Commission with SSTG Report on progress of SST noise activities.	Briefing to ANC	May/June 2019
N.05.04	Monitoring SST projects	Monitor, and report on, status of SST projects and expectations of supersonic development.	Report	CAEP/12
N.06	New entrants noise monitoring	Monitor developments around new entrants noise (e.g. RPAS/UAS, electric aircraft, air taxis) and where appropriate suggest specific work items to SG.	Report	CAEP/12
N.07.01	Helicopter Noise Correlation	Monitor the availability of appropriate operational helicopter noise datasets, and use them to: - augment the investigation on correlating the ranking of helicopters based on certification and operational noise levels, - assess the helicopter noise certification scheme and its relevance to day-to-day operations.	Report	CAEP/12
N.07.02	Helicopter Hover Noise	Monitor the availability of appropriate helicopter hover noise datasets, and use them to assess whether the current helicopter noise certification scheme is suitable for assessing hover noise.	Report	CAEP/12

CAEP/12 Working Group 1 – Noise Technical – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
N.08	Environmental Trends	WG1, WG2, WG3 and AFTF to update their respective input assumptions to the ICAO Environmental Trends Assessment, in coordination with MDG.	Status Report: SG2019 Final inputs: SG2020	SG2020
N.09	Review of Annex 16, Vol. I, Chapter 14	Review and analyse certification noise levels for subsonic jet and heavy propeller-driven aeroplanes. Based on the analysis, assess cumulative margin relative to Chapter 14 and the margins at each of the 3 certification points.	Report on the findings	CAEP/12
N.10	Exploratory Study For Supersonic Aircraft	Conduct the exploratory study for supersonic aircraft as detailed in Sections 4.3.29 to 4.3.31 of the CAEP/11 report.	Recommendations on procedures for LTO noise certification	SG2019
			Preliminary Results	SG2021
			Final Results	CAEP/12

CAEP/12 Working Group 2 –Airports and Operations – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
O.01	Understanding Aviation Stakeholder Community Engagement Needs in the Context of Delivering ATM Change	Having completed the report on PBN and community engagement, discussions at WG2 focused on the desire to continue working on this subject and to understand the needs of States and other stakeholders in the area of community engagement relating to deploying change in the ATM system. This task seeks views from States regarding their needs on community engagement practices and lessons learned.	Report	CAEP/12
O.02	Operational Opportunities to Reduce Aircraft Noise	Continue with CAEP/11, task O.02, to develop an ICAO document "Operational Opportunities to Reduce Aircraft Noise", to completion. The task will be aimed at identifying and highlighting good practices and the operational opportunities to minimize aircraft noise from aircraft operations where practicable and operationally safe to do so.	Report	CAEP/12
O.03	Environmental Metrics of relevance to the Global Aviation System	During the CAEP/11 cycle, WG2 was requested to consider the possibility to develop environmental KPIs for use in an ATM context. The work conducted during the CAEP/10 cycle by CAEP WG2 (Task O.12) in coordination with WG1 and WG3, demonstrated that the current level of understanding of the environmental impacts of the current GANP KPIs would not allow to satisfactorily address the definition of environmental indicator. Task O.12 led to the conclusion that further work would be necessary to understand better current environmental metrics used by States and operational stakeholders beyond an ATM environment, to assess the performance of all players within the global aviation system.	Report	SG3 (state-of-play) and CAEP/12 (recommendations if deemed necessary by SG3)

CAEP/12 Working Group 2 –Airports and Operations – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
O.04	Review of the 2019 update to the Global Air Navigation Plan	ICAO will undertake a major update of the GANP in 2019 including the ASBU documentation. In this update, a new structure is expected including updated blocks, modules and elements. The future task proposal is to undertake a review of the 2019 GANP (to be proposed for adoption at the 40th Session of the ICAO Assembly) with a view of understanding whether the new structure/content modules would result in the need for further ASBU analysis.	Oral report (initially)	SG2019
O.05	Flight efficiency	Based on the conclusions presented to CAEP/11, the global HFE analysis was considered as a first step towards analyzing global flight efficiency. The task proposed for the CAEP/12 cycle would consist of performing a global VFE analysis.	Report	CAEP/12
O.06	Climate Change Adaptation Synthesis Dissemination	1) Assist Secretariat in making relevant information from the climate adaptation synthesis adopted by CAEP/11 available on the ICAO website. Review and assess the synthesis information for suitability and relevance for dissemination, and determine the best format to make it available. 2) Determine a methodology and timeline for ensuring the information in the synthesis stays current and incorporates the latest scientific information. If significant and relevant information is published in the next CAEP cycle the update process may be initiated. 3) Assess whether an update of the survey sent for the CAEP/11 Synthesis Report would provide useful information and, if so, what would be an appropriate timeframe e.g. for CAEP/13.	Public dissemination of the CAEP/11 Climate Adaptation Synthesis, and report to CAEP on process for regular updates to the Synthesis.	CAEP/12

CAEP/12 Working Group 2 –Airports and Operations – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
O.07	Climate Change Risk Assessment, Adaptation, and Resilience	Building on the CAEP/11 Task O.07 Climate Adaptation Synthesis adopted by CAEP/11, this task will produce and distribute a report on identified steps to develop climate change risk assessments and adaptation and resilience measures, so as to provide a "menu" of options for aviation stakeholders to consider in their own planning. Aircraft operations will be included in the scope of the study (Climate Change risk assessment, adaptation and resilience for ANSP and airport infrastructure and operations). The document will be broadly-applicable and non-prescriptive.	Guidance Document	CAEP/12
O.08	Eco-Airport Toolkit e-collection	It is proposed to deliver four e-publications to be made freely available on the ICAO website and covering the following topics: • Water management at airports (including glycol management); • Air Quality Management; • Green airport surface access; • Climate resilient airports; These topics were identified by WG2 during the CAEP/11 cycle.	e-collection series	SG2019, SG2020, SG2021 and CAEP/12
O.09	Monitor Developments and Maintenance of Publications	The work of WG2 includes monitoring and reporting of national and international advancements in support of improved environmental procedures and operations. WG2 reviews these advancements in order to maintain the ongoing relevance of existing publications and to make recommendations for updates or additional information, as required.	WPs submitted to Steering Groups	on-going
O.10	Environmental Trends	WG1, WG2, WG3 and AFTF to update their respective input assumptions to the ICAO Environmental Trends Assessment, in coordination with MDG.	Status Report: SG2019 Final inputs: SG2020	SG2020

CAEP/12 Working Group 2 –Airports and Operations – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
O.11	Environmental Impact of Unmanned Aircraft Operations at and around airports	As Unmanned Aircraft (UA) operations are increasing and their applications diversifying (wildfire mapping, disaster management, weather/environment monitoring, package delivery/freight transport), Remotely Piloted Aircraft (RPA) are expected to be ultimately integrated into airspace for international, instrument flight rules (IFR) operations. ICAO has developed a work programme to review the relevant Annexes to the Chicago Convention and integrate RPAs-related element. The 13th Air Navigation Conference requested ICAO to "provide an update on a fully integrated approach for ICAO's RPAS related work programme to the 40th Session of the Assembly in 2019" (ANC/13). While CAEP WG1 (noise) is responsible for assessing the noise certification impacts of RPAs, it is proposed that CAEP gains understanding on the impact of RPAS operations at and around airports and communicates this information to Council. The objective would be to get a snapshot of the current situation at international airports throughout the world and to collect the views from aviation stakeholders on their assessment of the impact of RPAS operations on their own activities. This would allow responding to very concrete questions, such as the potential need for dedicated infrastructure at airports, the ability of operational stakeholders to pursue the implementation of ATM-related changes delivering environmental benefits.	Scoping report	SG2020 and CAEP/12 for recommendations, if deemed necessary by SG2020
O.12	Investigation on possible indicators for encroachment	Investigation of possible means to evaluate encroachment levels at a global scale.	Scoping Report	CAEP/12

CAEP/12 Working Group 2 –Airports and Operations – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
O.13	Assessment of the potential for an airport database on noise and emissions management initiatives	The task is to complete a scoping study to assess the potential, feasibility and resource necessary to create a centralized database of existing initiatives related to the environmental impact of aircraft operations at airports, globally. If it was found to be feasible and desirable, then a follow-on task could be to support the creation of a database containing a reliable, consolidated source for initiatives used to manage environmental impacts at worldwide airport operations, for use by airport operators, aircraft operators, policy makers, and others involved and interested with the management of noise and emissions at airports	Report	SG 2021

CAEP/12 Working Group 3 –Emissions Technical – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
E.01	Interdependencies	Coordinate with other working group Rapporteurs on interdependencies related to (a) technology, operational issues and goals (b) management and update of noise and emissions databases (c) environmental impacts (d) SARPs for future SST aircraft.	Coordination report for each SG	CAEP/12
E.02	Fuel composition and emissions	Monitor trends in 1) petroleum-based aviation kerosene fuel supply composition, 2) aviation alternative fuel based kerosene fuel supply, and 3) blended fuel types. Consider the impacts of fuel composition on nvPM or precursors of vPM at the engine exit and the corresponding emission indices. This would permit to assess, for example, the potential benefit of fossil fuel desulfurization on emission indices. Coordinate with ISG (I.04) when necessary.	Report	CAEP/12
E.03	Emissions Certification requirements - new subsonic aeroplane applications and concepts	Monitor developments in aeroplane and engine applications and concepts, such as freighter applications or technology developments e.g. blended wing body, or non-classical tube and wing configurations and open-rotor engines etc., and develop methodologies for emissions certification.	Report	CAEP/12
E.04	Annex 16, Volume II maintenance	Maintain Annex 16, Volume II on aircraft engine emissions.	Proposed Annex changes	CAEP/12
E.05	ETM, Volume II maintenance	Maintain Environmental Technical Manual, Volume II on aircraft engine emissions.	Proposed ETM changes	CAEP/12
E.06	Annex 16, Volume III maintenance	Maintain Annex 16, Volume III on aeroplane CO_2 emissions.	Proposed Annex changes	CAEP/12
E.07	ETM, Volume III maintenance	Maintain Environmental Technical Manual, Volume III on aeroplane CO_2 emissions.	Proposed ETM changes	CAEP/12

CAEP/12 Working Group 3 –Emissions Technical – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
E.08	Emissions Engine Databank maintenance	Maintain engine emissions certification databank.	up-to-date databank	CAEP/12
E.09	CO_2 Certification Database maintenance	Maintain aeroplane CO_2 certification database.	up-to-date database	CAEP/12
E.10	G&R database maintenance	Review and update a "Growth & Replacement" database in order to support development of models used to populate future fleets and the replacement of retired aircraft. Coordinate with MDG/FESG, WG1 and support groups to ensure consistency in assumptions.	up-to-date G&R database	CAEP/12
E.11	NOx + nvPM Cruise - Climb relationship	Review the LTO nvPM and NOx - cruise climb relationship for staged combustion and future engine technologies, to quantify control of mission emissions of nvPM/NOx, and identify any methodology issues with respect to the correlation between LTO and climb/cruise and to quantify interdependencies with other emissions, in coordination with ISG (item I.03) when necessary.	Report	CAEP/12
E.12	Certification Requirements - SST	Monitor trends in supersonic technology and assess consequences for engine based emissions and certification Standards.	Proposed changes to Annex 16, Volume II and ETM, Volume II	CAEP/12
E.13	SST CO_2	Monitor trends in supersonic technology and assess consequences for aeroplane emissions and certification Standards.	Report	CAEP/12
E.14	Modelling emissions at low power	Provide guidance on the modelling of emissions at low power settings.	Report	CAEP/12

CAEP/12 Working Group 3 –Emissions Technical – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
E.15	nvPM model inputs and emissions inventories	Develop improved nvPM model inputs to both local air quality models and, as required, global climate models per advice from ISG. Note input from ISG on nvPM impacts.	WG3 Report	CAEP/12
E.16	Update and review Doc 9889	Update Doc 9889 to reflect industry best practices, new emissions data for modern aircraft and airport emission sources, airport operational information that affect aviation emissions, and emissions modelling methodologies.	Updated Doc 9889	CAEP/12
E.17	NOx scoping study	Conduct NOx scoping study cut-off for in-production engines and present the analysis results to SG2019.	Report	SG2019
E.18	Environmental Trends	WG1, WG2, WG3 and AFTF to update their respective input assumptions to the ICAO Environmental Trends Assessment, in coordination with MDG.	Status Report: SG2019 Final inputs: SG2020	SG2020
E.19	Exploratory Study For Supersonic Aircraft	Conduct the exploratory study for supersonic aircraft as detailed in Sections 4.3.29 to 4.3.31 of the CAEP/11 report.	Report	Each SG and CAEP/12
E.20	nvPM Emissions	Following proposals in CAEP/11-WP/17 for WG3 further to investigate ambient conditions corrections for nvPM. Additional work is also needed to address nvPM losses in the measurement system.	Report	CAEP/12
E.21	Review CO_2 information	Monitor, review and analyze latest CO_2 information for subsonic aeroplanes and any available certification data. Based on the analysis, assess margin relative to the CO_2 subsonic Standard. The analysis should anticipate more information on new technologies, including project aircraft.	Report	CAEP/12

CAEP/12 Working Group 3 –Emissions Technical – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
E.22	Review of nvPM regulatory levels	Following CAEP/11 decisions on the new nvPM Standard, WG3 to review the nvPM regulatory levels. This will involve the collation and analysis of the certified and certification-like nvPM mass and number emissions data that becomes available for all in-production engines. This will include a review of margins to the new type nvPM mass and number Standards and an assessment of possible technological advancements to reduce nvPM emissions.	Report to inform the need to update the nvPM emissions Standards	CAEP/12

CAEP/12 Working Group 4 – CORSIA – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
C.01	Maintenance of Annex 16, Volume IV and related guidance material	Maintenance of Annex 16, Volume IV and related guidance material in line with similar work undertaken for other Volumes of Annex 16	If required, revised Annex 16, Volume IV	CAEP/12
			If required, revised Doc 9501 (ETM, Volume IV)	
			Continuous support to the ICAO Secretariat in the production of materials aimed at facilitating implementation of Annex 16, Volume IV	
C.02	Work on the ICAO CORSIA CO_2 Estimation and Reporting Tool (CERT)	Development of the 2019 and subsequent versions of the ICAO CORSIA CERT	2019 version of the ICAO CORSIA CERT and related technical documentation	June 2019
			2020 version of the ICAO CORSIA CERT and related technical documentation	June 2020
			2021 version of the ICAO CORSIA CERT and related technical documentation	June 2021
C.03	Development of further guidance on monitoring, reporting and verification (MRV) in CORSIA	Development of further guidance on monitoring, reporting and verification (MRV) in CORSIA	Guidance material to be incorporated in subsequent revisions of Doc 9501 (ETM, Volume IV)	CAEP/12
C.04	Supply, Demand and Price of Units	Further assessment of supply, demand and price of emissions units for CORSIA implementation	If requested, update of the work undertaken by GMTF on this topic in the CAEP/11 cycle, as reported in CAEP/11-IP/14	CAEP/12

CAEP/12 Working Group 4 – CORSIA – Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
C.05	EUC Management	Development of recommendations on technical approaches to the management of Emissions Units Criteria (EUC)	Recommendations on technical approaches to the management of EUC	CAEP/12-SG2019 for recommendations for items in CAEP/12-IP/18 Section 2 CAEP/12 for further items
C.06	Programme registry requirements to facilitate application of the SARPS	Identification of an approach for the application of programme registry requirements to facilitate application of the SARPs	Identified approach for applying programme registry requirements	To be determined
C.07	Support Council in preparation for the CORSIA periodic review	Development of methodologies and procedures for the CORSIA periodic review, including stocktaking of the implementation of Annex 16, Volume IV across all States, with a focus on Part II, Chapters 1 and 2, which will be used to inform the review	Report to CAEP for approval and submission to the Council, when requested	For CAEP consideration: as soon as practicable in advance of the first review in 2022. For Council consideration: upon Council's request.
C.08	Technical Analysis Support	Support Council requests and needs from other Working Group on CORSIA tasks (e.g., C.04) on technical analysis relating to the implementation of CORSIA. Support updates to technical analyses to (1) reflect the evolution of assumptions underlying the implementation of CORSIA and (2) ensure consistency with other CAEP analyses e.g., updates of GHG trends at CAEP/11.	Report on analyses (as needed and appropriate) during CAEP/12 and summary report at CAEP/12.	CAEP/12 (with interim reports as needed).

CAEP/12 Fuels Task Group (FTG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
S.01.01	Computation of induced land use change emissions for SAF for use in CORSIA	Over CAEP/12, continue to carry out the computations of induced land use change (ILUC) emissions associated with SAF production for requested world regions, for use in CORSIA.	List of ILUC values	SG2019 SG2020 SG2021 CAEP12
S.01.02	Low ILUC risk practices	Develop an approach for low ILUC risk practices for adoption beyond the CORSIA Pilot phase, in light of the experience gathered in real projects.	Proposal to amend the CEF Implementation Element	CAEP12
S.01.03	Feedstocks classification	Continuously update the positive list of feedstocks in the CORSIA Implementation Elements	Proposal to amend the CEF Implementation Element	CAEP12
S.02	Computation of default core LCA emission values for SAF for use in CORSIA	Over CAEP/12, continue to carry out the computations of default core LCA emission values for SAF, for use in CORSIA, with an emphasis on aligning the LCA values available for Alcohol (isobutanol) to jet (ATJ) and Alcohol ethanol to jet (ATJ).	List of default Core LCA values	SG2019 SG2020 SG2021 CAEP12
S.03	Co-processing of esters and fatty acids in petroleum refineries	Develop default LCA and ILUC values for co-processed fuels, including an approach for use in the CORSIA MRV system to quantify the CORSIA-eligible fuel present in co-processed products.	default LCA values, ILUC values, and approach for fuels produced using co-processing	SG2019
S.04.01	Methodology refinements – core LCA	Analyze the applicability of the core LCA methodology, reporting rules under CORSIA to Lower Carbon Aviation Fuels, and other considerations, and identify possible required adjustments to enable eligibility under CORSIA.	Report on the applicability of the LCA methodology and reporting rules under CORSIA to Lower Carbon Aviation Fuels.	SG2019

CAEP/12 Fuels Task Group (FTG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
			Proposed changes to the CEF Implementation Elements	SG2020 SG2021 CAEP12
S.04.02	Methodology refinements – ILUC	Reviewing the approach to ILUC in light of emerging scientific evidence and data. Develop definition of the ILUC regions.	Report on the need for amendments in the CEF Implementation Elements	CAEP12
S.04.03	Methodology refinements – Emission Credits	Define robust and specific criteria for determining when an exception to the LCA energy allocation approach is acceptable for generating emission credits. Develop additional requirements and guidance to ensure that emission credits for SAF generated under CORSIA are of an equivalent quality and quantity to emission units, with specific reference to the concepts described in paragraph 12 As requested, consider and approve new emissions credits for applicable pathways, based on the above-mentioned criteria, requirements and guidance. Develop further requirements for LEC and REC calculation to limit unintended incentives for poor landfill management.	Report on the need for amendments in the CEF Implementation elements	SG2019 SG2020 SG2021 CAEP12
S.05	CORSIA Package Updates	Maintain the components of the CORSIA SARP Package (e.g., Vol. 4, Implementation Elements, Supporting Documents, etc.) that relate to CORSIA Eligible Fuels, including on providing definitions for the terms included in the implementation elements.	Report on changes to the CORSIA SARP Package that pertains to CORSIA Eligible Fuels	SG2019 SG2020 SG2021 CAEP12

CAEP/12 Fuels Task Group (FTG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
S.06	Sustainability criteria	Develop further proposals, at the latest by the end of the pilot phase, on additional and/or strengthened Sustainability Criteria, including on Themes 1 and 2, specifically applicable to CORSIA Eligible Fuels and other sustainability themes, as requested.	Report: SG2019 Report: SG2020 Report: SG2021 Final report : CAEP12	CAEP/12
S.07	SCS Requirements	As needed, update information contained in the ICAO document, “CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes (SCS)” such that the SCSEG can evaluate SCS	As needed	As needed
S.08	Technology evaluation	Assess emerging and future technologies and processes that could lead to the production of CORSIA eligible fuels	Report: SG2019 Report: SG2020 Report: SG2021 Final report : CAEP12	CAEP/12
S.09	Fuel Production Evaluation	Using data on current offtake of CEFs and the TEA methods developed under S.10 and information from CAEP/10 AFTF Fuel Production Assessment, assess CORSIA Eligible Fuel availability through 2035 based on the range of estimated offset prices that have been developed by the GMTF.	Report: SG2019 Report: SG2020 Report: SG2021 Final report : CAEP12	CAEP/12

CAEP/12 Fuels Task Group (FTG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
S.10	Guidance on Potential Policies and Coordinated Approaches for the Deployment of SAF	Continue to develop the techno-economic analysis (TEA) of policy options available to foster the deployment of Sustainable Aviation Fuels (SAF) and Lower Carbon Aviation Fuels (LCAF), and produce guidance material that identifies policies, or combination of policies, that are particularly interesting as result of the analysis. The material developed could be made available as a "toolbox" to support Member States activities on SAF and LCAF.	Report containing the guidance to be shared with ICAO Member States	CAEP/12
S.11	Double counting	Develop approach(es) to minimize the risk of double counting related to LSf values within CORSIA including those that use either emissions credits or negative ILUC values. This could include a true-up mechanism in line with paragraph 1.2 of CAEP/11-WP/80.	Report	SG2020
S.12	ILUC Permanence	Examine permanence of the carbon reductions associated with the life cycle emissions reductions associated with negative ILUC values and develop approaches to minimize associated risks.	Report	SG2020

CAEP/12 Modelling and Databases Group (MDG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
M.01	Interdependencies	Coordinate with other working group Rapporteurs on interdependencies related to technology, operational issues, goals, environmental impacts and management and update of noise and emissions databases.	Coordinated WP	Each SG meeting and final report to CAEP/12
M.02	ICAO Environmental Trends Projection	Conduct an updated trends projection, for the 20xx baseline case and forecasts, for various cases which consider technology, operational improvements (both infrastructure and operator-initiated improvements) and alternative fuels life cycle, for noise, NOx, PM, fuel burn, and CO2. In doing so, consider potential input from WG3 Task E.11. The trends projection will support the display of the following information, as appropriate: 1. A static ATM (informed by WG2) and static aircraft technology scenario; 2. Progress being achieved toward the ICAO global aspirational environmental goals (i.e. 2% annual fuel efficiency improvement and carbon neutral growth from 2020); 3. Anticipated progress toward the goals based on the information communicated by States in their voluntary Action Plans; 4. Additional efforts that would be required to meet those goals (i.e. feasibility analysis results); and 5. The effects of ASBU Block 0, 1 and 2 implementation The MDG fuel trends results will be published in a Structured Query Language (SQL) database that could be easily accessed by experts from other CAEP groups. To the extent possible, the trends will use the same forecast, models and data as the other MDG analyses in the cycle.	Report that includes graphical depiction of the trends and database	CAEP/12

CAEP/12 Modelling and Databases Group (MDG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
M.03	Existing Model and Database Management	Maintain version control of models and databases to be used in support of specific CAEP analyses. Determine if updates to models or databases require a re-evaluation, including providing feedback to the ICAO Secretariat regarding databases to be used in CAEP that they maintain. In support of the CAEP/12 work programme, the following specific enhancements to air quality and or greenhouse gas models have been identified: 1. Advance modelling of nvPM mass and number (in conjunction with WG3) 2. Enhancement and standardization of low-power setting emissions modelling 3. Define a methodology to assess pollutant concentrations around airports in the trends and stringency analyses 4. Analyse and reconcile HC and CO computation across models as needed (in conjunction with WG3) 5. Update the tools as appropriate to support new policy analyses (e.g. supersonics) 6. To the extent possible, provide quantified uncertainties for data and models.	Updated models and databases	Each SG meeting and final report to CAEP/12

CAEP/12 Modelling and Databases Group (MDG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
M.04	New Model Evaluation	If new models are introduced to support CAEP/12, continue the candidate model evaluation process, which calls for sensitivity tests, comparisons with "gold standard data, and sample problems. Refine the process as appropriate on the basis of relevant criteria, to better inform CAEP which tools are sufficiently robust, rigorous and transparent, and appropriate for which analysis, and why there might be differences in modelling results.	Report	As model evaluations are complete Final report to CAEP/12
M.05	Doc 9911 Update	Update ICAO Doc 9911 as required. Potential areas for update that should be scoped out and considered (in coordination with WG1 and ISG) include: 1. full ICAO Doc 9911 harmonization and implementation across all models, including implementation of the extended level line segment, the latest start-of-take-off roll directivity, and speed-varying effects on noise-power-distance (NPD) curves; 2. standard approaches for modelling of helicopter noise; 3. modelling of reduced thrust departures; 4.sonic boom modelling; 5. noise modelling for commercial space vehicles and unmanned aerial vehicles(UAV) ; and 6. improved noise propagation modelling, possibly including terrain effects	Updated Doc 9911	CAEP/12
M.06	ICAO Support	Provide support to ICAO Secretariat in dissemination of MDG results.	As requested	As requested

CAEP/12 Modelling and Databases Group (MDG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
M.07	Analysis lessons learned	Conduct a review of lessons learned from CAEP/11 analyses since the development of the most recent MDG/FESG lessons learned document. This should include: 1) An identification of gaps in analysis assumptions, databases and tools. 2) Reviewing/discussing potential methodologies to assess the costs, benefits and interdependencies of a "new type" Standard with a view to potential application to future stringency analysis. 3) A methodology to quantify and report uncertainties in the noise and emissions trends projections. The objective is to present the benefits and interdependencies of Standards in relative terms (per cent change) compared to the total noise and emissions of aviation, thereby improving the assessment of trade-offs.	Report	CAEP/12

CAEP/12 Modelling and Databases Group (MDG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
M.08	COD Improve-ment(s)	Develop and maintain a 20xx Common Operations Database (COD) (preferably including a full 52-weeks of operations) and manage the acquisition and treatment of additional State data. Two versions of the COD will be maintained: 1. A version that can be used by the ICAO Secretariat and those States who contribute data to the COD, with sensitive data removed or de-identified; and 2. A version that is limited to those organizations who have signed an appropriate agreement This task will also include a comparison of the COD and WISDOM, e.g. using 20xx traffic, and identify areas of improvements in the process applied to generate the databases. Further work could be undertaken to refine and harmonize the description of aircraft in the base year operations (airframe, engine, age, seat / freight capacity), which would help improve the fidelity of the future fleet and operations forecast.	Database	SG2020
M.09	ADAP Participation	FESG/MDG to ensure coordination with the ICAO Aviation Data and Analysis Panel (ADAP) Multi-Disciplinary Working Group on Long-Term Traffic Forecasts (MDWG-LTF).	As requested	As requested
M.10	Airports Database	Augment the data included in ICAO Doc 7910 (Location Identifiers) to add information required to support CAEP analyses, in cooperation with the ICAO Secretariat and relevant panels.	Airports database	Prior to the start of analyses requiring the data
M.11	CORSIA Support	Provide technical support to CORSIA, as requested.	As requested	As requested

CAEP/12 Modelling and Databases Group (MDG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
M.12	CO2 Goals Assessment	Conduct a scoping exercise to assess the contribution of CO2 Standard to ICAO global aspirational goals in CAEP/12 cycle.		CAEP/12
M.13	Exploratory Study For Supersonic Aircraft	Conduct the exploratory study for supersonic aircraft as detailed in Sections 4.3.29 to 4.3.31 of the CAEP/11 report.	Report	Each SG and CAEP/12

CAEP/12 Forecasting and Economic Analysis (FESG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
F.01	New CAEP Forecast consistent with the long-term traffic forecasts developed by the ADAP MDWG-LTF	Develop a new CAEP forecast in support to the CAEP/12 analyses (e.g. passenger aircraft and freighter fleet forecasts, forecast for aircraft with less than 20 seats, retirement curves, and supersonics) using as an input the long-term (passenger and cargo) traffic forecasts developed by the ADAP MDWG-LTF. Agree with ADAP on a regular schedule for new forecast development, including base year, which would allow CAEP to use the same forecast for all their analyses in a given CAEP cycle	Forecast and Report	SG2020
F.02	Review of Economic Models	Review of economic models as needed for the future analyses. A review of the underlying economic cost assumptions used in the fleet evolution modelling tools is needed. These include crew, route, capital, and landing costs, all of which will need to be re-estimated and updated in concert with the development of a new fleet forecast. A review of the data and methodologies used to assess manufacturer and airline costs in stringency analyses should also be performed, in coordination with WG1 and WG3.	Report	SG2020 CAEP/12
F.03	ADAP Participation	FESG/MDG to ensure coordination with the ICAO Aviation Data and Analysis Panel (ADAP) Multi-Disciplinary Working Group on Long-Term Traffic Forecasts (MDWG-LTF).	Status report	Per ADAP MDWG-LTF schedule

CAEP/12 Forecasting and Economic Analysis (FESG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
F.04	Influence of airport capacity constraints on global air traffic	1. Assessing the methodology and results of a modelling tool suite developed at the German Aerospace Center (DLR) with a focus on airport capacity constraints and its effects on global air traffic, fleets and emissions 2. Assessing the potential and identifying options to improve the ICAO forecast	Methodology and results on traffic forecast to consider current & future Airport Capacity Constraints	CAEP/12
F.05	Exploratory Study For Supersonic Aircraft	Conduct the exploratory study for supersonic aircraft as detailed in Sections 4.3.29 to 4.3.31 of the CAEP/11 Report.	Report	Each SG and CAEP/12
F.06	Interdependencies	Coordinate with other working group Rapporteurs on interdependencies within the integrated approach to CAEP work items.	Coordinated WP	Each SG meeting and final report to CAEP/12

CAEP/12 Aviation Carbon Calculator Support Group (ACCS) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
A.01	Support updates to the ICAO Carbon Calculator	Assist the Secretariat in updating the current methodology used in the Carbon Calculator, identifying areas of improvement and potential changes to improve functionality.	Recommendations for enhancements to the Calculator to be implemented by the Secretariat	Report to SG meetings CAEP/12

CAEP/12 Sustainability Certification Schemes Evaluation Group (SCSEG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
G.01	SCS evaluation	Evaluate whether Sustainability Certification Schemes (SCS) comply with the SCS requirements defined in the CORSIA SARPs	SCS evaluation reports	Ongoing

CAEP/12 Impacts and Science Group (ISG) Work Programme				
Task Number	**Task Title**	**Task Description**	**Deliverables**	**Deliverable Date**
I.01.01	Coordination (internal group)	Coordination on activities.	Coordination	Ongoing
I.01.02	Coordination (internal ICAO)	Coordination with other WGs, TFs, RFPs, etc. Rapporteurs and ICAO Secretariat on activities.	Coordination	Ongoing
I.01.03	ISG membership	As per the ISG Terms of Reference, the ISG co-rapporteurs, in conjunction with the ICAO Secretariat, will identify suitable scientific experts. This will involve requesting that CAEP Members and observers nominate experts who are appropriately qualified and who conduct research in a subject area relevant to the CAEP/11 work programme.	Membership	SG2019
I.02	Aviation Emissions in context	ISG to focus on a bottom-up approach to analysis of the aviation sector's efforts to address climate change including implementation of the "basket" of technical solutions and market-based measures, and would be conducted through a staged approach that focuses first on carbon dioxide (CO2), acknowledging that further expansion to integrate short-lived climate pollutants would require more detailed climate modelling, and noting that the task should not be to define a share of a global carbon budget.	Report	Progress Report: SG2019
I.03	NOx Impacts	Assessment of: the impact of airport emissions on local levels of NOx and human health, impacts of cruise emissions of NOx on human health; impacts of cruise NOx on climate.	Report	Status Report: SG2019 Status Report: SG2020 Status Report: SG2021 Final report: CAEP/12

I.04	nvPM and fuel composition	Assessment of the role of fuel composition in nvPM emission characteristics and eventual trade-offs associated	Report	Status Report: SG2019 Status Report: SG2020 Status Report: SG2021 Final report: CAEP/12
I.05	Exploratory Study For Supersonic Aircraft	Conduct the exploratory study for supersonic aircraft as detailed in Sections 4.3.29 to 4.3.31 of the CAEP/11 Report.	Report	Status Report: SG2019 Status Report: SG2020 Status Report: SG2021 Final report: CAEP/12
I.06	White Paper on non-acoustic factors	ISG to develop a white paper on non-acoustic factors accounted to be responsible for about 70% of community annoyance related to aircraft noise.	White paper	CAEP/12

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