ART
Advanced Realtime Tracking

System user manual

SMARTTRACK & DTrack®

version 2.11
April 2015

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What's new in version v2.11?

Following, a short overview of the main new features in ***DTrack2*** version v2.11:

- No major changes

What's new in version v2.10?

Following, a short overview of the main new features in ***DTrack2*** version v2.10:

- ***SMARTTRACK*** now supports:
- calibration and measurement using a measurement tool&reference,
- calibration of more than four targets (license upgrade required)
- export and import of configurations (chapter 4.3.6.2 on page 60)
- new license model

What was new in version v2.9?

Following, a short overview of the main new features in ***DTrack2*** version v2.9:

- Improved filtering options (chapter 4.3.5 on page 56)
- Support for 5DOF targets (chapter 4.3.3 on page 50)
- Support for ring markers (chapter 3.1 on page 14)

Contents

Terms and definitions

term	definition
3DOF	three degrees of freedom (i.e. only position)
6DOF	six degrees of freedom (i.e. position and orientation)
5DOF	five degrees of freedom (i.e. one degree less in orientation)
base	imaginary connecting line between the two integrated cameras of the ***SMARTTRACK***
body calibration	teach the system the geometry of a rigid body
body, rigid body	rigid arrangement of several single markers (see also "target")
calibration angle (410mm)	belongs to the room calibration set and defines origin and orientation of the room coordinate system
ceiling suspension	equipment to mount the ***SMARTTRACK*** to the ceiling
DTrack2	
backend software	Linux-based software which does all necessary calculations
frontend software	graphical user interface to control the ***SMARTTRACK***
Flystick	wireless interaction device for virtual reality (VR) applications
hybrid tracking	fusion of optical and inertial data into one consolidated output
inertial sensor	An inertial measurement unit simultaneously measures 9 physical pro infrared optical tracking
position measurement of bodies (subjects or objects) based upon infrared light and optical measurement procedures	
license code (license key)	software key to unlock certain capabilities of the ***SMARTTRACK***
marker	object either made of retro reflective material or LED for position tracking (3DOF)
Measurement Tool	a pointing device which allows to measure the position of the tool's tip with high accuracy
measurement volume	defines the volume where optical tracking is possible
modulated flash	infrared signal which is used for wireless synchronization
mutual blinding	***SMARTTRACK*** sees disturbing reflections caused by the infrared flashes of another ***SMARTTRACK***
prediction	predicts output for the specified time in the future to compensate tracking and rendering latency
Radio Transceiver (integrated)	exchange data with Flystick
room calibration	teach the system the position of each camera and define origin and orientation of the room coordinate system
room calibration set	consists of angle and wand
synccard (integrated)	unit integrated in ***SMARTTRACK*** which serves for synchronizing the cameras
target	rigid arrangement of several single markers (= rigid body)
tracking	position measurement of bodies that move in a defined space
virtual point cloud	used for calculating the relative position of the ***SMARTTRACK***
wand	precalibrated stick carrying two markers. The wand belongs to the room calibration set and is used to generate a virtual point cloud and to scale the system

1 Safety

1.1 Symbols and their meaning

You can find the following symbols and their signification on the equipment or in the manual:

	Useful and important notes.
☞	Important notes, which may lead to system malfunction or to the loss of warranty by non-observance.
	Important safety warning to assure operation safety. These warnings have to be considered, otherwise user and equipment could be endangered, the equipment could be damaged or the function of the equipment is not warranted.
	Safety warning for infrared radiation. These warnings have to be considered, otherwise users eyes could be endangered.

Table 1.1: Symbols and their meaning

1.2 Safety warnings

☞ **Safe operation of the equipment is only warranted if the warnings in this manual and on the equipment are observed.**

- Never use the equipment if any part looks damaged.
- Safe operation is not possible, if
  - the housing is damaged,
  - any fluid attains in the housing,
  - objects attain inside the equipment,
  - the equipment shows any visible faults (smoke, sparks, fire, smells, etc.) or
  - the power cord is damaged.
- In any of the cases mentioned above (or similar) pull the power cord out of the power

socket immediately. Otherwise, users or environment are endangered. Please contact the ***ART*** service.

- Never change or alter the equipment, neither mechanically nor electrically. Only the components described by ***ART*** shall be used. The conformity and the warranty of the producer (***ART***) expire by non-compliance.
- Never open the equipment! Only personnel authorized by ***ART*** is allowed to open the equipment. Inside of the equipment there are various hazards like high voltage, electric shocks - even if the equipment is disconnected - which can lead to death on contact. In case of malfunction of the equipment please contact the ***ART*** service.
- Only peripheral devices which meet the safety requirements of EN/IEC 60950 for extra low voltage may be attached on Ethernet-, BNC- and the DC-circuit of the equipment.
- The ***SMARTTRACK*** emits infrared light. Keep a distance of min. 20 cm when operating the ***SMARTTRACK*** . The ***SMARTTRACK*** is assigned to the Exempt Group according to IEC62471-1 and therefore poses no risk or hazard to the human eye or skin at this distance.
- Be sure that the cameras are firmly mounted in the correct position.
- Do not touch the front pane of the cameras, since the acrylic pane and the lens are highly sensitive surfaces. Be careful to avoid permanent damages (e.g. scratches). Only touch the housings of the cameras.
- The ventilation holes of the ***SMARTTRACK*** must not be covered. Air circulation is necessary to prevent the cameras from overheating. If the air circulation is restricted overheating will damage the cameras. The minimum distance between equipment and environmental objects has to be greater than 3 cm.
- The equipment has to be attached to a power socket with grounding. If the grounding wire is defective the requirement of the safety and the electromagnetic compatibility (EMC) are not guaranteed. To check the function of the grounding wire ask your regional located electrician.
- Before switching on any device, verify that voltage and frequency of your electric installation are within the allowed ranges of the equipment. The characteristics of the equipment can be found on the appliance rating plate or in chapter A on page 117. The appliance rating plates are on the equipment's housing (***SMARTTRACK*** on the backside of the housing)
- The power switch on the backside does not completely separate the devices from the electricity network. To completely separate the equipment from the electricity network the power plug must be disconnected from the power socket. The power plug has to be accessible freely. The power socket must be close to the equipment.

- Please install the cables such that
  - no one can stumble over the cords,
  - the cords cannot be damaged,
  - the cords cannot damage the ***SMARTTRACK*** due to mechanical strain,
  - the line of sight of the ***SMARTTRACK*** is not obstructed.

Install a strain relief!

- Only use original ***ART*** (or ***ART*** authorized) components and accessories. Using non-original components or accessories may damage the equipment, cause malfunctions or may void operation safety. The provided components and original accessories can be found in chapters 4 on page 22 and 5 on page 83. Only use the originally provided external power supply for operating the ***SMARTTRACK***
- The equipment must not be dropped and/or knocked.
- Do not use any solvents or water to clean the cameras. For more information about cleaning the cameras please read chapter 7.2 on page 111.
- Never expose the equipment to high levels of humidity or condensating humidity. Protect the cameras against water and chemicals.
- The equipment must not be operated in environments with intensive formation of dust or hot environments where temperatures rise above 40° C (100° F).

☞ ***ART*** **explicitly denies any liability or warranty if the product is modified in any way or not used according to this manual and the specification labels on the equipment.**

2 Introduction

The ***SMARTTRACK*** is a fully integrated stand-alone infrared optical tracking system. It is designed to be used in small volumes (approx. $2m^3$). In this user manual we are going to perceive "tracking" as measurement of the position of objects or subjects that move in a defined space. These objects or subjects to be tracked have to be equipped with single markers or rigid arrangements of markers (= rigid body or target).

Position and/or orientation of those rigid bodies can be measured. If only the spatial position (X, Y, Z) is measured we call this "three degrees of freedom" (3DOF) tracking. The simultaneous measurement of position and orientation (three independent angular coordinates) is called "six degrees of freedom" (6DOF) tracking.

Single markers are sufficient if only 3DOF coordinates are needed. For 6DOF tracking, a rigid body is mandatory.
Passive markers are covered with retro reflective material - they act as light reflectors. Active light emitters (i.e. based on infrared LEDs) are called active markers.

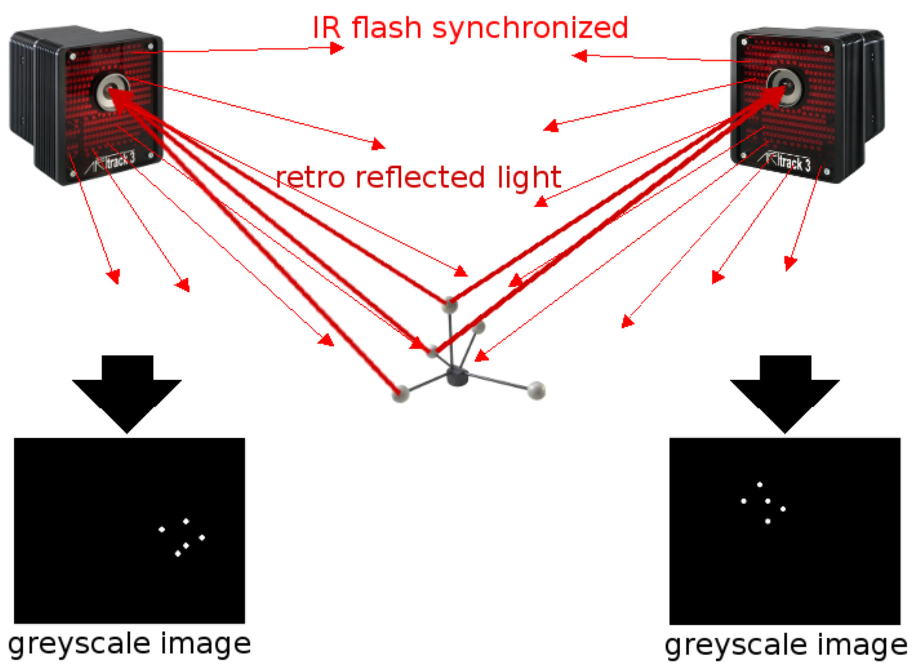


Figure 2.1: Principle of optical tracking (stereo vision)

Figure 2.1 shows the principle of infrared optical tracking with a two-camera system and a standard target. The ***SMARTTRACK*** makes use of the same principle.

The cameras are sending out synchronized IR flashes which are reflected towards the lens by the retro reflective material which is covering the markers of the target. The integrated tracking cameras scan a certain volume, detect the IR radiation that is reflected by the markers and create a greyscale image based on the received IR radiation. The ***SMARTTRACK*** calculates the 2D marker positions with high accuracy using pattern recognition internally. A mean 2D-accuracy of 0.04 pixels (0.1 pixels maximum 2D-deviation) is standard in ***ART*** tracking cameras.

Then, based on the 2D data, the ***SMARTTRACK*** calculates 3DOF or 6DOF data. The base for this calculation is that the cameras' field of views are overlapping. ***DTrack2*** calculates the path of the optical rays from the cameras to the markers and delivers the ray intersections in three-dimensional coordinates. These intersections are the positions of the markers.
The position and orientation of the cameras are known from the room calibration. During body calibration, ***DTrack2*** identifies certain marker arrangements as rigid bodies. Based upon this, ***DTrack2*** is able to calculate 6DOF data and, finally, knows position and orientation of the target and, therefore, of the object or subject to be tracked.

In optical tracking systems you have to be aware that tracking is only possible as long as the target is positioned in tracking range of the cameras and is not occluded by any other objects or the object to be tracked. More in detail, at least four markers of a target have to be visible for a minimum of two cameras to enable tracking.

The *SMARTTRACK* has a limited field-of-view and range! It is designed to be used in small volumes. Please refer to chapter 4.1 on page 22 for more information on the tracking volume of the *SMARTTRACK* .

3 Markers and targets (rigid bodies)

3.1 Passive markers

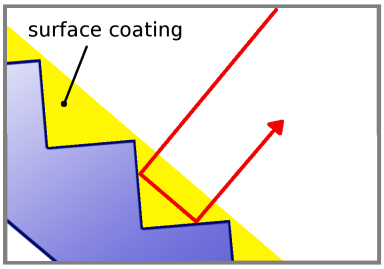
The passive markers used in ***ART*** tracking systems are retro reflectors. These markers reflect the incoming IR radiation into the direction of the incoming light. More precise: the IR radiation is reflected into a narrow range of angles around the (opposite) direction of the incoming light. Passive markers can be either

1. spherical markers:
   + excellent visibility from any perspective,
   - expensive fabrication,
   - sensitive surface,
   - target requires larger volume $\rightarrow$ danger of mechanical damage.
2. flat markers:
   + cheap,
   + flat targets possible,
   + robust surface because cover may be applied,
   - the angular range of visibility is limited to approx. $\pm 45°$.
3. ring markers:
   + cheap,
   + cylindrically shaped targets possible,
   + robust surface,
   - the angular range of visibility is limited to approx. $\pm 45°$.

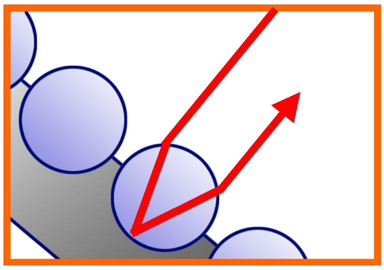
Passive markers are mostly spheres covered with retro reflecting foils. However, they can also be stickers made from retro reflecting material.

Retro reflecting sheets or foils available on the market can be based on two different optical principles:

1. **Triple mirrors**, which are arranged such that their planes form angles of 90° by pairs, are reflecting light in the described way. Mostly foils with arrangements of many very small mirrors in a plane are used.



2. **Glass spheres** (with a proper refraction index) are focussing incoming light approximately to the opposite surface of the ball. A layer of microscopic glass spheres, carried by a reflecting material, acts as a retro reflector. These foils can be fabricated on a flexible carrier material, thus they are widely used for equipping spherical markers with retro reflecting surfaces.



ART spherical markers are covered with retro reflecting foils, based on the glass spheres principle.

☞ **The quality of the markers decreases when they are in contact with dust, dirt, fat, liquids, glue or comparable contaminants. Please make sure that the markers are not touched or damaged.**

3.2 Active markers

Basics Active markers are light (i.e. infrared light) emitting elements, mostly LEDs.

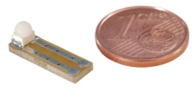
In ***ART*** tracking systems four types of LED-based active markers may be used, depending on the application:

1. **Single LEDs without diffusor sphere:**

   + can be covered with acrylic protection film,
   + results in simple and robust markers providing visibility up to high distances (up to 10m),
   - the angular range of visibility is limited to approx. ±60°.

Chapter 3

2. **Single LEDs with diffusor sphere:**
   - \+ for optimum angular range of visibility,
   - \- distance between marker and tracking camera is limited to a short distance (up to 4.5m).

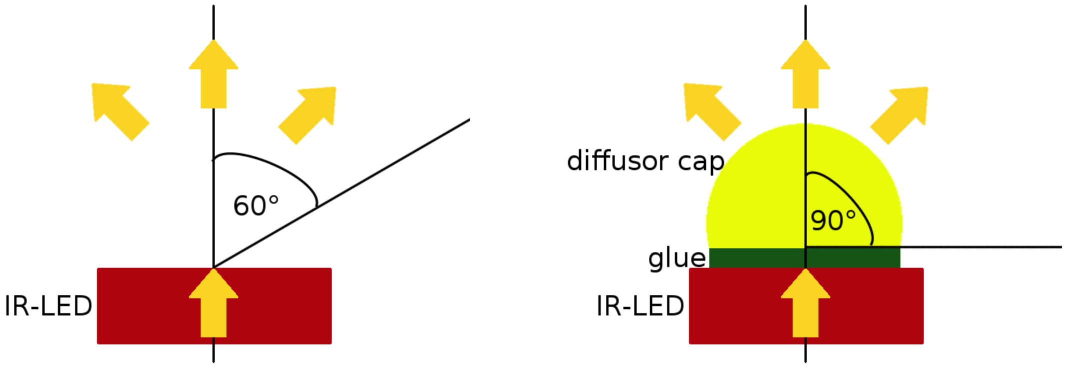


3. **Big active spherical markers:**
   - \+ several single LEDs per marker, covered with light scattering spheres,
   - \+ provide visibility from all sides and up to very high distances (approx. 20m),
   - \+ suitable for outdoor tracking,
   - \- diameter: 50mm,
   - \- weight: 50g.

4. **Big active flat markers:**
   - \+ several single LEDs per marker, covered with light scattering surface,
   - \+ tracking up to very high distances (approx. 20m),
   - \+ suitable for outdoor tracking,
   - \+ magnetic base for easy positioning on metal surfaces,
   - \- the angular range of visibility is limited to less than 180°,
   - \- diameter: 30mm.

All active markers provided by ***ART*** are controlled by a special PC board and need power supply.

Synchronization of active markers Active markers could in principle be activated in CW mode (i.e. continuous light emission). However, this would not be very clever because tracking cameras have a very narrow time slot of sensitivity, i.e. most of the light emitted by the markers would be useless for tracking. As a consequence, maximum distance between cameras and marker would be very short due to an upper limit of power dissipation allowed for each single LED. Therefore, all active markers provided by ***ART*** are emitting radiation only when the tracking cameras are sensitive, thus having to be synchronized with the cameras.
Synchronization can be done by a wired connection between the tracking system and the pc-board controlling the active markers, but can also be done in a wireless way.



(a) Single LED (b) Single LED with diffusor sphere

Figure 3.1: Angular range of visibility

For wireless synchronization a coded IR flash is being sent out by a tracking camera. The active marker's PC board recognizes the coded flash and activates the LEDs.

Chapter 3

3.3 Standard targets

Type	Description	Weight	approx. Dimension	Marker size
Hand target 	The hand target is designed for hand tracking in usability and assembly studies respectively. It is also frequently used as a small general-purpose target. Due to the small size this target is easily occluded by the hand carrying it. Therefore, proper arrangement of tracking cameras has to be used in order to avoid occlusions.	25g / 0.9oz	$(110 \times 80 \times 28)$mm	12mm
Large hand target 	This hand target is designed for hand tracking in a two camera tracking system. Its large size allows to move the hand in almost all directions, without losing tracking.	30g / 1.1oz	$(170 \times 120 \times 35)$mm	12mm
Claw target 	The claw target looks just the same as the hand target. But it comes in a bigger size and is equipped with bigger markers.	35g / 1.2oz	$(160 \times 110 \times 30)$mm	16mm

Type	Description	Weight	approx. Dimension	Marker size
Tree target 	Originally designed for tracking HMDs, the tree target is a general-purpose target for tracking from longer distances. It is equipped with 20mm markers.	75g / 2.65oz	(195 × 170 × 120)mm	20mm
Generic glasses target 	For head tracking mostly in passive stereo systems, tracking targets must be fixed to the stereo glasses. ***ART*** offers several light-weight standard targets for this purpose.	min: 14g / 0.5oz max: 22g / 0.7oz	(270 × 120 × 35)mm	12mm
INFITEC PREMIUM target 	Target tailored to the INFITEC PREMIUM passive stereo glasses.	26g / 0.9oz	(225 × 85 × 80)mm	12mm

Type	**Description**	**Weight**	**approx. Dimension**	**Marker size**
CrystalEyes® 2/3 target 	Target tailored to the shutter glasses of the StereoGraphics active stereo system. It fits to both CrystalEyes® 2 and 3.	28g / 1oz	(215 × 120 × 60)mm	12mm
CrystalEyes® 5 target 	Target tailored to the shutter glasses of the StereoGraphics active stereo system. It fits to the CrystalEyes® 5.	19g / 0.7oz	(195 × 105 × 40)mm	12mm
NuVision APG6000 and APG6100 target 	Target tailored to the NuVision APG6000 and APG6100 shutter glasses.	17g / 0.6 oz	(220 × 125 × 75)mm	12mm

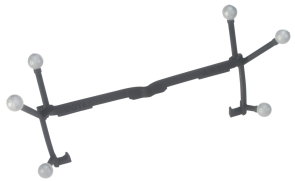
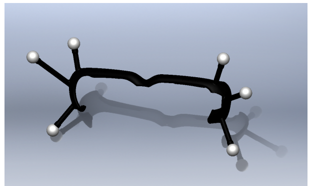
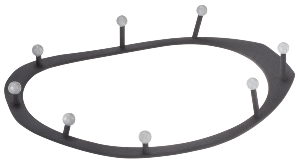
Type	Description	Weight	approx. Dimension	Marker size
Volfoni EDGE® target 	Target tailored to the Volfoni EDGE® shutter glasses.	23g / 0.7 oz	(230 × 95 × 60)mm	12mm
NVIDIA 3D Vision® Pro target 	Target tailored to the NVidia 3D Vision Pro shutter glasses.	25g / 0.9 oz	(225 × 100 × 60)mm	12mm
NVisor SX 60 target 	Target tailored to the NVisor SX 60 head mounted display.	55g / 1.94oz	(300 × 215 × 35)mm	12mm

Table 3.3: Standard targets overview

4 System setup

4.1 The *SMARTTRACK*

Keep a distance of min. 20 cm when operating the *SMARTTRACK* ! The *SMARTTRACK* is assigned to the Exempt Group according to IEC62471-1 and therefore poses no risk or hazard to the human eye or skin at this distance.

Description The ***SMARTTRACK*** is a fully integrated stand-alone infrared optical tracking system. It is designed to be used in small volumes of approx. $2m^3$.

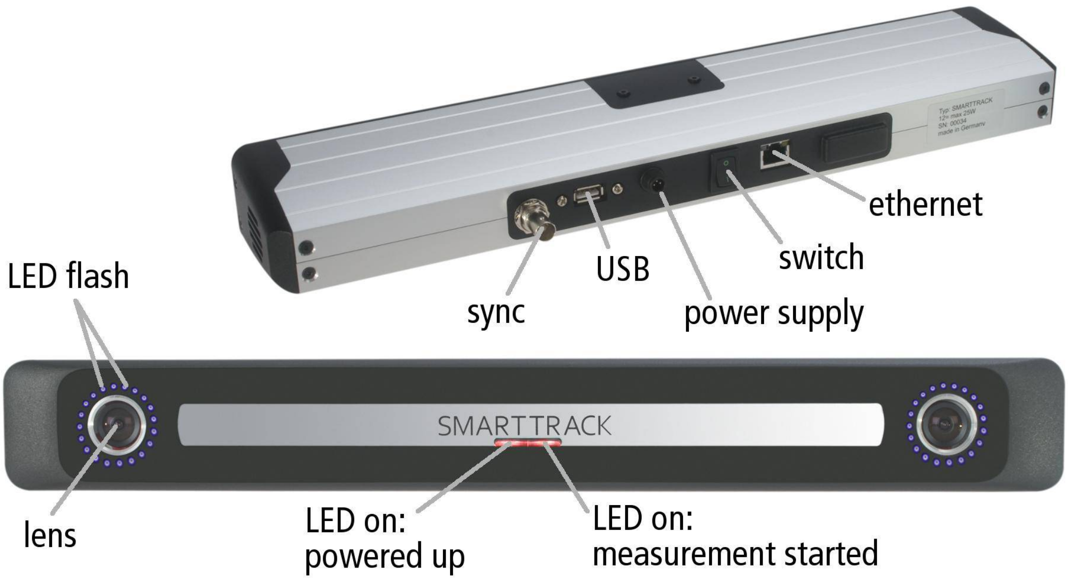


Figure 4.1: ***SMARTTRACK***

Tracking volume The typical tracking volume of the ***SMARTTRACK*** is illustrated in figure 4.2 on page 23.

Mounting The ***SMARTTRACK*** is optimized for a predefined measurement volume. System operation in smaller or bigger measurement volumes can lead to reduced accuracy or other malfunctions. The measurement volume can be adjusted within certain limits simply by changing the flash intensity of the ***SMARTTRACK*** (see chapter 4.3.6.3 on page 62).

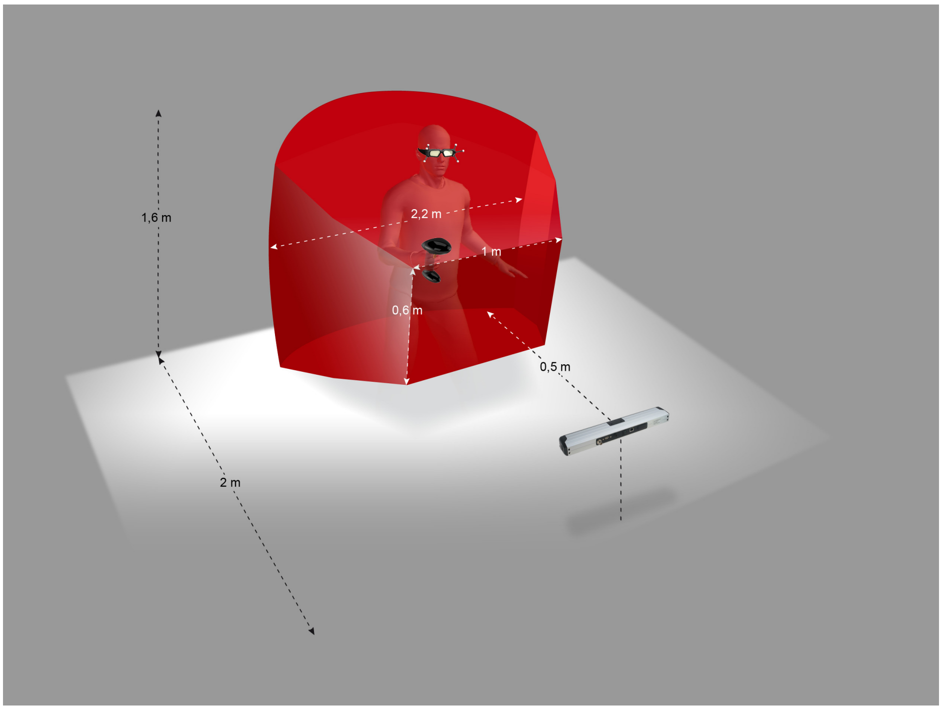


Figure 4.2: 3D Visualization of the tracking volume

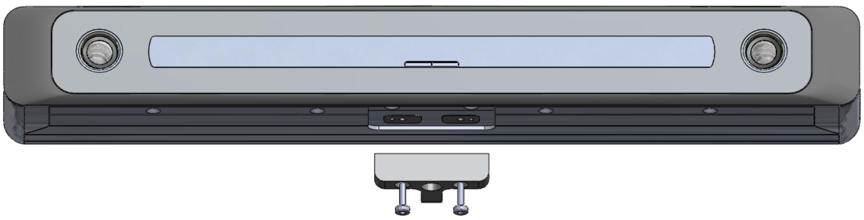


Figure 4.3: Attaching the T-piece to the ***SMARTTRACK***

Tracking is very sensitive to camera movements. Therefore, the ***SMARTTRACK*** have to be mounted in a way that reduces camera movements (especially vibrations) as much as possible.

Mounting on tripods may be sufficient for presentations and preliminary installations, but is not recommended as a final solution!

Feel free to contact ***ART*** in case you want to realise a more complex installation. We will assist you in your planning.

The T-piece for the ***SMARTTRACK*** can be attached on both bottom and top side (see figure 4.3).

Only use screws supplied with the carrier for mounting it.

You shall never unfasten other screws of the ***SMARTTRACK*** (see chapter 1.2 on page 9). Otherwise, the ***SMARTTRACK*** may be damaged and liability and warranty is void.

Furthermore, please make sure the ventilator holes are not covered.

Make sure to install the ***SMARTTRACK*** in a way that you can easily access its cables. Be especially careful to mount the ***SMARTTRACK*** firmly so it cannot fall down. If unsecured, it may pose a serious hazard to health and safety.

Avoid hard shocks! A new camera calibration at the *ART* facilities might become necessary in that case.

Please install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the ***SMARTTRACK*** due to mechanical strain,
- the line of sight of the ***SMARTTRACK*** is not obstructed.

Inappropriate cabling may pose a serious hazard to health and safety. Cable ducts or fixings should be used and a strain relief should be installed!

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the ***SMARTTRACK*** . Especially strong point light sources like e.g. halogen lamps and direct or reflected sunlight may imply problems for the measurement (fluorescent lamps are ok).

Please refer to 4.3 to learn how to install the ***DTrack2*** frontend software.

4.1.1 The controller inside the *SMARTTRACK*

The ***SMARTTRACK*** is an integrated tracking system. This means, inside the small housing we integrated not only two tracking cameras but also the Controller which performs all calculations and generates the data output stream.

The software ***DTrack2*** consists of frontend and backend software. The frontend software is installed on a remote PC which is connected to the ***SMARTTRACK*** via Ethernet. A GUI for easy handling enables the user to control the tracking system completely from the remote PC. The benefit is that the system becomes more flexible, i.e. different users can control the tracking system at any one time (but not simultaneously!) from different working places.

Furthermore, ***DTrack2*** provides the possibility to control its functions via Ethernet (i.e. without the ***DTrack2*** frontend software). This is done by establishing a TCP/IP connection with the ***SMARTTRACK*** and exchanging short command strings (refer to chapter 4.1.6 on page 30). Please contact ***ART*** if you are interested in using this feature.

The backend software, which is Linux-based, runs on the integrated ATC - all necessary calculations (3DOF, 6DOF data, ...) are done by it. The data and control commands are interchanged via a TCP/IP connection between the ***SMARTTRACK*** and the ***DTrack2*** frontend software on the remote PC. Data output to the application or graphics workstation is done via a UDP connection.
Interaction devices can be accessed directly due to the integrated radio transceiver (refer to chapter 5 on page 83).

The ***SMARTTRACK*** uses the single Ethernet plug (100 Base-TX) for data output to the remote PC or to any PC within the local network. You may either use the ***SMARTTRACK*** as a DHCP client within your network, i.e. the tracking data is transmitted directly via your local network. Or, if due to your company security guidelines it is not allowed to connect the controller directly to your network, you may install two network cards in your remote PC - one is connected to the ***SMARTTRACK*** and the other one is connected to your local network. In this case, the ***DTrack2*** Frontend will act as a router for the tracking data.

The ***SMARTTRACK*** is controlled by a remote PC via ***DTrack2*** frontend software. When delivered, the ***SMARTTRACK*** is set up to support DHCP. Therefore, it will acquire an IP address automatically given that a DHCP server is running.
Verify that the ***SMARTTRACK*** is connected to its power supply. Connect the Ethernet cable to your local network and connect the plug of the power supply to a socket. If you want to set a specific static IP address before booting the ***SMARTTRACK*** please refer to chapter 4.1.2 on page 26 for more information.

Press the switch on the back to start the ***SMARTTRACK*** . If it is booting without connected Ethernet cable it will use its fall-back IP address.

The fall-back IP address of the *SMARTTRACK* is 192.168.0.1 (subnet mask 255.255.255.0)!

You may configure another static IP address as follows:

- select *Settings* → *Controller*
- untick the checkbox *DHCP client*
- enter *IP address* and *subnet mask*
- optionally, enter *gateway* and *nameserver*
- reboot the ***SMARTTRACK*** for the changes to take effect

☞ **Please make sure to remember these settings. Otherwise, your *SMARTTRACK* may become unreachable due to wrong IP settings! Refer to chapter 4.1.2 on page 26).**

Finally, start the ***DTrack2*** frontend software on the remote PC. Please refer to chapter 4.3 on page 37 for more details.

External synchronization The ***SMARTTRACK*** can be synchronized with an external source. On the back of the ***SMARTTRACK*** there is a BNC plug ("ExtIn") which serves as input for the external synchronization signal. The sync signal may be of type TTL or video (see also chapter 4.3.6.3 on page 64).
Typically, external synchronization has to be used when other systems inside the tracking system are also using infrared signals for controlling their equipment (e.g. if IR-controlled shutter glasses are used). The goal is to reduce or eliminate interference. The ***ART*** tracking system follows the external synchronization signal and chooses time slots when it is safe to emit infrared radiation without causing interference. The effect is, for example, that active shutter glasses are not flickering but offer a stable picture for the user.

☞ **The external sync input is not internally terminated.
When synchronizing with a video input, a T-piece with an external 75Ω terminating resistor should be used if the signal line ends at the *SMARTTRACK* .
When using a TTL-signal you should not use a terminating resistor. However, you should use a shielded cable for the synchronization with a TTL-signal.**

4.1.2 Setting a static IP address without the *DTrack2* Frontend

It is possible to configure the IP address of the ***SMARTTRACK*** without the ***DTrack2*** frontend software. You only need a standard USB stick (FAT32 formatted) on which you save a setup file (format see below).

- Plug in the USB stick. It doesn't matter if the ***SMARTTRACK*** is running or not.
- If necessary start up the ***SMARTTRACK*** .

- Wait some time (approx. 20-30 seconds) for the ***SMARTTRACK*** to write the two files onto the USB stick.
- Unplug the USB stick.
- Now, you may view the information file or edit the setup file with any editor (instructions given in the setup file).
- In case you changed the setup file, please plug in the USB stick to the ***SMARTTRACK*** again.
- Wait some time (approx. 20-30 seconds) for the ***SMARTTRACK*** to read the setup file.
- Shut down and restart the ***SMARTTRACK*** for the changes to take effect.

Now, your ***SMARTTRACK*** is configured according to your requirements.

4.1.3 The setup file

This file is used to configure the ***SMARTTRACK*** without using the ***DTrack2*** frontend software regarding three parameters, which are:

- configuring the ***SMARTTRACK*** to be a DHCP client,
- setting a static IP address and
- carrying out a factory reset.

Carrying out a factory reset will result in the loss of all your settings!

Following, a description of the file (e.g. smarttrack00007_setup.txt) format:

```
# ARTtrack Controller Setup:


# ethernet settings:
#  - uncomment just one of the lines starting with 'SETNET'

# ethernet settings: DHCP
#  - uncomment the following line to activate DHCP
#SETNET="dhcp"

# ethernet settings: fix IP address and subnet mask
#  - uncomment the following line to set a fix IP address and subnet mask
#SETNET="ip 192.168.0.1 255.255.255.0"
```

```
14
15# factory reset of all other settings:
16#  - CAUTION: use with care, all your settings will be lost!
17#  - uncomment the following line to reset all other Controller settings
18#RESETSETTINGS="yes"
```

Example:
If you wanted to setup a static IP you would have to remove the '#' sign and enter the desired IP address, here for example: 123.123.0.1

before:

```
13#SETNET="ip 192.168.0.1 255.255.255.0"
```

after:

```
13 SETNET="ip 123.123.0.1 255.255.255.0"
```

4.1.4 The information file

This file contains the current settings of the ***SMARTTRACK*** . Following, a description of the file format (e.g. smarttrack00007_info.txt):

```
ARTtrack Controller Information:

Serial Number      : 00007

Ethernet (LAN)     : dhcp
Ethernet IP (LAN)  : 10.10.5.22 255.255.0.0 10.10.0.253
Ethernet MAC (LAN): 00:24:1D:00:C3:B3
```

4.1.5 Wake On LAN

The ***SMARTTRACK*** is capable of Wake On LAN (WOL) if it has been forced into standby mode before by the user (***DTrack2*** → *ARTtrack Controller standby*).

There are two options for waking up the controller remotely:

1. you may use ***DTrack2*** or
2. use a separate tool (Windows: WOL program; Linux: console-based command).

Option 1 - WOL via *DTrack2* Start the ***DTrack2*** frontend software as usual. The '*Connect*' button will change its name into '*Wake On LAN*' (refer to figure 4.4).

Please make sure that the *SMARTTRACK* is still connected to the local network! *DTrack2* cannot wake it up if no physical connection between remote PC and *SMARTTRACK* is established!

Figure 4.4: Welcome screen of ***DTrack2*** with Wake On LAN option

Press the '*Wake On LAN*' button and ***DTrack2*** is trying to wake up the ***SMARTTRACK*** - this may take up to two minutes as the ***SMARTTRACK*** has to boot up (see figure 4.5).

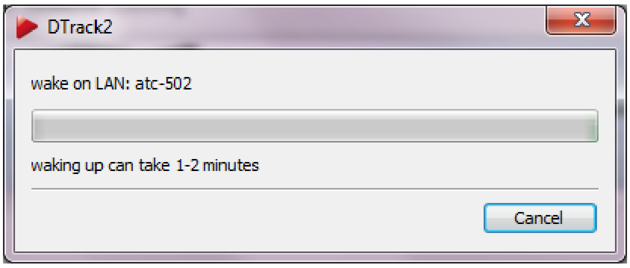


Figure 4.5: Wake On LAN progress bar

If Wake On LAN was successful ***DTrack2*** will automatically establish the connection with this ***SMARTTRACK*** and start the frontend software.

Option 2 - WOL via separate tool You will need the hostname of the ***SMARTTRACK*** as well as its MAC address. To get this information, please press *Settings* → *Controller* and remember the '*hostname*' and its MAC address ('*ethernet-MAC LAN*').

If you are a Windows user you need a separate WOL program to use this feature. Please refer to the manual of the WOL program you are using to find out how to configure the WOL function.

When using Linux you only need to switch to the console and type in the following command and your ***SMARTTRACK*** restarts:

for Linux openSUSE:

```
$ wol <MAC address of your SMARTTRACK>
e.g.: $ wol 00:1D:92:3A:58:5F
```

for Ubuntu:

```
$ wakeonlan <MAC address of your SMARTTRACK>
e.g.: $ wakeonlan 00:1D:92:3A:58:5F
```

4.1.6 Remote command strings

The following commands may be used in combination with the ***DTrack2*** SDK to control the tracking system remotely (e.g. with your media control) and without the ***DTrack2*** frontend. The ***DTrack2*** SDK is available from ***ART*** upon request.

Command string (always preceded by "dtrack2")	**Description**
tracking start	Start the measurement
tracking stop	Stop the measurement
set config active_config <name>	Change the configuration to <name>
set output net <channel id> udp <host> <port>	Configure where the data has to be sent to
example: dtrack2 set output net ch02 udp 231.231.0.1 5003	
set output net <channel id> multicast <host> <port>	Configure where the data has to be sent to
example: dtrack2 set output net ch02 multicast 231.231.0.1 5003	
set output active <channel id> <output type> <yes/no>	Activate or deactivate the data output and specify the data to be transmitted
example: dtrack2 set output active ch02 all yes	
system shutdown	Force the ***SMARTTRACK*** to go into standby

4.2 Setting up the Hybrid Inertial System

With the introduction of v2.10.0 ***DTrack2*** supports inertial sensors. The main advantage of hybrid targets is that inertial sensors still deliver information through the rotation of the target, even when the optical target may not be tracked any longer due to viewing limitations or occlusions. On the other hand, drift correction of the inertial sensors is achieved by fusing their output with position measurements calculated from the optical tracking system. Inertial sensors are communicating with the ***DTrack2*** system via a 2.4 GHz ISM radio connection.

Connecting the wireless transceivers The wireless antenna comes pre-assembled with two transceivers ('Dongles') for communication with the inertial sensors. First connect the USB plugs of these dongles to any free USB port of the controller using the supplied extension cables. The dongles are activated after rebooting the controller or calling *DTrack2* → *Search hardware*.

Now within ***DTrack2*** go to *Settings* → *Inertial Sensors* and check that all attached dongles have been found with correct device ID, model, name, firmware version and channel (see figure 4.6 on 31). Please also check the frequency the sensors are operating at (default: 100 Hz).

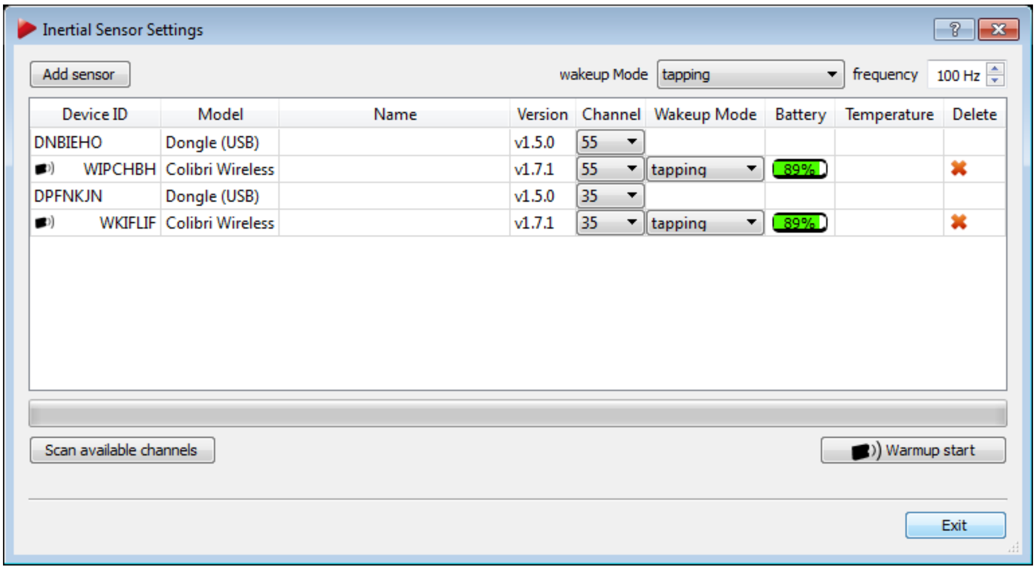


Figure 4.6: Inertial Sensor Settings

At this point only dongles and no wireless sensors should be listed. Otherwise continue reading in chapter 4.2 on page 34.

☞ **The default channels for all dongles and sensors are 35 and 55 (out of 80). In case these frequencies are already occupied by other devices in range (e.g. WLAN), connection problems may occur. *ART* recommends to scan for available channels and to select free channels accordingly. Keep a minimum distance of 10 channels between dongles or from otherwise unavailable channels for optimum connectivity.**

Next scan the available radio channels by pressing *Scan available channels*. After completion the drop-down menu in the column *Channel* will show a list of all available channels for each dongle. The currently used channels are marked in bold digits, while all not recommended channels are greyed out. If the current channel of a dongle is not suitable, ***DTrack2*** recommends another one (marked green).
Please select an appropriate channel for each dongle. The selected dongle will change its channel accordingly, like for all assigned sensors. Do not set both dongles to the same channel or on occupied frequencies from other devices in range.

Adding the inertial sensors to the configuration in *DTrack2* This needs to be done initially - in case the sensors are already connected please skip this step.
Please ensure that all sensors have been charged or alternatively attach the sensors to the supplied charging hub prior to the following steps.
In the menu *Settings* → *Inertial Sensors*, press *Add sensor* to identify and connect all inertial sensors in range.

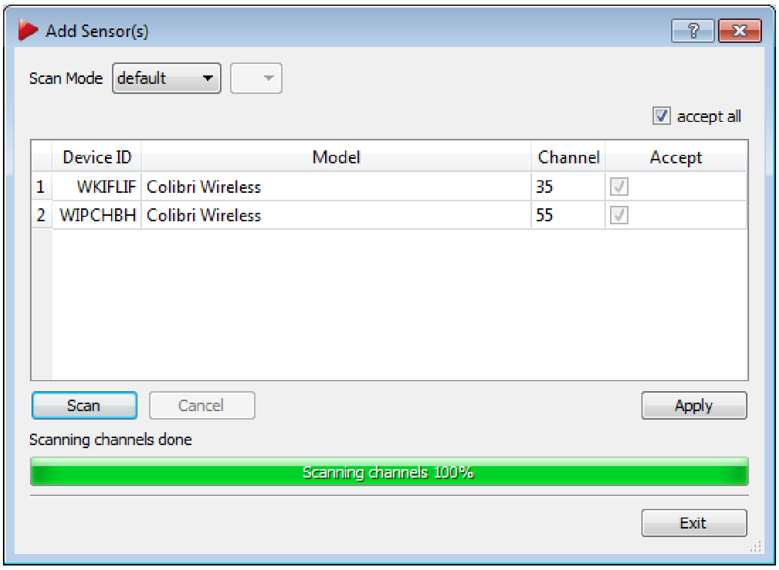


Figure 4.7: Add Sensors

In the appearing dialogue (see figure 4.7 on 32) you should find the *Scan mode* being '*default*'. In this mode ***DTrack2*** will search for the sensors on default channels 35 and 55, even if the dongles / sensors have been set to different channels manually. In this case, please change the scan mode to '*single*' and select the corresponding channel in the adjacent selection box. If you don't know the current radio channel of your sensors, choose '*all*' (takes some time). With '*USB*' you can identify sensors that are connected to the ***ART*** Controller via an USB charging cable.
Press *Scan* and the system will identify all sensors in range. Tick the checkboxes of all sensors to be added to the configuration in the column *Accept* or add all sensors by ticking '*accept all*'. Then press *Apply* and exit this dialogue.

***ART* delivers pre-calibrated targets, i.e. both the optical target geometry as well as the HBC result are stored directly on the sensor. Unless the hybrid target is disassembled or becomes damaged, it is sufficient to identify and add all sensors using the menu *Settings* → *Inertial Sensors* → *Add Sensors*. There is no need to calibrate the targets manually.**

The dialogue *Inertial Sensor Settings* (see figure 4.6 on 31) now shows all available dongles and sensors with the following properties:

- Device ID + wireless icon
- Model (e.g. Colibri Wireless)
- Name (target name pre-calibrated or user-defined)
- Firmware Version
- Currently used channel (default: 35 / 55); with this menu you can also change the radio channel of a single sensor
- Wake-up mode (radio, tapping, USB/button)
- Battery level
- Temperature (only during measurement)

☞ **Take care that all inertial sensors use a radio channel of one of the dongles; otherwise this sensor won't be used during measurement. Also take care that (approximately) the same number of sensors are assigned to each dongle.**

The temperature values between single inertial sensors may vary. The operating temperature is reached as soon as there are no more temperature changes inside the sensors indicated by a green status bar. It is not dependent on the absolute temperature value.

For warming up the sensors to operating temperature press the button *Warmup start*.

All inertial sensors are turned to stand-by mode after a pre-defined idle time, which corresponds to the selected wake-up mode.

via: radio (idle time: 1 min.), i.e the sensors are switched on as soon as they are addressed by the controller.

via: tapping (idle time: 3 min., older sensors only), i.e. the sensors are switched on by tapping on the sensors with your fingertip or tapping the sensors on a hard surface (e.g. table).

via: USB/button (idle time: 10 min.), i.e. the sensors are switched on by pressing the button on the sensor for 3-4 seconds or by connecting them to the supplied charging hub.

☞ **For optimal battery life, *ART* recommends to switch all sensors to wake-up mode "USB/button" when not in use for a longer period of time.**

Calibration of Hybrid Bodies As requirement for the following steps it is necessary to warm-up the sensors to operating temperatures and to maintain a constant temperature during the calibration. Otherwise the measured data and thus the calibration will have poor quality. Additionally please double-check that all sensors have been charged to at least 30 % before you continue.
You can simply use the button *Warmup start* in the dialogue *Inertial Sensor Settings* (see figure 4.6 on 31) or in ***DTrack2*** frontend (top right) and leave the process running for about 5-10 minutes. The progress bar will stop at 100% (progress bar turns green) even though the warming up of the sensors continues. This shall guarantee that the sensors work continuously until the calibration and the actual measurement take place. Otherwise they would cool down again.

Administration of the bodies Within ***DTrack2*** go to *Settings* → *Body Administration* (see figure 4.31 on page 68). All ***ART*** pre-calibrated targets have their corresponding optical target geometries stored inside the inertial sensor. Thus when adding the recognized inertial sensors, all corresponding target geometries are also added to the tab '*standard bodies*' in the Body Administration (F8). Unknown or custom hybrid targets, however, will show up as '*not calibrated*' in the column *Calibration*. At this point the desired optical target and the corresponding inertial sensor have to be matched according to their body ID and device ID.

For new hybrid targets, a three-step calibration procedure has to be performed:

1. A standard optical body calibration needs to be carried out. Just press *Calibration* and move around the target in front of the cameras. Please refer to 4.3.3 on 50.

2. A hand-eye calibration has to be performed to combine an inertial sensor with its corresponding optical target. During this Hybrid Body Calibration process (HBC) the relative rotation of the two sensors is determined.

3. Drift correction for the inertial sensors needs to be measured and applied. Optical tracking data of the corresponding target allows for correction of residual drift of the inertial sensor.

☞ **Please perform all inertial sensor calibrations with warmed-up sensors in a constant temperature environment for optimum tracking performance.**

Hybrid Body Calibration Select the sensor to be calibrated and press *Hybrid Body Calibration* (see figure 4.8 on page 35). During this hand-eye calibration the target has to be moved with moderate speed in any spatial direction of the inertial sensor (please refer to the animation in the HBC dialogue). Select the desired target from the drop-down menu '*Body ID*' and check the '*sensor ID*' of the inertial sensor for correspondence with the selected optical target. Then press *Calibrate*. The appearing dialogue will show the status of the calibration via a progress bar.

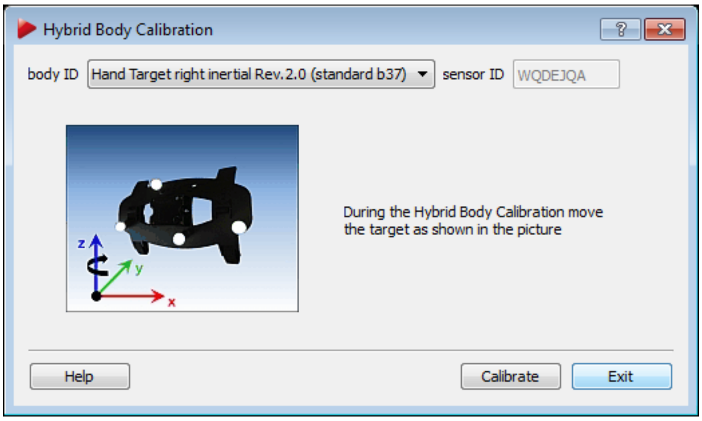


Figure 4.8: Hybrid Body Calibration

As a result you will receive a value for the residual of the calibration. This residual is a representation of how well the rotational data from the inertial sensor matches the optical tracking data. Thus it is a measure of the accuracy of the HBC. Values ranging from 1° to 2° are ideal. Anything less than 3° is still acceptable. Please refer to figure 4.9 on 35
In case the values are acceptable you can assign the calibration and return to the *Body Administration*. Now, the sensor should show '*full*' in the column *Calibration*. Repeat this procedure for each sensor.

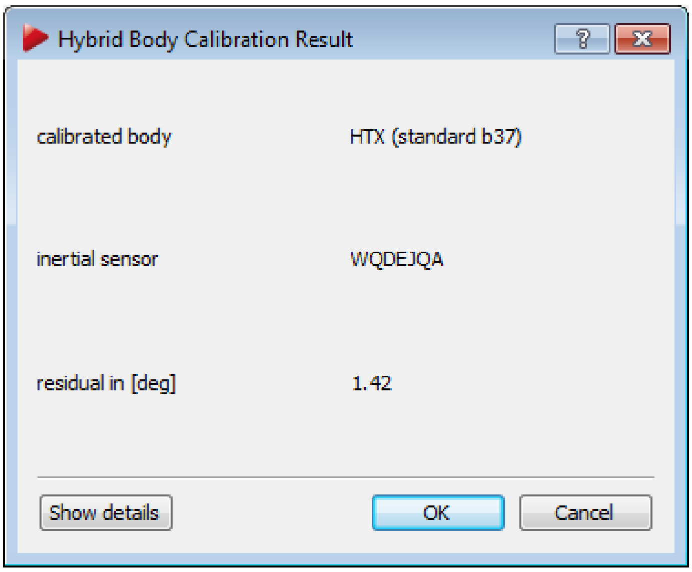


Figure 4.9: Hybrid Body Calibration Result

***ART* delivers pre-calibrated targets, i.e. both the optical target geometry as well as the HBC result are stored directly on the sensor. Unless the hybrid target is disassembled or becomes damaged, it is sufficient to identify and add all sensors using the menu *Settings* → *Inertial Sensors* → *Add Sensors*. There is no need to calibrate the targets manually.**

Please perform all inertial sensor calibrations with warmed-up sensors in a constant temperature environment for optimum tracking performance indicated by a green temperature bar.

Inertial Sensor Calibration After successful calibration of all hybrid bodies, a drift correction for all inertial sensors should be measured and applied. To this end, please select *Calibration* → *Inertial Sensor Calibration* (see figure 4.10 on page 36). Put all sensors in the tracking volume (pre-condition: a successful Hybrid Body Calibration for each inertial sensor) or put them anywhere on a level surface. Do not move or touch them during the following calibration. Tick the checkboxes in the column *Calibrate* of all sensors to be calibrated and press *Calibrate*. Values around 0.1°are ideal and still acceptable up to 0.2 °, values indicate possible movement during the calibration. When the calibration is done, you can apply the drift correction either to single sensors by ticking the appropriate checkboxes in the column *Accept* or by ticking '*accept all*' for all sensors in range. Press *Apply* and exit the dialogue.

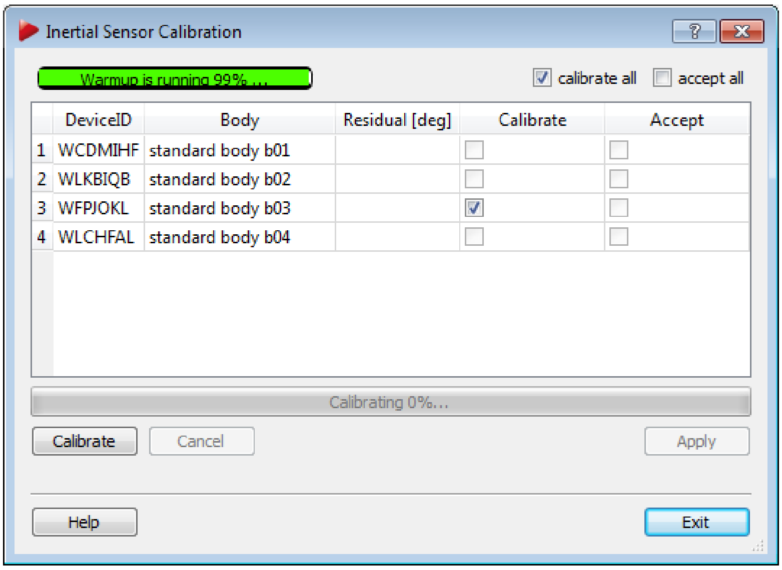


Figure 4.10: Inertial Sensor Calibration

After the Inertial Sensor Calibration has been performed and applied its result is stored directly on the sensor for future use.

4.3 *DTrack2* frontend software

The software ***DTrack2*** is intended to run on a remote PC (Windows or Linux). The ***SMARTTRACK*** can be controlled remotely via Ethernet. The software ***DTrack2*** itself is delivered via CD-ROM.

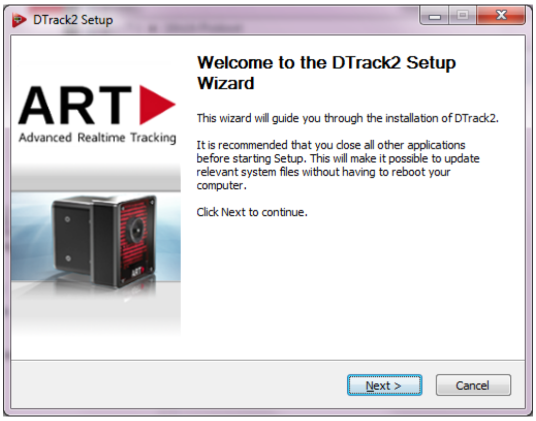
☞ **_DTrack2_ supports the _SMARTTRACK_ starting with version v2.7.0. Please don't use it with older versions of the _DTrack2_ frontend software.**

4.3.1 Getting started

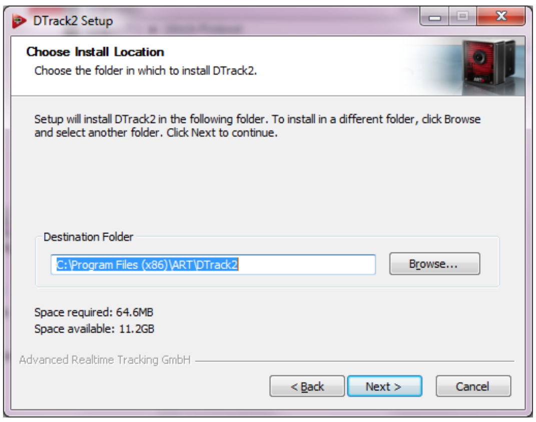
Please refer to chapter A.3 on page 119 for more information on supported operating systems.

4.3.1.1 Installation guide (Windows)

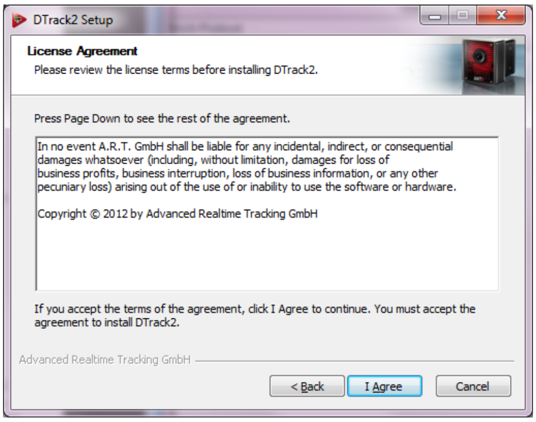
Run the installation executable "*DTrack2_v2.x.x_win32_install.exe*" and the installation wizard of ***DTrack2*** starts.



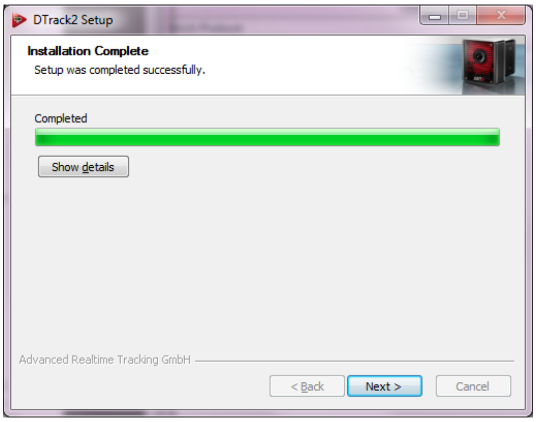
Click *Next* to continue and to start the installation process for ***ART DTrack2*** software. Administrator rights are not necessary.



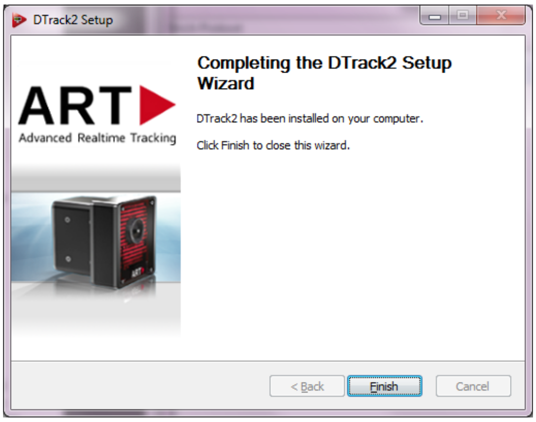
Now, please choose the destination folder in which you want to install ***DTrack2*** .



Please read the license terms carefully and press *I Agree* if you agree indeed. A new window shows the installation progress.



The installation of the ***DTrack2*** software is complete now. ***DTrack2*** has been installed on your computer. Click *Next*.



Press *Finish* to complete the ***DTrack2*** setup wizard. Now, you can use ***DTrack2*** .

4.3.1.2 Installation guide (Linux)

The software (32-bit and 64-bit package available) is packed in an archive (*DTrack2_v2.x.x_linux32.t* You do not need to have administrator rights to extract all files to a user-defined folder. In a shell, change to the user-defined folder and type in the command `tar xvf DTrack2_v2.x.x_linux3` in order to extract the files. For ease of use, you may create a shortcut on the desktop.

DTrack2 can be started with the command `./DTrack2`.

4.3.1.3 Software update

Please contact ***ART*** in order to receive the latest ***DTrack2*** software. For the installation of the update, please proceed as mentioned before in chapters 4.3.1.1 and 4.3.1.2.

4.3.1.4 Start *DTrack2* frontend software

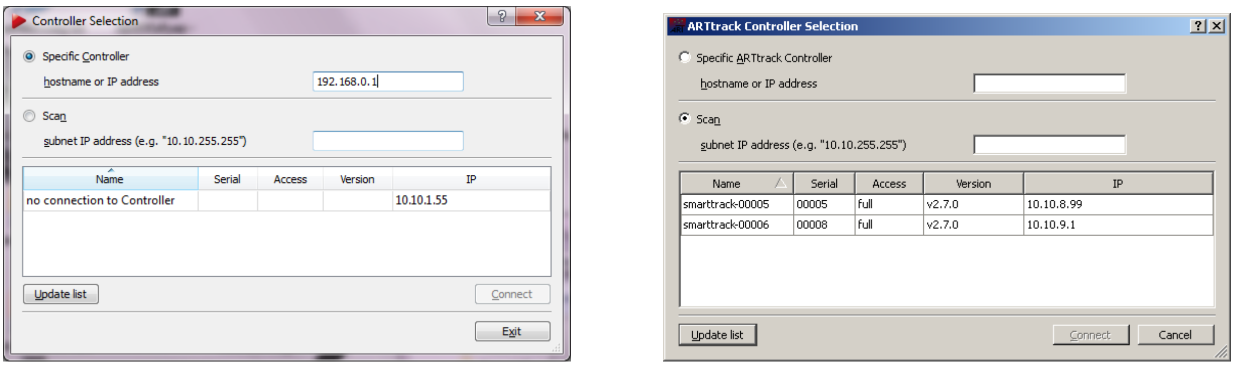
When you start ***DTrack2*** on the remote PC you will see the following start window (see figure 4.11).

Figure 4.11: Welcome screen of ***DTrack2***

4.3.1.5 Connecting to the *SMARTTRACK*

The first time you start ***DTrack2*** , no default ***SMARTTRACK*** will be found and another window will be opened automatically (see figure 4.12). The radio button at position *Specific ARTtrack Controller* will be ticked.

If you know the name (typically like "smarttrack-00001") or IP address of your ***SMARTTRACK*** you may enter it in line *hostname or IP address* and press *Connect*.



(a) specific ***SMARTTRACK*** (b) scan the network

Figure 4.12: Controller Selection

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Otherwise, you can select *Scan*, if you don't know the hostname or the IP address of your ***SMARTTRACK*** . You will see a list of the available ***SMARTTRACKs*** in your network.

In column *Name* every ***SMARTTRACK*** in your network will be listed. If no ***SMARTTRACK*** or not the desired ***SMARTTRACK*** is listed there please press *Update list*. Now, the list should contain your desired ***SMARTTRACK*** .

You can identify the correct ***SMARTTRACK*** by comparing the serial number on the label on the back of the ***SMARTTRACK*** with the serial number listed in this window (column *Serial*). ***SMARTTRACKs*** set in grey are used by other PCs in the network ($\rightarrow$ IP address listed at the bottom of the welcome screen). It is only possible to connect to ***SMARTTRACKs*** set in black. Select the entry which fits to your desired ***SMARTTRACK*** and press *Connect*.

The next time you start ***DTrack2*** your ***SMARTTRACK*** is still known by the software and ***DTrack2*** automatically searches for it. The welcome screen shows the name of your ***SMARTTRACK*** . If this is the one you want to connect to, just press *Connect*.

The graphical user interface The graphical user interface of ***DTrack2*** offers different views which can be switched on and off by the user:

1.	Monitor 2DOF	Graphical display of markers seen/tracked by the cameras. Colour code signifies the circularity or the size of the markers, respectively.
2.	Event Display	Displays ***DTrack2*** events (e.g. "no valid room calibration")
3.	Data Display	Displays measurement results (6DOF and/or 3DOF)
4.	Flystick	Shows the measurement results (6DOF and/or 3DOF) and the operation of the buttons and the joystick
5.	Measurement Tool	Shows the measurement results of the Measurement Tool and, if assigned, the reference body

By default the first three are shown (see figure 4.13).

In the status bar, a button for starting and stopping of the measurement is integrated. Additionally, you may retrieve information regarding the cameras connected, the synchronization frequency, the number of bodies tracked and the number of single markers seen.

The synchronization frequency field is changing its colour to yellow, orange and red in case the effective frequency is decreasing (see figure 4.14):

- grey: max. 5 frames per minute lost (i.e. 3600 frames per minute are transmitted)
- yellow: 5 - 10 frames per minute lost
- orange: 10 - 15 frames per minute lost
- red: > 15 frames per minute lost

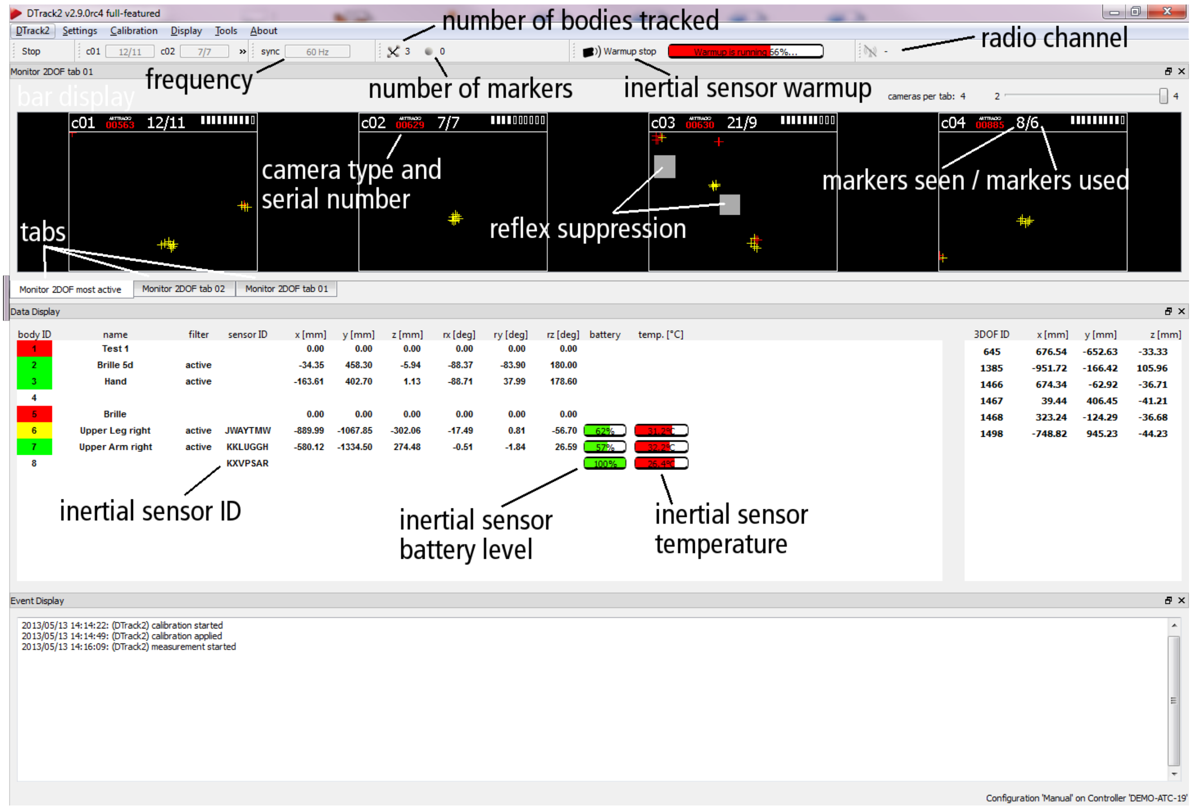
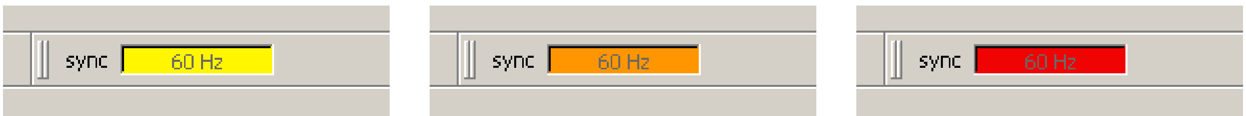


Figure 4.13: Graphical user interface of ***DTrack2***



(a) yellow: 5 - 10 frames per minute lost

(b) orange: 10 - 15 frames per minute lost

(c) red: > 15 frames per minute lost

Figure 4.14: Visualization of the synchronization frequency decrease

4.3.1.6 Adjustment of the *SMARTTRACK*

So far, the ***SMARTTRACK*** has been mounted and connected to the remote PC either directly or via a network.

Now, adjust the ***SMARTTRACK*** in a way that allows to cover the desired measurement volume as good as possible. To check that, ***DTrack2*** provides the *Monitor 2DOF display* that essentially is a graphical display of the field of view of the ***SMARTTRACK*** and of the markers that are seen by it (presented two-dimensional).

As the ***SMARTTRACK*** is pre-calibrated there's basically not much more to do - you can start tracking right away. If you need to arrange the coordinate systems of the tracking system and the application software you'll have two possibilities:

1. within ***DTrack2*** go to *Calibration* → *Room adjustment* (refer to 4.3.6.4 on page 74),

or

2. adjust the values within the application software.

Monitor 2DOF display The Monitor 2DOF view shows two black windows for the integrated IR cameras (equivalent to the field of view) with a schematic display of positions and sizes of all recognized markers. A simple colour code signifies the size and the circularity of the markers (green = very good quality, yellow = good quality, red = bad quality).

As a rule of thumb, for measurement applications with high accuracy requirements the markers should be displayed in green; for VR applications yellow markers are always ok. The Monitor 2DOF display is particularly useful for the final adjustment (especially orientation adjustments) of the ***SMARTTRACK*** .

Additionally, the intensity of the brightest pixel in the field of view is shown using a bar display (refer to figure 4.13).

A click with the right mouse button into one of the windows opens a menu (see figure 4.15) with settings for the respective camera.

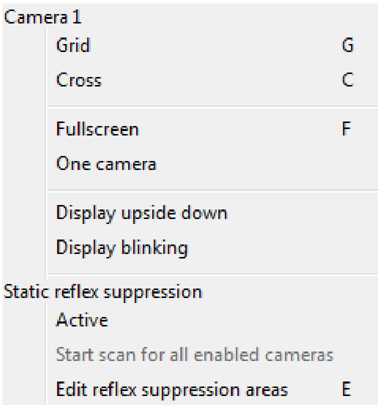


Figure 4.15: Monitor 2DOF view menu (e.g. camera 1)

By clicking and holding the left mouse button on one of the camera displays, its position can be moved within Monitor 2DOF view.

A more detailed description of the features of the *Monitor 2DOF view* can be found in chapter 4.3.6.5 on page 78.

License overview Up to ***DTrack2*** v2.10 only one specific type of license was available for the ***SMARTTRACK*** . Starting with ***DTrack2*** version v2.10 a new license model has been established.
You may use 4, 10, 30 or up to 50 targets depending on the license purchased. Please refer to table 4.1 for a detailed overview.

Feature denotation	***Values***	***Possible license status***
Measurement Tool		supported / not supported
DTrack2 max. *B* bodies DTrack2 all bodies	*B* = 4, 10, 30	supported supported

Table 4.1: Licenses overview

The maximum number of bodies that may be used in the *SMARTTRACK* includes the calibrated interaction devices (Flystick, Measurement Tool)!

4.3.1.7 Localizing and removing of disturbing reflections

Reflections may be detected when starting the Monitor 2DOF view in ***DTrack2*** . They are illustrated the same way as single markers, i.e. with small coloured crosses. Sometimes you can also tell from the display bar which is indicating (high) radiation intensities.

Sources of disturbing reflections may be diverse. Typically, however, the reflections are produced from one (or more) of the following:

- strong infrared radiation sources (e.g. sunlight or sunrays, halogen lamps, ...),
- active or passive targets, that are still in tracking range of the cameras,
- any kind of reflecting material on clothes or shoes,
- blank metal surfaces, especially curved surfaces and surfaces with 90° angles,
- some types of packaging foils.

For removing disturbing reflections there are different approaches:

- reduce the flash intensity of the ***SMARTTRACK*** to "0":
  remaining reflections are originating from infrared radiation sources (e.g. sunlight, halogen lamps, ...). Try to localize and remove them.
- try to localize the reflection by moving a target towards the origin of the reflection (use the Monitor 2DOF display) and proceed as mentioned above.

If reflections cannot be eliminated you may use the reflex suppression tools of ***DTrack2*** (please refer to 4.3.6.3 on page 62):

1. static reflex scan:
   reflexes will be suppressed automatically by ***DTrack2*** upon detection
2. suppress static reflexes manually :
   areas to be suppressed may be defined manually

4.3.2 Room calibration

The *SMARTTRACK* is pre-calibrated and therefore it is unnecessary to perform a room calibration.
Despite our best efforts for optimal shipping conditions in rare cases it may occur that harsh environmental conditions during shipment lead to a degradation of the *SMARTTRACK* pre-calibration (e.g. temperatures below -30°C or severe vibrations). Please perform a re-calibration to ensure optimal tracking.

By default, the origin of the calibration system lies centered between the two status LEDs in the front. The orientation is as shown in figure 4.16.

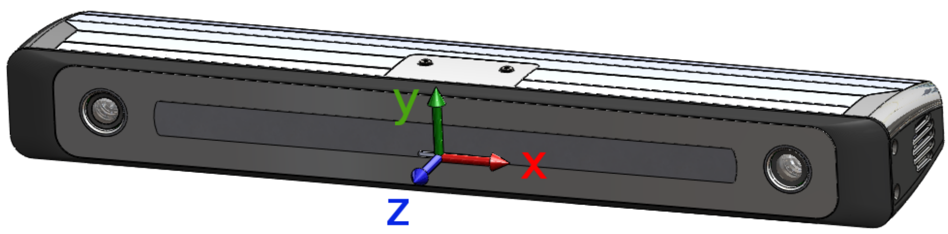


Figure 4.16: Origin of the room coordinate system (default)

If the default orientation and position of the coordinate system (i.e. '*Middle of cameras*', see figure 4.16) is not adequate for your application, it will still be possible to perform a new room calibration with the ***SMARTTRACK*** . In this way you define how the coordinate system of the room is created relative to the calibration angle (refer to table 4.2).

In principle, it is recommended to always perform a room calibration after a certain operating time of the ***SMARTTRACK*** , especially if the ***SMARTTRACK*** was subject to extreme vibrations or changing environmental conditions (e.g. high or low temperatures).

During the room calibration, the system determines the three-dimensional coordinate system.

For room calibration, the calibration angle of the "room calibration set" is inserted anywhere into the field of view of the ***SMARTTRACK*** . Both IR cameras have to see all markers of the calibration angle. Therefore, ***DTrack2*** 's Monitor 2DOF display is started in the background when selecting *Calibration* → *Room*. Here you can verify that all markers of the angle are seen by the ***SMARTTRACK*** .
cameras.

The longer arm of the angle defines the X axis (refer to figure 4.18); the shorter one the Y axis. The center of marker #1 defines the origin of the room coordinate system (at a height of 15.5mm).

The pre-calibrated stick carrying two markers is called the "wand". Its function is to create a virtual "point cloud" in the measurement volume that is used for calculating the room calibration with high accuracy. Furthermore, the wand is scaling the system. That's why damages of the wand (loose markers, bent poles, etc.) lead to miscalculations of the measurement volume.
The room calibration dialogue allows the input of the marker distances of the calibration angle, the input of the wand length and marker quality, the input of the offset and the input of the calibration type, as well as the calibration duration.

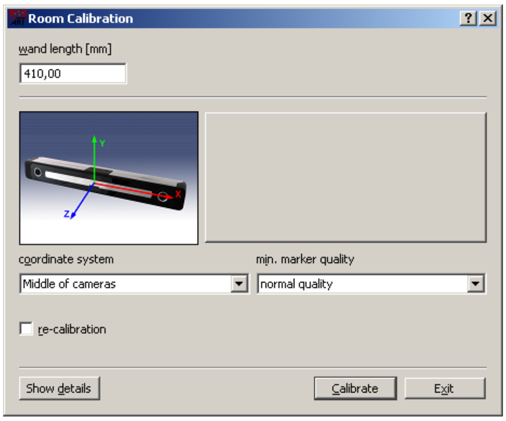


Figure 4.17: Room calibration settings (e.g. RCS 410)

Marker distances of the calibration angle can also be set manually using the setting *expert*. The numbering of the markers is as seen in figure 4.18.

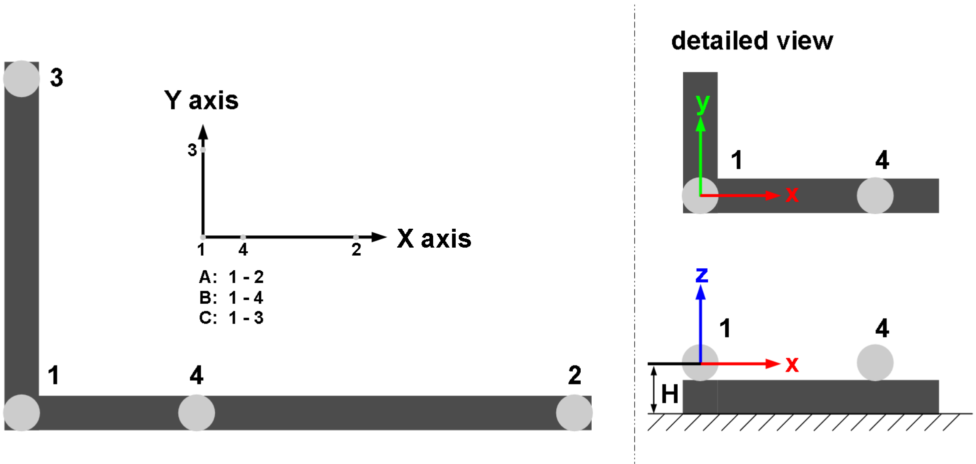


Figure 4.18: Marker distances (including numbering) on the angle and definition of room coordinate system

The wand length has to be set manually in this dialogue - it is written on the label of the wand.

Incorrect input data for this dialogue will lead to a poor room calibration, to wrong system scaling, or to an abortion of the whole room calibration process.

With the select list at the bottom you may define how the coordinate system of the room is created relative to the calibration angle (refer to table 4.2).

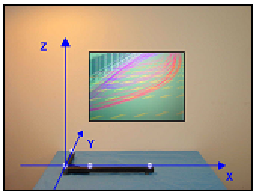
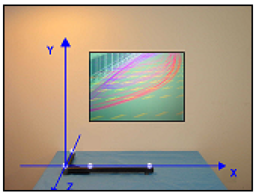
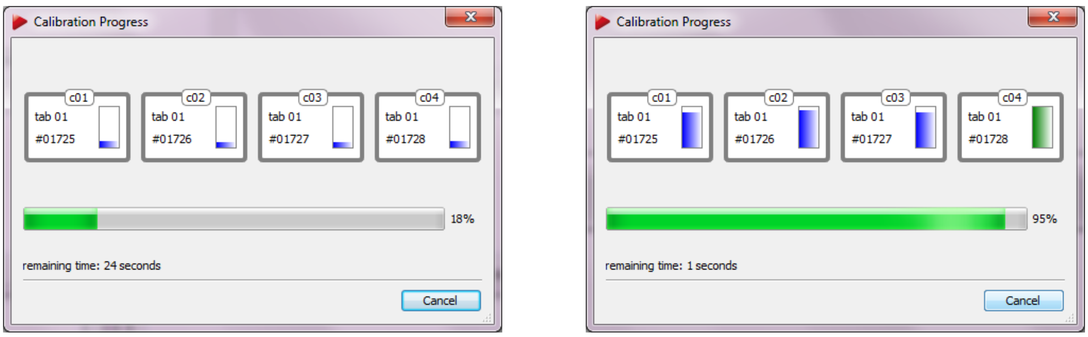
Standard	Powerwall
	
In the *Standard* setting the angle defines the X/Y plane (X at the long, Y at the short beam) and Z upward.	With the *Powerwall* setting the X/Y plane is in the screen and the Z axis pointing out of the screen. This is the standard screen coordinate system of many VR systems (e.g. OpenGL, TrackD, etc.).

Table 4.2: Options for coordinate system definition

After pressing *Calibrate*, the room calibration is started with five seconds delay.

A window showing the progress of the room calibration appears (see figure 4.19(a)). The progress is shown for each camera which is especially helpful for big systems. As soon as the display for a camera changes its colour to green (see 4.19(b)) enough data for calculation of the camera position has been collected for this camera.



(a) (b)

Figure 4.19: Room calibration progress

If necessary, you may adjust the '*duration*' of the room calibration (→ *Show details*) in a range of 10s - 100s. Resetting the value to default is achieved by pressing the *Set to* *default* button (default = 30s).

☞ **Changing the duration of the room calibration, especially towards shorter durations, may lead to bad room calibration results! Please make sure that you are always able to cover two thirds of the tracking volume within the set time.**

Move the wand gently within the measurement volume, in order to generate a virtual point cloud. This point cloud should fill at least about two thirds of the measurement volume. It is used for calculation of the ***SMARTTRACK*** 's positions, so moving the wand in only a very small volume will result in reduced accuracy of calibration. Here, a compromise has to be found between (1) too wide movements that often cause the failing of room calibration, and (2) sparse movements that lead to a valid, but inaccurate room calibration. Avoid rapid and hectic movement (see figure 4.20).During calibration, the two markers of the wand should be visible to both integrated cameras.

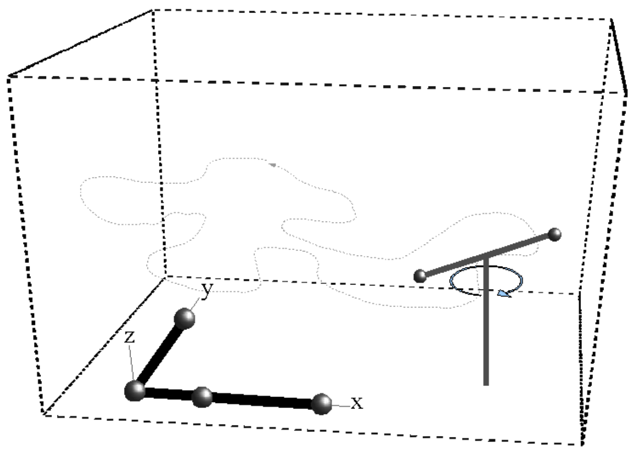


Figure 4.20: Room calibration process

After a successful room calibration, the ***DTrack2*** info window with the calibration results is displayed. This window shows the mean residuals for the single cameras (here: '*Residual*' = mean residual of rays during marker detection), as well as the mean deviation ('*wand residual*') and the maximum deviation ('*wand range*') of wand length during the calibration process. These values depend on the system geometry and can give information about the quality of calibration only to an experienced user. The value '*Used Frames*' represents the percentage of valid (i.e., used for room calibration) data for each camera. It should be as high as possible for all cameras. Values under 50% indicate poor room calibration quality. The number of valid frames should be greater than 70% for each camera. The room calibration is confirmed (i.e., the data are stored) by pressing the button *OK*.

Room re-calibration The ***SMARTTRACK*** 's pre-calibration may degrade after a certain operation time; if e.g. movement due to vibrations cannot be excluded or changes in

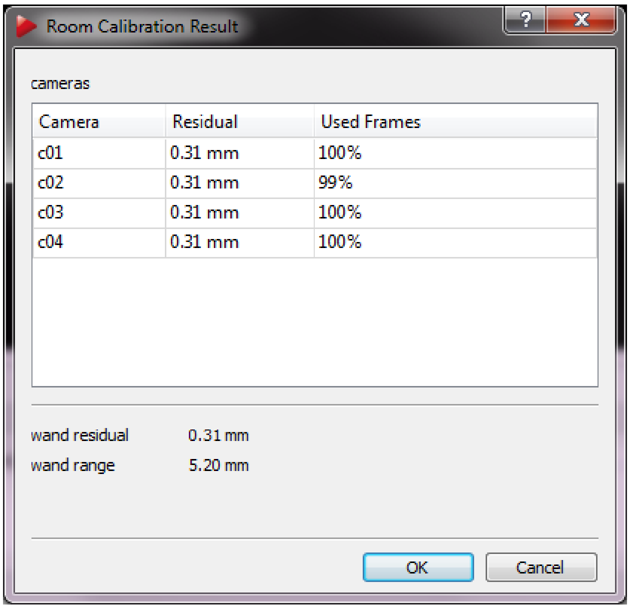


Figure 4.21: Room calibration result

the ambient temperature occur. In this case it is necessary to perform room calibrations periodically. ***DTrack2*** provides a simplified room calibration to revise an existing room calibration without need of the calibration angle, called room *re-calibration*.

Check the corresponding field in the room calibration dialogue (see figure 4.22) to activate re-calibration. Most settings have to be the same as during the previous standard room calibration, therefore most values of the dialogue cannot be changed - settings regarding the wand may be modified.

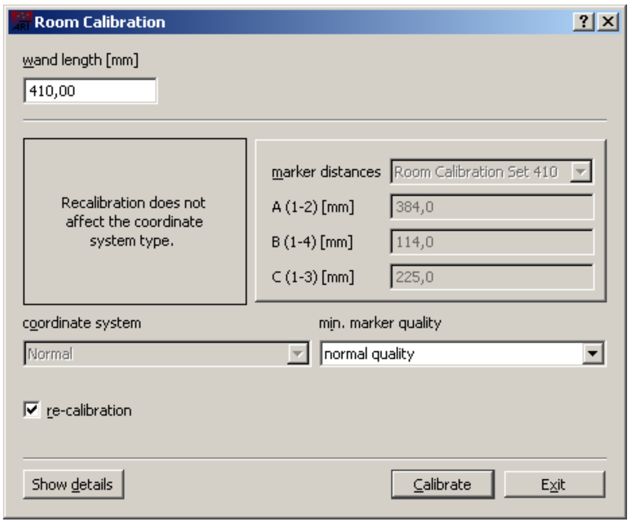


Figure 4.22: Room re-calibration dialogue

To perform a re-calibration, no angle tool has to be present in the measurement volume; only the wand has to be moved within the measurement volume in the same way as for a

standard room calibration.
The main advantage of a room re-calibration is that ***DTrack2*** preserves the origin of your coordinate system and therefore, the orientation of the coordinate system as well.

4.3.3 Body calibration

The targets for the *SMARTTRACK* are pre-calibrated and therefore it is usually unnecessary to perform a body calibration.

However, it will still be possible to perform a body calibration with the ***SMARTTRACK*** in case you want to calibrate self-built targets or if you experience a degradation of tracking performance.

The process of teaching a target's geometry to the tracking system is called body calibration. For a body calibration, the target (= rigid body) to be calibrated has to be in the field of view of both integrated cameras of the ***SMARTTRACK*** . The number of bodies to be tracked has to be configured in *Settings* → *Body Administration*.
After pressing *Calibrate*, the body calibration is started within five seconds delay. The body can be moved during body calibration, always considering that the cameras should see each marker of the body at the best.

If the body is not moved during the body calibration it should be considered that each marker of the target has to be seen by the cameras. If two markers, seen from one camera's point of view, are merging to one reflex, body calibration may be affected. These "merging marker situations" should be avoided during body calibration, i.e. the target should be oriented in a way that reduces merging markers to a minimum. The target orientation can be checked before starting the body calibration, using ***DTrack2*** 's Monitor 2DOF display, which is opened automatically in the background after selecting *Calibration* → *Body*.
The following figure 4.23 shows a rigid body with five markers that are all correctly seen by one of ***SMARTTRACK*** 's cameras

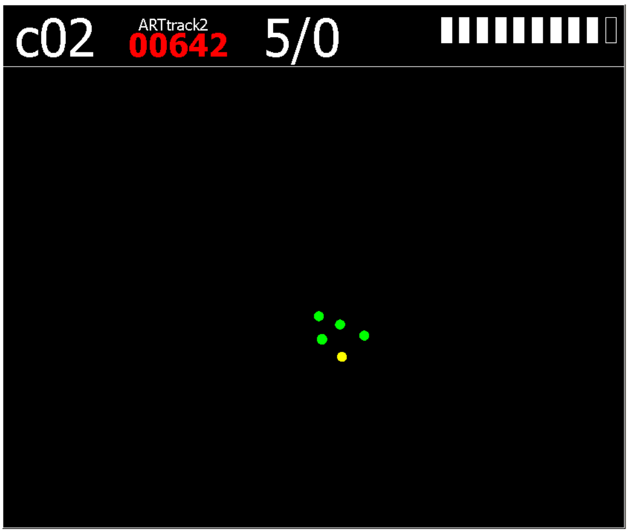
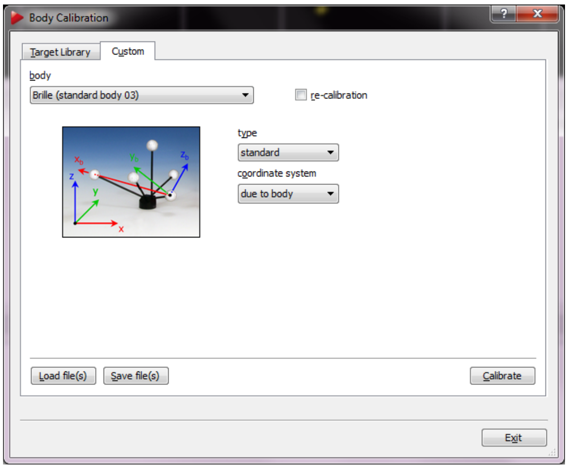
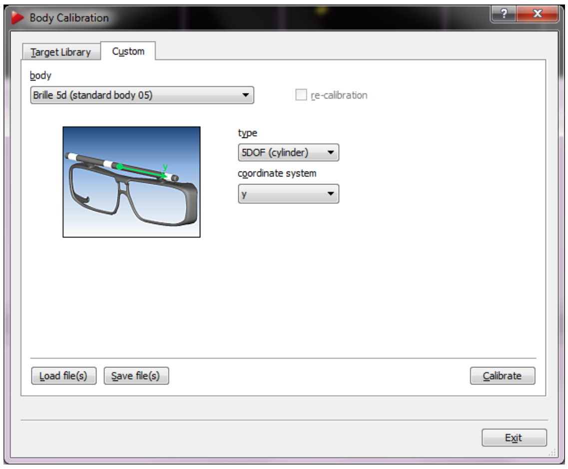


Figure 4.23: Recognized target in ***DTrack2*** *Monitor 2DOF display*

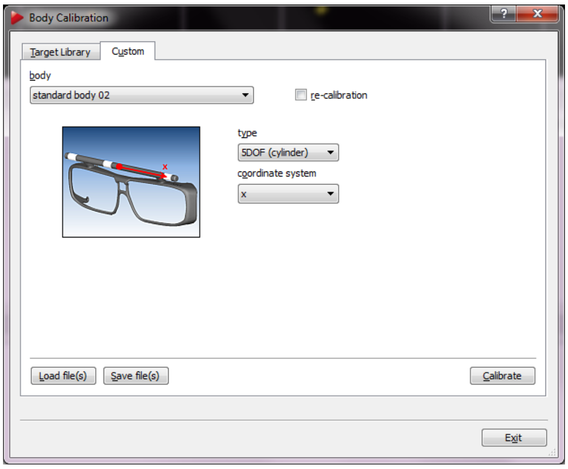
Furthermore, the absence of any additional markers in the measurement volume has to be ensured for body calibration. If additional markers that are not part of the target to be calibrated are in the field of view of the IR cameras during body calibration, these markers will be assigned to the target. That means, the target is not correctly calibrated and, therefore, tracking problems may occur.



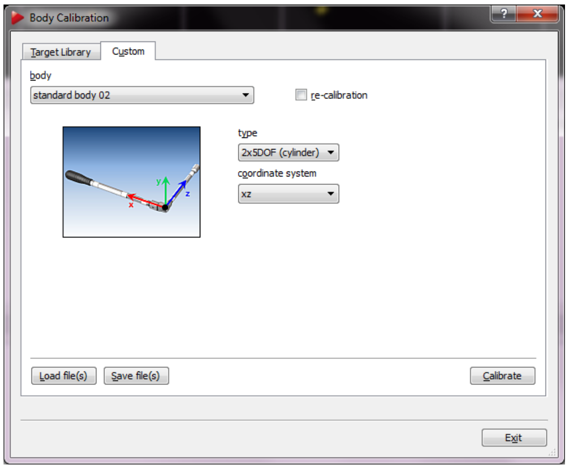
(a) Target type "standard"



(b) Target type "5DOF"



(c) Target type "5DOF (cylinder)"



(d) Target type "2x 5DOF (cylinder)"

Figure 4.24: Body calibration dialogue

First, the target that shall be calibrated has to be selected in the select list *Body*. By default the '*type*' is set to standard which allows for calibrating a 6DOF target with spherical, flat or active markers. When you are using a target made of ring markers you would select the '*type*' according to the geometry of the target:

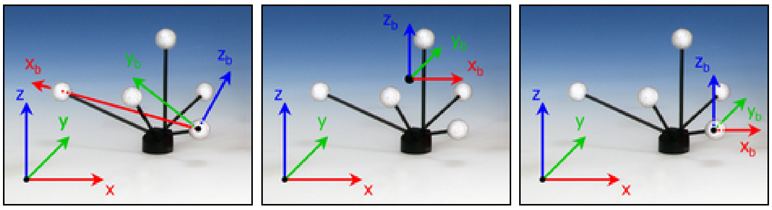
- '*5DOF*' .. a target made of spherical markers which are aligned along one main axis. The rotation around that axis cannot be detected by the system - you loose one dimension of freedom. Therefore, we call it 5DOF target.
- '*5DOF (cylinder)*' .. a target made of ring markers which are aligned along one main axis.

- *'2x 5DOF (cylinder)'* .. an L-shaped target made of ring markers which delivers 6DOF data.

Selecting the coordinate system for 6DOF targets The type of body calibration can be set as '*due to body*', '*due to room*' or '*due to room (zero in marker)*'. The difference between these calibration types is to be found in the orientation of the body coordinate system relative to the body. During body calibration, ***DTrack2*** defines a local coordinate system (body coordinate system) for each target.

Body calibration setting due to body The body coordinate system is fixed by the markers of the rigid body according to a set of rules:

1. Search the biggest distance between two markers of the rigid body. These two markers (# 1 and # 2) will define the X axis.
2. Search for a third marker (# 3) that has the smallest distance to one of the two markers # 1 and # 2. The marker that has smallest distance to marker # 3 becomes marker # 1. It will define the coordinate origin. The other marker will be # 2. The positive X axis is directed from marker # 1 to marker # 2.
3. Marker # 3 defines the X/Y plane, together with markers # 1 and # 2. Marker # 3 has a positive Y coordinate.
4. The Z axis is already defined by these rules, resulting in a right-handed coordinate system.



(a) Body calibration "due to body" (b) Body calibration "due to room" (c) Body calibration "due to room (zero in marker)"

Figure 4.25: Defining the target coordinate system

Body calibration setting due to room The origin of the body coordinate system is set to the center (center of gravity) of all markers building the rigid body. The axes of the body coordinate system are parallel to the axes of the room coordinate system in the beginning of the body calibration. I.e., the result of a body calibration will depend on the angular position of the target during calibration. A 6DOF measurement, following calibration without having moved the body, will give the angular coordinates 0°/ 0°/ 0°.
If the target was moved during calibration, the angular position of the target at the beginning of the calibration will be taken.

Body calibration setting due to room (zero in marker) A combination of the first two methods. The direction of the axes of the body coordinate system will be set parallel to the room coordinate system in the moment of body calibration - like done with setting due to room. The origin of the body coordinate system is given by one marker of the body, according to the rules given for setting due to body.

Selecting the coordinate system for 5DOF targets Analogue to the settings for the standard targets it is also necessary to define the body's coordinate system in case of 5DOF targets. The approach is a bit different but also straight forward.

Coordinate system setting for type '5DOF' and '5DOF (cylinder)' In the body coordinate system all markers of the target are on the selected axis. The origin is in the middle between the two markers with the largest distance to each other. The orientation is defined by the marker with the smallest distance to the origin. Its position has a negative sign. The other two directions are undetermined due to the one degree of freedom.

Coordinate system setting for type '2x 5DOF (cylinder)' The body is expected to consist of two connected 5DOF targets with a roughly perpendicular and constant angle in between. These are placed on the two axes. The origin is placed at the position where the two 5DOF targets intersect. The first axis is assigned to the 5DOF target which includes the marker with the largest distance to the origin. The other 5DOF target is placed in the plane created by the two axes.
A click-type torque wrench is one the most prominent members of this class of bodies. Due to the engineering backlash and other high mechanical tolerances in these devices often times the resulting body calibrations are error-prone.

☞ **Please double-check whether all markers of the rigid body have been recognized.**

Then, confirm the result with *OK*. If this is done, the geometry data of the calibrated target will be stored in the Backend.

ℹ **After a new room calibration or room re-calibration it is not necessary to perform a new body calibration. Only if the body itself changes you have to calibrate the body again.**

☞ **The previous body calibration will be lost if you carry out a new body calibration. If you want to save the previous body calibration please use the '*Save file(s)*' option in the *Body calibration* dialogue.**

Calibration with a calibration file The calibration files for our targets are available on request. Each file is specific for just one type of target. It contains the dimensions of the target and the distances between the markers. The file is created at ***ART*** on site performing a body calibration in a defined environment or measurement volume respectively.

Press *Load file(s)* (see figure 4.24) and choose the calibration file(s) for your targets. The format of the file name has to be according to "*standard b01.txt*" - the identifier "*b01*" refers to the ID of the target.

The previous body calibrations will be lost if you load new calibration files.

DTrack2 automatically assigns the calibration file to the respective target by using the identifier in the file name.

Invalid or corrupt files are not loaded by *DTrack2* .

This is indicated by an error message in the confirmation dialogue (see figure 4.27). Press '*Load*' to confirm the import of the body calibration files.

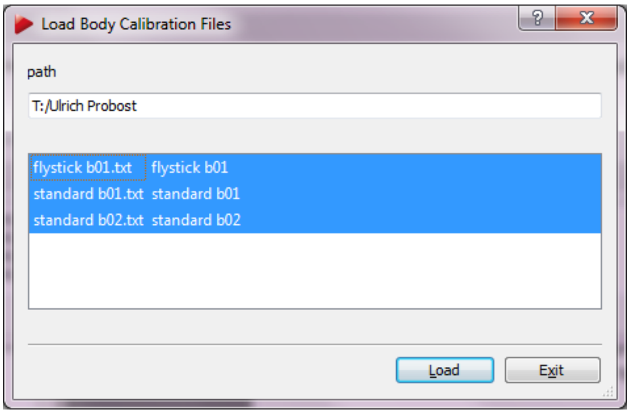


Figure 4.26: Import of calibration files

Press *Save file(s)* to store the body calibration files of the currently used bodies. The files can be saved at a desired location on the remote PC. This function is intended as a simple means for the user to easily create backups of calibrated bodies.

Body re-calibration ***DTrack2*** provides a possibility to re-calibrate a rigid body. When performing a body re-calibration the origin of the initial coordinate system and the orientation of the coordinate system, as well, are preserved.
You might need to re-calibrate bodies in case their geometry is changed due to mechanical impact.

4.3.3.1 Target Library

With the introduction of ***DTrack2*** v2.8.1 it is possibe to make use of an integrated library that contains calibration data for most ***ART*** standard targets (e.g. glasses targets, etc.). When you go to *Calibration* → *Body* choose '*Target Library*' (refer to figure 4.27). The filter is set to '*Found Targets*' by default whereas the other options may be used in case only targets of this type are to be calibrated.

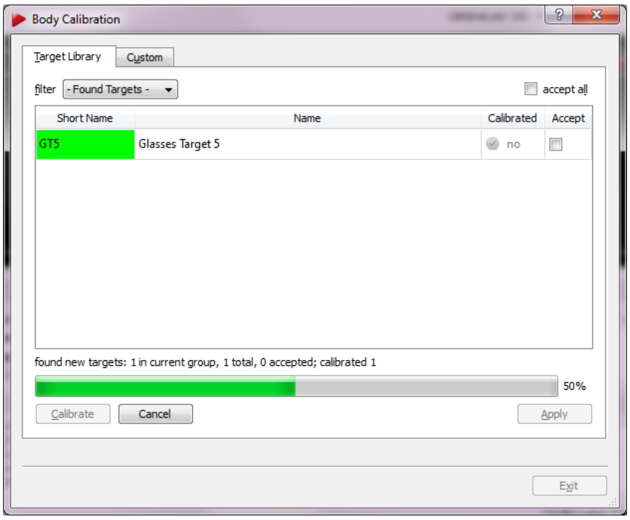


Figure 4.27: Calibrate bodies with the target library

With the '*Found Targets*' filter all targets presented, i.e. shown to the system, will be found. In the unlikely case that a target is not found by the system it needs to be calibrated using the standard body calibration. The calibrations for all found targets only need to be accepted either by ticking the checkbox '*accept all*' or one at a time. Finalize the assignment of the targets by pressing '*Apply*'.

***DTrack2* compares the geometry of the physical target with the calibration data of the target library. In some cases a re-calibration might be necessary, e.g. when a clip-on target is applied to the glasses bending is possible.**

If you haven't increased the number of targets before the system will ask you if this number should be adjusted automatically. Press '*OK*' if you want the system to do so.
First, make sure that all targets are in the calibrated volume. Then, start the calibration (*Calibration* → *Body* → '*Target Library*' → '*Calibrate*') and allow the targets to move around. While this movement the targets must be visible for the ***SMARTTRACK*** .

Finally, one after the other target should be recognized and appear in the display. Tick the checkbox '*accept all*' and start the measurement in order for your application to receive tracking data.
In case you need to adjust the order of the targets please go to *Settings* → *Body Administration (F8)*.

4.3.4 Body adjustment

The *Body adjustment* function is a tool to manipulate calibration data of rigid bodies, i.e. the body coordinate system may be changed relative to the markers of the body. This tool adds the functionality of the formerly separate tool "ABCMan" directly into ***DTrack2*** .

Body adjustment is not available for 5DOF targets.

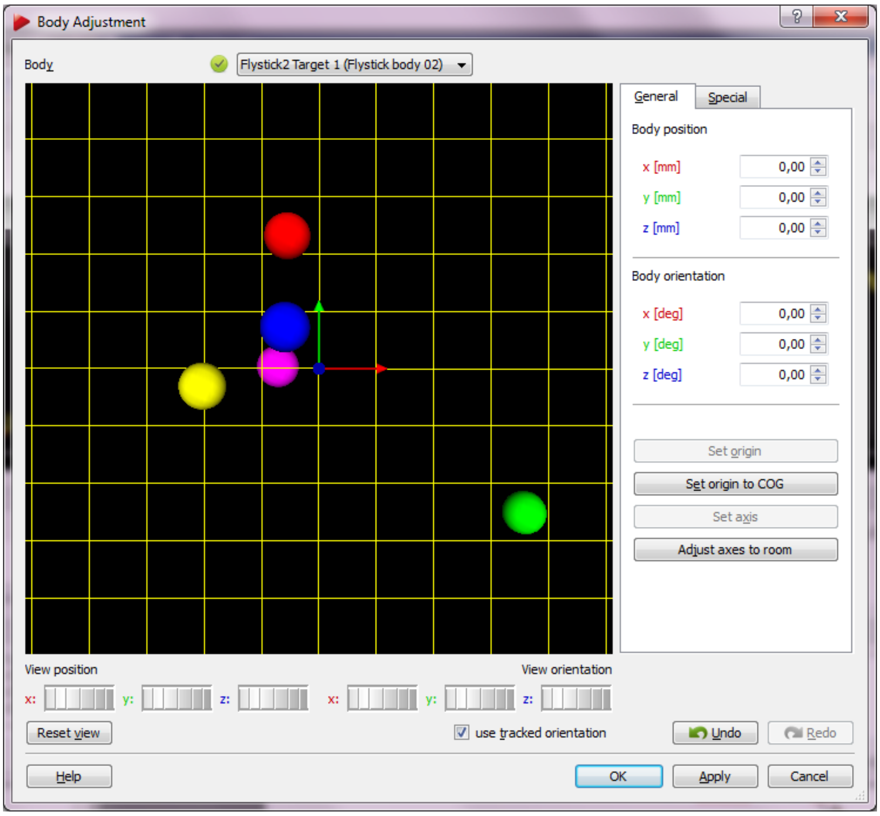


Figure 4.28: Body Adjustment

The main features of *Body adjustment* are:

- adjust body coordinate system of each target within the ***DTrack2*** frontend,
- online mode (i.e. the representation of the target in the graphical view may be moved by moving the "real" target) available,
- adjust axes of body coordinate system to the axes of the room coordinate system without changing the origin,
- use predefined body coordinate systems,
- move the origin of the body coordinate system,
- set the origin of the body coordinate system in selected marker.

⇒ There is no need for a separate tool anymore and, more important, the body coordinate system may be defined very comfortable as desired.

For detailed information please refer to chapter 4.3.6.4 on page 75.

4.3.5 Filtering options in *DTrack2*

With the ***DTrack2*** release v2.9.0 we introduce highly improved filtering options which allow for ideal settings according to the requirement for the tracking performance. For example in applications where reference targets are used to get the position of a seating buck it is now possible to apply a strong filter for this specific target which results in absolutely static tracking data.

Using three main settings for defining a filter, i.e. strength, prediction and mode, it is possible to customize the tracking behaviour in general or for single targets according to the requirements. Following, a description of these settings.

Setting	Description	Usage
Strength	Sets the strength of the filter. Low values mean less filtering with faster reaction but higher jitter. High values mean stronger filtering with smoother output but slower reaction.	a strong filter may be ideal for tracking seating bucks
Prediction	Predicts output for the specified time in the future to compensate tracking and rendering latency. Note that too high positive values can increase jitter and reduce precision. Negative values can be used for smoothing the output at the cost of higher latency.	a "negative" prediction may be ideal for recording data as latency doesn't matter so much
Mode	Specifies the elementary behavior of the filter. Several options are available.	–
'*Adaptive fast*'	Automatically adapts to the observed motion.	Moving targets that change between fast and slow motions, such as Flysticks.
'*Adaptive slow*'	Automatically adapts to the observed motion, with stronger filtering of fast motions.	Moving targets with slow and medium motions
'*Fast*'	Optimized for fast motions without special filtering of slower motions.	Targets where quick reaction is important, such as HMDs.
'*Slow*'	Optimized for medium motions without special filtering of slow motions.	Targets where quick reaction is important, but motions are slow.
'*Static*'	Optimized for targets that are known not to move at all.	Reference targets attached to non-moving objects
'*Reference target*'	Optimized for generally static objects, with automatic detection of occasional motions.	Reference targets attached to occasionally moving objects.

4.3.6 Menu structure

4.3.6.1 Overview

DTrack2	*Shortcut*	page 59
Licenses		License overview → Licenses can be added by entering a license key (for the Measurement Tool or for the Flystick MultiUser function)
Configurations		Create and save different configurations, lock the used configuration and save its settings
Start/Stop	M	Start/Stop measurement
Controller standby		Force the ***SMARTTRACK*** to go into standby mode
Quit	Q	Quit ***DTrack2***

Settings	*Shortcut*	page 62
Cameras	F7	Camera settings
Synccard		Synccard settings
Inertial Sensor		Settings for intertial sensors
ART Radio Info		Opens a dialogue where you can see available transceivers and devices within your setup
Tracking		General settings
Body Administration	F8	General settings for all targets and interaction devices
Output	F9	Set output channels and configure the data to be transmitted
Flystick		Configure your Flystick
Measurement Tool		Configure your Measurement Tool
Controller		Configure the controller for your local network

Calibration	*Shortcut*	page 72
Start static reflex scan for all enabled cameras		Starts the static reflex scan
Inertial Sensor Calibration		Re-calibrate the internal sensors of the inertial sensor
Room	F5	Room calibration
Room adjustment	Shift + F5	Adjust room coordinate system
Body	F6	Body calibration
Body adjustment	Shift + F6	Adjust body coordinate system
Hybrid Body		Determine the relative rotation between optical and inertial sensor
Measurement Tool		Start tip calibration process for the Measurement Tool

Display	*Shortcut*	page 78
Monitor 2DOF		Graphical display of markers recognized by the cameras (monitor 2DOF view)
Data	F10	Display measurement results (6DOF and/or 3DOF)
Flystick		Display Flystick measurement data
Measurement Tool		Display Measurement Tool data
Events		Display event messages generated by ***DTrack2***
Set to default		Reset the shown displays to default

Tools	*Shortcut*	page 80
Controller Update		Start the assistant for the controller update
Measurement Tool demo		Provides a convenient way to perform measurements, either by pressing a button or by performing a gesture with the Measurement Tool

About	*Shortcut*	page 81
DTrack2		Frontend software version
Controller		Backend software version
What's new?		Overview of the new features
What's this?	Shift + F1	Help

Table 4.4: ***DTrack2*** menu structure overview

4.3.6.2 Menu DTrack2

DTrack2	*Shortcut*
Licenses	
Configurations	
Start/Stop	M
Controller standby	
Quit	Q

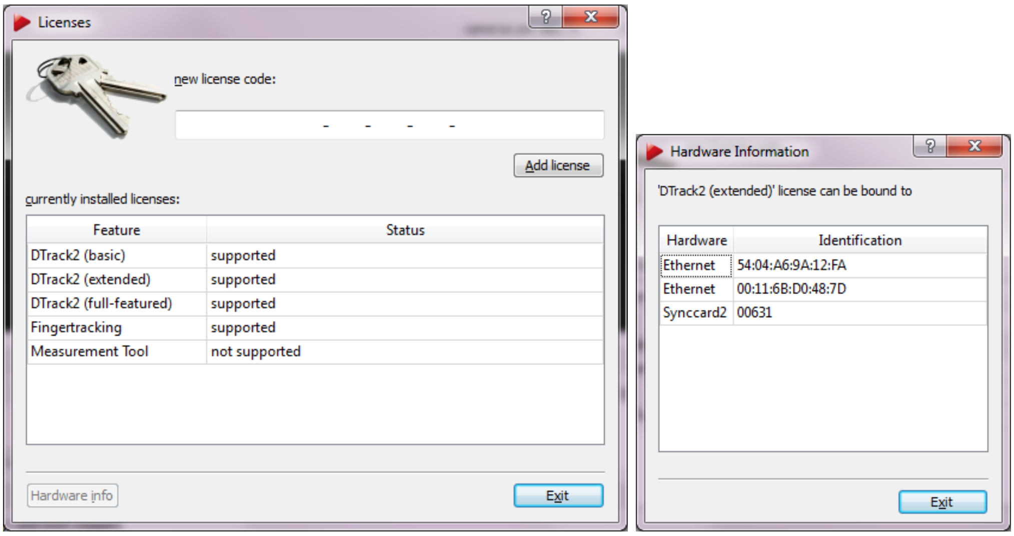
Table 4.5: Menu *DTrack2*

Licenses The capability of the ***SMARTTRACK*** is defined by licenses which can be managed here. You can add functionality for the Measurement Tool or the MultiUser function for the Flystick by simply entering a license code which can be provided by ***ART*** (see figure 4.29).
If you want to add the Measurement Tool , for example, go ahead as follows:

- Select the feature *Measurement Tool*.

Chapter 4

- Click on *Hardware Info*.
- Contact ***ART*** and communicate the serial number of the synccard or the MAC address of the Ethernet port (=*Identification*) in order to receive a license code.
- Enter the license code you received from ***ART*** in the field *new license code*.
- Click on *Add license*.



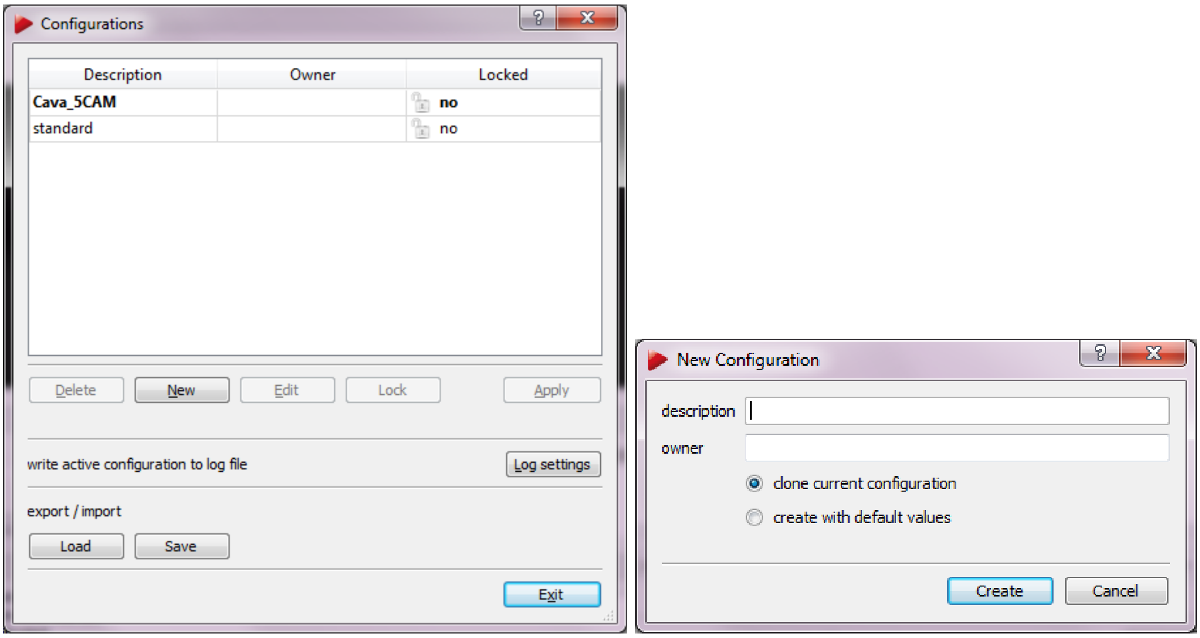
(a) Licenses overview (b) Hardware information

Figure 4.29: Managing the licenses

The process is the same for other modules.

Configurations It is possible to create different configurations, e.g. with different targets or flash settings. These are related to the name of the user and, thus, are easily accessible.
When creating a new configuration you need to describe your configuration in a few words (→ '*description*') and enter your name (→ '*owner*'). The configuration can be changed later on with *Edit* (see also figure 4.30).
Your personal configuration is created using the values of the current configuration (→ '*clone current configuration*') or default values (→ '*create with default values*'), respectively:

- '*clone current configuration*':
  all existing calibrations (room and body calibration) and flash settings are inherited.
- '*create with default values*':
  the system will start from scratch - i.e. as manufactured. That means, you will not have a room calibration or any body calibrations.



(a) Main window (b) Create a new configuration

Figure 4.30: Managing the configurations

Just press *Create* and the configuration is saved on the controller.

It is possible to protect the used configuration by pressing the button *Lock*. Then, you will be forced to enter a new password and your configuration is locked.

☞ **Please do not forget this password! Otherwise, please contact our support.**

Existing configurations may be used by selecting the corresponding entry and clicking *Apply*. Quit this dialogue by pressing *Exit* - the configuration is loaded.

Existing configurations can be deleted if not in use any more. Select the entry to be deleted and click *Delete*.

Log settings saves the selected configuration in a text file which can be saved on the remote PC. This function is mainly intended for supplying information to ***ART*** in case a problem arises.

It is also possible to export and import configurations. '*Save*' will export the complete active configuration. '*Load*' imports previously saved configurations. The imported configuration will automatically become the active configuration. It's possible to import several configurations at a time.

When you export a configuration please make sure that you rename it before exporting, for example by adding the exporting date (e.g. "Standard 07122012"). Configurations with the same name (e.g. "Standard") will be overwritten.

Start/Stop Start/Stop measurement.

Controller standby Force the ***SMARTTRACK*** to go into standby mode with this command. You can restart the ***SMARTTRACK*** by using Wake On LAN. Please refer to chapter 4.1.5 on page 28 for more details.

Quit Quit ***DTrack2*** frontend software - the active measurement doesn't have to be stopped.

4.3.6.3 Menu Settings

Settings	*Shortcut*
Cameras	F7
Synccard	
Inertial Sensor	
ART Radio Info	
Tracking	F8
Body Administration	F8
Output	F9
Flystick	
Measurement Tool	
Controller	

Table 4.6: Menu *Settings*

Cameras This dialogue offers the possibility to adjust the '*flash intensity*' and to activate the '*modulated flash*'. The modulated flash may only be used with active targets. It is used to synchronize an active target.

Reflex suppression ***DTrack2*** is capable of suppressing reflexes (e.g. sunrays on the floor) in a static way. However, reflex suppression should always be the last option to be considered. If possible try adjusting the cameras in order to minimize reflexes.

☞ **You should always be aware that reflex suppression results in removing of the area, in which the reflex originated, from the tracking volume.**

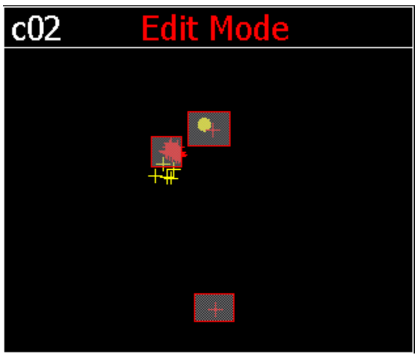
There are two possibilities to carry out a reflex suppression:

1. Mark the checkboxes for each camera when you want to suppress reflexes. Afterwards, select *Calibration* → *Start Static Reflex Scan for all enabled cameras* to make sure that static reflexes will be suppressed.

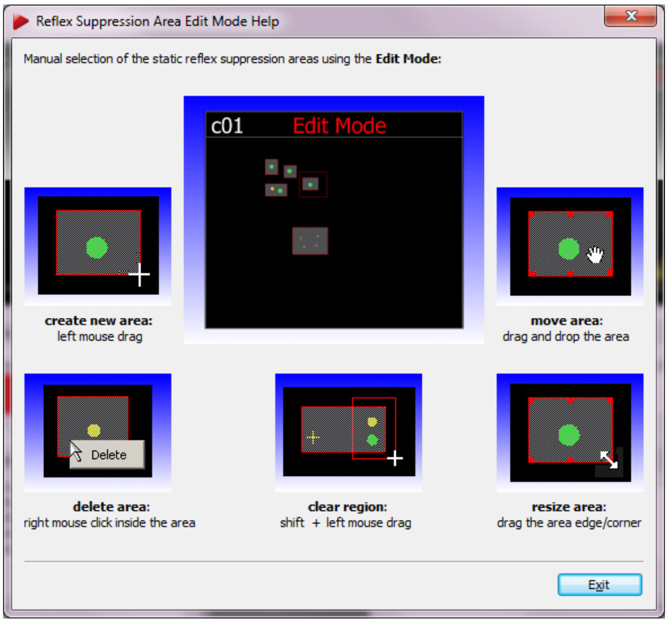
2. While measurement is running you may define the areas to be suppressed manually. In the Monitor 2DOF display, right-click on the respective camera window and enable '*Edit reflex suppression areas*'. Alternatively, you may use the shortcut ('*E*') to enable this mode (shown in figure 4.31(a) on page 63).

   Within the edit mode you may (also refer to figure 4.31(b) on page 63)

   - create new areas,
   - delete areas,
   - clear regions,
   - resize areas and
   - move areas.



(a) Reflex suppression edit mode



(b) Reflex suppression edit mode help

Reflex suppression areas are enabled when you leave the edit mode (by disabling '*Edit reflex suppression areas*') and accept the changes. The single areas defined are stored in the ***SMARTTRACK*** and can be edited each time you enter this mode.

If you want to disable all reflex suppression areas for a camera at the same time, just right-click on the respective camera and deactivate the option '*Active*'.

Flash settings The flash intensity may be changed within an interval of 0 .. 7. These settings strongly depend on the working area and range. If you have a small working area where you are close to the cameras small flash intensities may be sufficient.

Otherwise, if your working area is a bit further away from the ***SMARTTRACK*** (but still within tracking range) it may be necessary to change to greater flash intensities.

Generally speaking, you should adjust the flash settings in a way that the recognized markers are coloured in green or yellow.

Keep a distance of min. 20 cm when operating the cameras ! All cameras are assigned to the Exempt Group according to IEC62471-1 and therefore pose no risk or hazard to the human eye or skin at this distance.

To be safe, always double-check whether the markers of the target are seen properly by the cameras. Therefore, please use the Monitor 2DOF view:

- markers coloured in red are characterized by bad circularity, small size or low intensity; this may result in poor tracking quality
- markers coloured in yellow offer a good tracking quality
- markers coloured in green offer a very good tracking quality

Increase the flash intensity until all markers are yellow or green (recommended).

Modulated flash The ***SMARTTRACK*** can be used with active markers, i.e. markers consisting of infrared LEDs instead of retro reflective material. This allows both, more robust and longer ranging targets. These LEDs do not light continuously but also emit light flashes like the camera flash and thus have to be synchronized with the camera's timing. This can either be achieved by a synchronization cable or by using a modulation on the flash.
The option *modulated flash*, allows selecting the ***SMARTTRACK*** to emit the coded flash that triggers active targets. The modulation reduces the flash intensity in lower flash settings, so it might be necessary to increase the flash intensity. In higher settings the reduction is insignificant.

Display upside down The checkbox *display upside down* specifies how the ***SMARTTRACK*** is mounted (upright or upside down). This setting does not have any influence on the correct working of the tracking system because the orientations of the cameras are correctly determined by the photogrammetric algorithms in any case.

Synccard This dialogue shows the model and the serial number of the synccard. Furthermore, it offers a dropdown list to select the mode of synchronization.
Basically, you can select between internal and external synchronization. The further differentiation is shown in table 4.7.

supported synccard mode	field of application
internal generated signal (15 - 60Hz)	
external video signal external video signal, for validated shutter glasses [1] external video signal, for validated shutter glasses, divisor 2 [2]	active-stereo projection with an analogue video sync signal (=VGA)
external TTL signal external TTL signal, for validated shutter glasses [1] direct settings	active-stereo projection with a TTL sync signal advanced custom settings

[1] predefined settings that should be used with the shutter glasses mentioned in table 4.8
[2] if, additionally, the frequency of the external synchronization signal is greater than 60Hz, this mode should be used

Table 4.7: Overview of the supported synccard modes

If you select '*direct settings*' you may use advanced options for configuring the synccard:

Option	Description
source	configure the type of synchronization to be '*internal*', '*video*', '*ttl*' or '*ttlinv*'
frequency [Hz]	change the frequency in an interval of 10 Hz to 60 Hz (only for internal synchronization!)
divisor for external signal	reduce the tracking frequency (only for external video synchronization!)
Delay [us]	N/A for ***SMARTTRACK***

Brand	Type
RealD	CrystalEyes 1, 2, 3, 5
NuVision	APG6000, APG6100
XPand	X103 (with NuVision Long-Range Emitter)
NVidia	3D Vision Pro (RF sync'ed)
Volfoni	EDGE (with Volfoni or NuVision LR Emitter)

Table 4.8: Overview of validated shutter glasses

Chapter 4

Inertial Sensor In this dialogue all available wireless transceivers (dongles) are shown. Furthermore, it is possible to set the frequency the sensors are operating at (default: 100 Hz). Additionally all inertial sensors that have been previously added to the ***DTrack2*** configuration are listed with the following properties:

- Device ID + wireless icon
- Model (e.g. Colibri Wireless)
- Name (targets from Hybrid Motion Capture suit or user-defined)
- Firmware Version

- Currently used channel (default: 35 / 55)
- Wake-up mode (radio, tapping, USB/button)
- Battery level
- Temperature (only during measurement)

☞ **The default channels for all dongles and sensors are 35 and 55. In case these WLAN frequencies are already occupied by other devices in range, connection problems may occur. *ART* recommends to scan for available channels and to select free channels accordingly. Keep a minimum distance of 10 channels between dongles or from otherwise unavailable channels for optimum connectivity.**

☞ **For optimal battery life, *ART* recommends to switch all sensors to wake-up mode "USB/button" when not in use for a longer period of time.**

For more information, please refer to chapter 4.2 on page 31.

ART Radio Info When you are using a Flystick, for example, you will get information about the integrated transceiver and the Flystick device itself. The following information is offered:

	Description
'*Model*'	the model of the transceiver or the device respectively
'*Serial*'	the serial number
'*Version*'	the firmware version
'*Is free (only for Devices)*'	the device is not free (= '*no*') if it is assigned to an interaction device ID
'*Is present*'	the device or the transceiver is present in the tracking volume

By clicking the button *Show details* you may change the channel the transceiver is transmitting on.

The *SMARTTRACK* comes with an integrated radio transceiver. There is no need to plug in an additional USB Radio Transceiver (RT2)

Tracking In this dialogue you can configure whether 3DOF markers are calculated or not and you can enable or disable the '*automatic start of measurement after booting*'.

Also, you can globally define the '*central axis*' for all 5DOF targets. For these the rotation around the body axis cannot be measured by the tracking system. This rotation is therefore set to a certain value by the system. Thus, the 5DOF central axis is only important if you intend to use the rotation around the body axis. The most important properties are:

- If the 5DOF body is positioned parallel to the 5DOF central axis the rotation around the body axis remains undetermined.

- The rotation around the body axis is reduced to a minimum.

We recommend that you choose the 5DOF central axis as the direction which is the least often parallel to the tracked body axis (e.g. floor to celling for glasses targets).

The best choice for the 5DOF '*central axis*' may be found when using the tracking data in your appplication.

Details of the definition:

In addition to the 5DOF central axis the system selects an axis for each body in the body coordinate system (i.e. "pulled axis"). The rotation around the body axis is set to the value minimizing the angle between the pulled axis and the 5DOF central axis. The pulled axis is always perpendicular to the body axis. In addition the following criteria are used:

- If the 5DOF central axis is not the body axis the pulled axis is the axis minimizing the angle to the 5DOF central axis.
- If the 5DOF central axis is the body axis the pulled axis has a random direction in the plain.

The '*automatic restart of measurement after loss of sync signal*' option is set to '*active*' by default and therefore, it is not shown anymore (from ***DTrack2*** v2.8.1).

Body Administration The menu allows for administering all targets (e.g. Standard, Flystick, etc.) in the system (refer to figure 4.31).

The *number of 6DOF bodies* represents the number of targets that should be tracked. In this context, the number of targets does not include the interaction devices (e.g. Flystick or Measurement Tool). These are completely configurable in separate tabs.

However, the maximum total number of bodies that may be used in *ART* systems includes the calibrated interaction devices (Flystick, Measurement Tool)!

Here, you can activate, delete or reset target calibrations and change the order of the single targets. Additionally, you get the information by which means the target has been calibrated:

- '*Custom*' means that the standard body calibration has been used.
- '*Target Library*' means that the predefined calibration file from the system has been used.

For a detailed description of the single actions please refer to table 4.9.
As mentioned before you can administer interaction devices as well. Therefore, you may use the tabs *Flystick*, *Measurement Tool*.

In the bottom right of the dialogue you will find four buttons:

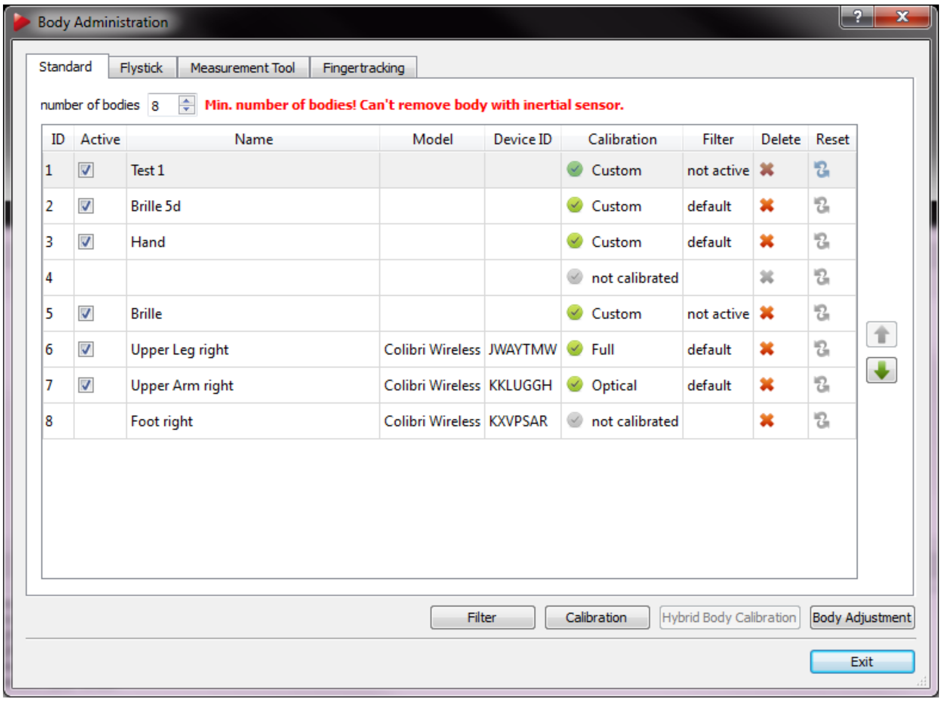


Figure 4.31: Flexible Body Administration (from ***DTrack2*** v2.9.0)

Action	Description
'*Active*'	Activate or deactivate a target. Data of deactivated targets will not be transmitted in the data stream. The target order will not be affected.
'*Delete*'	Deletes the calibration of a target - effective immediately after confirming the security query. The target order will not be affected.
'*Reset*'	In case the target has been calibrated initially with the '*Target Library*' and re-calibrated later by the user, it is possible to reset the calibration to '*Target Library*'.
'*Change order*'	With the arrows on the right-hand side of the window you may change the order of the targets. The data output will change accordingly.

Table 4.9: Body Administration - Detailed description of the actions

Button	Description
'*Filter*'	Activate or deactivate the filter for each target. You can either use defined presets or customize it to your requirements. A detailed description of the filtering options can be found in chapter 4.3.5 on page 56.
'*Calibration*'	Directly access the Body Calibration dialogue and perform the calibration for the selected target. A detailed description for body calibration can be found in chapter 4.3.3 on page 50.
'*Hybrid Body Calibration*'	Directly access the Hybrid Body Calibration dialogue and perform the calibration for the selected hybrid target. A detailed description for hybrid body calibration can be found in chapter **??** on page **??**.
'*Body Adjustment*'	Directly access the Body Adjustment dialogue and perform the necessary adjustment for the selected target. A detailed description for body adjustment can be found in chapter 4.3.4 on page 55.

Output The dialogue *Output* determines the settings of data output via Ethernet. Data output will be enabled when you tick the checkbox *active*.

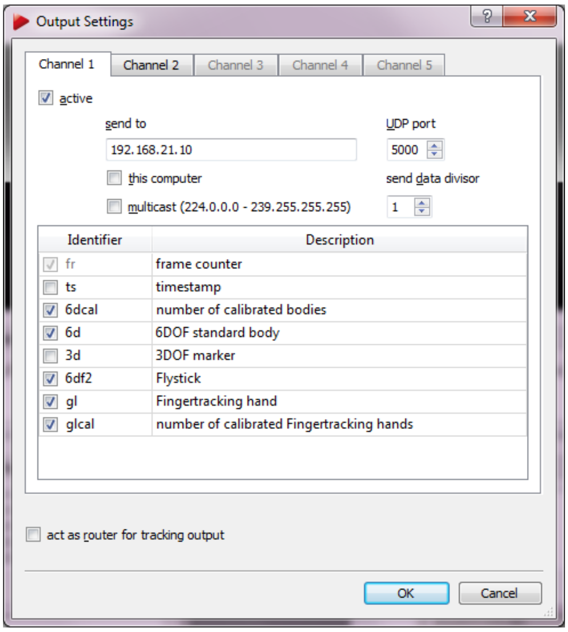


Figure 4.32: Output settings

Identifier	**Description**
fr	frame counter
ts	timestamp
6dcal	number of adjusted bodies
6d	6DOF standard body
3d	3DOF marker
6df2	Flystick
6dmt	Measurement Tool
6dmtr	Measurement Tool reference
6dmt2	Measurement Tool (also for ball probes)
6di	6D inertial body
6df	Flystick (old) only available if activated in Flystick settings (→ checkbox '*use old output format*')

Table 4.10: Output identifiers

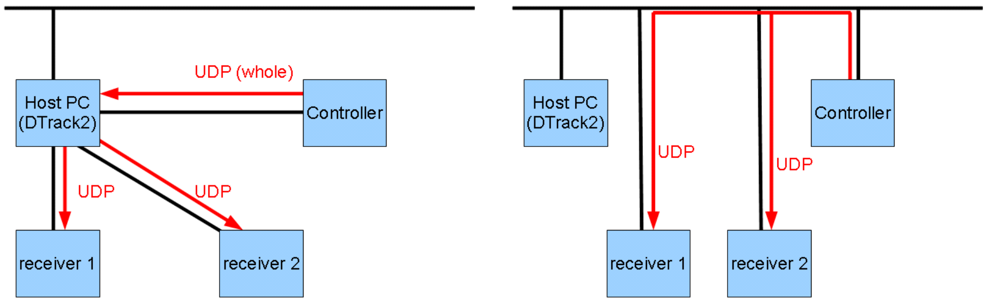
In total, up to 5 UDP channels for ***DTrack2*** data output can be configured. Tick the checkbox *this computer* to send data to the remote PC you are currently working at. If you want to send data to any computer within your local network just enter the IP address of the receiver and a port number. In addition, it is possible to define a *multicast* output. By ticking this checkbox the UDP data is sent to a group of addresses in the range of 225.0.0.0 to 238.255.255.255.

In order to reduce the data of the UDP output data stream you may set the '*send data divisor*' to values from 1 to 10. The numbers have the following meaning:

- 1 .. every frame is transmitted,
- 2 .. every second frame is transmitted,
- ...
- 10 .. every tenth frame is transmitted.

The UDP output data may be routed by ***DTrack2*** by ticking the checkbox *act as router for tracking output*. This functionality is especially important for customers where it is not allowed to connect the ***SMARTTRACK*** to their local network due to security reasons.

The mandatory requirement to use this function is that the PC, where ***DTrack2*** is installed, needs to have two separate Ethernet plugs: one for connecting to the ***SMARTTRACK*** and one for the respective local network. The ***DTrack2*** frontend reads the data from the ***SMARTTRACK*** and routes it to the local network where the application PC is



(a) *act as router* enabled (b) *act as router* disabled

connected to.

Using this function will cause a short delay during forwarding of the data.

Do not use this function if the application PC and the *SMART-TRACK* are in the same network!

Please refer to chapter B on page 121 for the format of the data output.

Flystick In the *Flystick Settings* you can define the *number of Flysticks* to be used.

Checkbox	Description
'*use old output format*'	Use the output format of the old Flystick1 (see chapter B on page 121)
'*activate MultiUser function*'	Refer to page 86 in chapter 5.1 for more information.
'*use head targets*'	The data pair (Flystick and head target) of one user is made available as output data (if MultiUser function is activated).

Table 4.11: Flystick settings - Description of the checkboxes

Below, there are two more properties which can be configured for Flystick3:

- *sync groups*:
  Configure your Flystick3 to send out IR flashes for one or more syncgroups (syncgroup #1, syncgroups #1 and #2, . . . ; default = syncgroup #1).

- *flash intensity*:
  Set the flash intensity of the active target of the Flystick3 (default = 3) by moving the slider.

If you change the number of Flysticks you will immediately recognize entries in the *selected Flysticks* field. The fields *Model*, *Serial* and *Port* are empty by default.
Make sure that your Flystick is in the *available Flysticks* list - if necessary, compare the serial number listed here to the one printed on the battery compartment of the Flystick2 or on the back cover of the Flystick3. Now, you have to assign your Flystick to the respective

Flystick ID.

Therefore,

- mark the respective Flystick ID,
- mark the desired available Flystick and
- press *Select*.

Repeat these steps if you want to use another Flystick. Please refer to chapter 5.1 on page 83 to learn how to install the Flystick2 and refer to chapter 5.2 on page 88 for the Flystick3.

Measurement Tool Within the Measurement Tool dialogue you may define the *number of Measurement Tools* and the *number of references*. It is limited to a total number of four each.
Below, there are several fields where you may change the default values within the allowed ranges to suit your application.

Control	Description
'*number of Measurement Tools* '	configure the number of devices to be used
'*number of references*'	configure the number of reference bodies to be used
'*measurement duration [s]*'	configure the time to perform a measurement with the Measurement Tool (valid range: 0.2 - 10.0 sec)
'*tool tip tolerance [mm]*'	specify the range within which the tip is assumed to be static (valid range: 0.1 - 5.0 mm)
'*activate measurement start simulation*'	activate the start button simulation and enable the respective controls
'*minimal angular variation [deg]*'	specify the minimum angle that the Measurement Tool has to be tilted over to start a measurement (valid range: 10°- 120°)
'*maximum lead time for this angular variation [s]*'	waiting time before the measurement start by the start button simulation

Table 4.12: Measurement Tool settings

If you are working with a reference body you may assign it to a specific '*Measurement Tool ID*':

- mark the respective Measurement Tool ,
- mark the reference body and
- press *Select*.

Repeat these steps if you want to assign references to other Measurement Tools .

Please refer to chapter 5.3 on page 93 to learn how to install the Measurement Tool .

Controller The menu for the *Advanced Controller Settings* is divided into two tabs - *Network* and *Time*.
On the *Network* tab you may change the *hostname* (not recommended!) and the *domain* according to your network guidelines. When the network cable has been plugged into the ***SMARTTRACK*** while booting, the ***SMARTTRACK*** is a DHCP client and the checkbox is ticked. If the network cable is unplugged while booting the ***SMARTTRACK*** uses its default IP address (i.e. 192.168.0.1).
You may also specify *IP address*, *subnet mask*, *gateway* and *nameserver* as desired. The MAC address of the ***SMARTTRACK*** is printed in the last line for your information (*ethernet-MAC LAN*).

On the *Time* tab you can set the *UTC time* of the ***SMARTTRACK*** . Furthermore, you can synchronize the UTC (=Universal Time Coordinated) time using NTP (=Network Time Protocol). NTP is a protocol designed to synchronize the clocks of computers over a network. Tick the checkbox *activate NTP* and enter hostname or IP address of your server.
If NTP is activated the ***SMARTTRACK*** is trying to connect to the NTP server repeatedly in order to update its clock. The values for '*reachability*' range between 0% - 100% (typically). They are a measure for the quality of the reachability of the NTP server. Only NTP servers which are contacted over the internet may provoke some problems. The quality of the synchronization of the clocks is indicated with '*estimitated precision*' in the unit milliseconds (=ms).

Synchronizing with NTP takes quite a long time. Active measurements won't be disturbed.

4.3.6.4 Menu Calibration

Calibration	*Shortcut*
Start static reflex scan for all enabled cameras	
Inertial Sensor Calibration	
Room	F5
Room adjustment	Shift + F5
Body	F6
Body adjustment	Shift + F6
Measurement Tool	

Table 4.13: Menu *Calibration*

Start static reflex scan for all enabled cameras The ***SMARTTRACK*** is able to suppress all reflexes in certain areas of the image sensor. This is especially important for setups where there are a lot of unwanted reflexes from the nearby walls. To gain good tracking results, these reflexes should be suppressed. The feature can be enabled or disabled for each of the two cameras individually in the Monitor 2DOF display. Scanning for static reflexes allows searching the measurement volume for unwanted reflexes. Areas are defined around the visible reflexes, where all reflexes should be suppressed later during measurements.

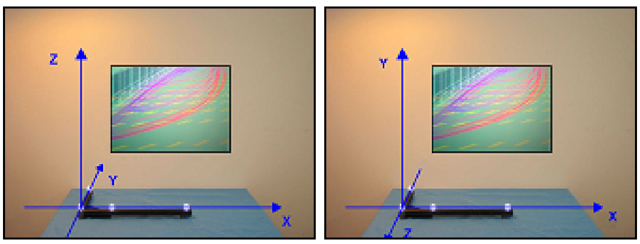
☞ **Be sure to remove all targets from the measurement volume before starting the scan.**

Inertial Sensor Calibration This function carries out a drift correction for all inertial sensors. Please refer to chapter 4.2 on page 31 for more information.

Room Use the room calibration menu to configure your room calibration set concerning *wand length* and *marker distances*. The wand length is printed on a label on the wand - please enter the value here.

Figure 4.33: A room calibration set consisting of angle and wand

Marker distances defines the type of room calibration set - for ***SMARTTRACK*** it is always *Room Calibration Set 410*. When choosing *expert* the angle of the room calibration set may be defined by the user. Then, the distances between the markers on the angle have to be configured.
Define the *coordinate system* as '*normal*' or '*powerwall*'. The layout of the coordinate sys-



(a) '*normal*' (b) '*powerwall*'

Figure 4.34: Defining the coordinate system for the room calibration

tem is shown in the 4.34 on page 73. You may adjust the '*duration*' of the room calibration

(→ *Show details*) in a range of 10s - 100s. Resetting the value to default is achieved by pressing the *Set to default* button (default = 30s).

☞ **Changing the duration of the room calibration, especially towards shorter durations, may lead to bad room calibration results! Please make sure that you are always able to cover two thirds of the tracking volume within the set time.**

If you are re-calibrating your room use the checkbox *re-calibration* in the bottom left corner to indicate it to the tracking system. For more information about room re-calibration please refer to page 47.

Please refer to chapter 4.3.2 on page 44 for the details on how to perform a room calibration.

Room adjustment In many cases it might be necessary to shift or rotate the coordinate system after calibration. For a good calibration, the angle should be placed such that as the ***SMARTTRACK*** is able to see it. The corner marker of the angle defines the origin of the coordinate system. For software configuration it is more suitable to have the origin at a well-defined point, e.g. in the center of the screen.
If a ***SMARTTRACK*** already in use has to be calibrated again due to movement, the angle might have been put slightly different than in the previous calibration. To avoid reconfiguration of all installed software, the tracking coordinate system should be moved to exactly reproduce the previous calibration.
The calibration angle should be put exactly parallel to one of the screens. On large systems, even very small angular errors might lead to substantial deviations over the full width of the projection (0.1° on 5m length is 8.7 mm deviation).

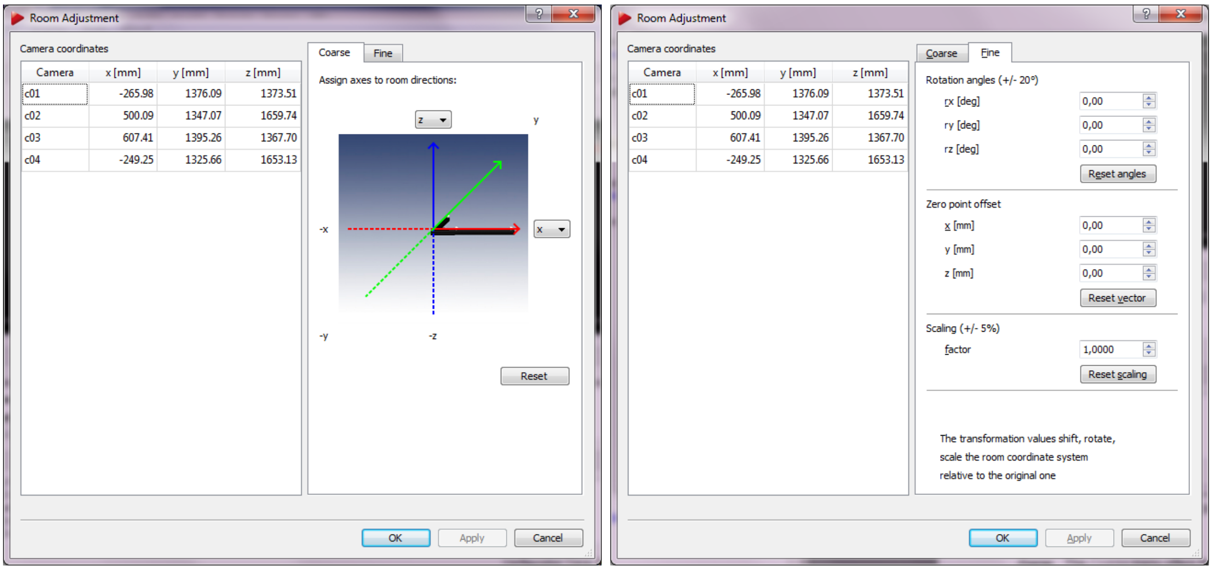
In all these cases, the coordinate system must be altered after calibration. This functionality is called from *Calibration → Room adjustment*.

Coarse The *Coarse* menu offers the opportunity to manipulate the orientation of the room coordinate system with just one click. You can define the orientation of two axes - the third one will be oriented automatically according to the right-hand rule.

Fine The offsets in this menu are the coordinates of the new (desired) coordinate system in the original coordinate system given by the calibration angle. E.g., when the angle was placed on the ground with standard coordinate system (Z axis up), the desired origin is 1m above the floor, and the marker center was 42mm above the ground, then the value for Z is 958mm.

Angular corrections are only allowed up to 20° in any direction. The transformation values shift, rotate and scale the room coordinate system relative to the original one.

Body Select the body you want to calibrate and tick the checkbox if you want to perform a re-calibration. Define the coordinate system which can be '*due to body*', '*due to room*' or '*due to room, zero in marker*'.



(a) '*coarse*' (b) '*fine*'

Figure 4.35: Room adjustment dialogue

If you want to use body calibration files for calibrating your target, just click *Load file(s)* and select the appropriate calibration file(s). By clicking on *Save file(s)* you can save your body calibrations in separate text files.

Please refer to chapter 4.3.3 on page 50 for the details on how to perform a body calibration.

Body adjustment If you want to manipulate calibration data of rigid bodies this menu offers the solution. Just select the body you want to manipulate from the drop-down list which appears at the top of the window. Then, you have the choice between a *general* or a *special* manipulation:

General manipulation The body coordinate system may be defined in a general manner, i.e. as desired by the user.

Chapter 4

Action	Description
Body position [mm]	translate the body coordinate system along its axes in steps of 1mm
Body orientation [deg]	rotate the body coordinate system around its axes
Set origin	activate a marker in the graphic view by left-clicking with the mouse. The marker is highlighted and the button *Set origin* is activated. Pressing this button translates the origin of the body coordinate system into the center of the selected marker.
Set origin to COG	translate the origin of the body coordinate system into the target's center of gravity
Set axis	activate two markers sequentially in the graphic view by left-clicking with the mouse. The first one is highlighted in white, the second one in grey. Additionally, the button *Set axis* is activated. Pressing this button opens a dialogue to configure the transformation.
Adjust axes to room	pressing this button aligns the body coordinate system in parallel to the room coordinate system

Special manipulation Choose from the following predefined transformations:

- *due to body*
  The body coordinate system is completely defined by the target geometry (see page 52).
- *due to room (origin in COG)*
  The coordinate system is rotated in order to be aligned in parallel to the room coordinate system with the origin to be in the center of gravity (COG) (see page 52). In order to use this function, the checkbox '*use tracked orientation*' has to be ticked.
- *due to room (origin in marker)*
  The coordinate system is rotated in order to be aligned in parallel to the room coordinate system with the origin to be in the marker (see page 53). In order to use this function, the checkbox '*use tracked orientation*' has to be ticked.

The default view for the calibration data of the rigid body is the '*Graphic view*'. Press the right mouse button and a menu with the following options pops up:

Option	Description
'*Small markers*'	reduce the size of the markers
'*Colored markers*'	show the markers in different colours (default: greyish)
'*Long axes*'	extend the vector arrows of the body coordinate system by infinite dashed lines
'*Show COG*'	show the center of gravity when changing the orientation of the view
'*Show XY plane*'	show the XY plane
'*Show YZ plane*'	show the YZ plane
'*Show XZ plane*'	show the XZ plane
'*Show room orientation*'	shows the room coordinate system (only available when checkbox '*use tracked orientation*' is ticked)
'*Add line between markers*'	add a line between two selected markers (option greyed out until two markers are selected)
'*Delete line between markers*'	remove a line between two selected markers (option greyed out until line is selected)
'*Data view*'	switch to the data view

The *View position* and *View orientation* may be changed according to the customer's choice. The graphic view may be moved along and/or rotated around the axes. This may be achieved in two different ways:

1. hold down the "Strg" key and the left (right) mouse button to change the position (orientation)
2. use the six control dials to adjust position and orientation

To restore the default view, just press '*Reset view*'. Tick the '*use tracked orientation*' checkbox if you want to rotate or move the target in the graphic view by rotating or moving the real target within the measurement volume.

If you press *OK*, the changes which have been done for all bodies will be confirmed (changes are sent to the controller) and the dialogue closes.
Pressing *Apply* only results in a confirmation of the changes only for the currently selected body - the body will directly be reloaded afterwards.

☞ **If the MultiUser function for Flysticks is enabled the *Body Adjustment* module will only load standard bodies. If you want to adjust the body calibration data of your Flystick, please make sure that the MultiUser function is disabled (*Settings* → *Flystick*) - a label *'MultiUser function should be disabled!'* will appear at the bottom of the dialogue.**

Hybrid Body This function performs a hand-eye calibration to combine an inertial sensor with its corresponding optical target. Please refer to chapter 4.2 on page 34 for more information.

Measurement Tool Perform a tip calibration for the Measurement Tool that is currently inside the tracking volume. *DTrack2* automatically detects the ID of the Measurement Tool and assigns the tip calibration. Just press *Calibrate* to start the calibration process.

During calibration please move the Measurement Tool while keeping the tip still at exactly one position.

☞ **Note that the progress bar is not continuing if the pointing device is not moved sufficiently.**

Please refer to chapter 5.3 on page 94 for more information.

4.3.6.5 Menu Display

Display	*Shortcut*
Monitor 2DOF	
Data	F10
Flystick	
Events	

Table 4.14: Menu *Display*

Monitor 2DOF The *Monitor 2DOF display* essentially is a graphical display of the field of view of the ***SMARTTRACK*** and of the markers that are seen by it. The Monitor 2DOF display shows two black windows (equivalent to the field of view), with a schematic display of positions and sizes of all recognized markers. A simple color code signifies the size and the circularity of the markers (green = very good quality, yellow = good quality, red = poor quality). Each marker is either displayed as a circle or as a cross. This indicates the projected size of the marker on the CCD chip inside the camera (i.e. circle = big marker and cross = small marker).

As a rule of thumb: for measurement applications with high accuracy requirements the markers should be displayed in green; for VR applications yellow markers are sufficient. The *Monitor 2DOF display* is particularly useful for the final adjustment (especially for orientation adjustments) of the IR cameras.

In the *Monitor 2DOF display* it is possible to interact with your mouse as certain functions are assigned to the mouse buttons.

- left mouse button:
  Click and hold down to move a camera display within the *Monitor 2DOF view*.

- middle mouse button:
  Click to hide all camera displays except for the one you pointed at. Click once again and all camera displays are shown.

- right mouse button:
  A menu is opened; see table 4.15 for more details.

Function	Shortcut	
Grid	G	Shows a grid in the camera display.
Cross	C	Shows a cross in the camera display.
Fullscreen	F	Resizes *Monitor 2DOF view* to full screen and back.
One Camera		Only show the view of the selected camera.
Display upside down		Changes display orientation. '*UD*' is displayed in the camera display.
Display blinking		N/A for ***SMARTTRACK***
Static Reflex Suppression		
Active		Enable static suppression of reflexes. '*SR*' is displayed in the camera display.
Start scan for all enabled cameras		Initiates a scan for static reflexes. Enabled only if *Active* is ticked.
Edit reflex suppression areas	E	Enter the reflex suppression area edit mode in order to interactively suppress unwanted reflexes.

Table 4.15: Features of the *Monitor 2DOF view*

Data On the left hand side, the *Data* display shows the 6DOF measurement results of the position and orientation of the body relative to the room coordinate system. The rotation angles are rotations around the X, Y and Z axis. The mathematical definition can be found in chapter B on page 121. A simple colour code indicates if the body is tracked or not:

green	...	body is being tracked; tracking data is displayed
yellow	...	body is being tracked only by the means of the intertial sensor (only rotational data!)
red	...	body is not being tracked; instead of tracking data dashes are displayed
white	...	body is not calibrated; columns are left blank

On the right hand side, the 3DOF calculation for single markers or uncalibrated targets is shown. All recognized single markers that are have not been assigned to a calibrated 6DOF body are shown here.
Note that the *calculation of 3DOF markers* has to be activated in *Settings* → *Tracking* by ticking the checkbox. Otherwise, the positions will not be calculated.

Additional information for inertial sensors In the Data Display additional information is provided for the inertial sensor:

- sensor ID
- battery level
- temperature in °C

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The sensor's temperature will be coloured in green as soon as it reached working temperature. The working temperature is not depending on the absolute value of the temperature but on the change over time. So, in case there's no change anymore working temperature is reached.

Flystick The *Flystick* display shows the measurement results of the position and orientation of the Flystick. Additionally, the operation of the Flystick buttons and of the joystick are shown. A simple colour code shows the status of the Flystick:

green	...	Flystick is being tracked; tracking data is displayed
red	...	Flystick is not being tracked; instead of tracking data dashes are displayed
blue	...	button is being pressed
white	...	Flystick is not calibrated; columns are left blank

Measurement Tool The *Measurement Tool* display is split into two parts:

1. position and orientation of the Measurement Tool 's tip and the respective reference body
2. position and orientation of the reference body

A simple colour code indicates if the Measurement Tool or the reference body, respectively, are tracked:

green	...	tool is being tracked; tracking data is displayed
red	...	tool is not being tracked; instead of tracking data dashes are displayed
blue	...	measurement is being performed
white	...	tool is not calibrated; columns are left blank

A Measurement Tool , which a reference body has been assigned to, can only be tracked if the reference body is tracked as well.

Events The *Event display* presents the status of the tracking system. It offers feedback of the operational state concerning errors or warnings. Furthermore, it informs the user about successful room or body calibrations. Each entry is associated with a timestamp and date.

Set to default If, for some reason, the appearance of the ***DTrack2*** Frontend got messed up you may reset all views and the size of the window back to default values. This means that only the *Monitor 2DOF*, the *Data* and the *Events* displays are shown (refer to figure 4.13 on page 41).

4.3.6.6 Menu Tools

Tools	*Shortcut*
Controller Update	
Measurement Tool Demo	

Table 4.16: Menu *Tools*

Controller Update If you update your ***DTrack2*** frontend software it is mandatory that you also update the software of the Controller. An assistant will guide you through the process of the software update. In case you abort the update of the Controller software (not recommended!) during this process you can carry it out later. Just click *Tools* → *Controller update* and follow the instructions of the assistant given during this process. It is necessary to restart the Controller when the assistant is finished.

Personal settings and configurations (e.g. room and body calibration, output settings, etc.) will be preserved during update!

Measurement Tool Demo This demo provides a convenient way to do measurements with the Measurement Tool . Points may be collected by using up to four Measurement Tools . The distances between adjacent points are computed automatically. You may add or delete points from the list and, if wanted, you may save it to a file.

Control	**Description**
'*Measure point*'	Place the Measurement Tool at the position you want to measure and press this button.
'*Insert point*'	Add an additional point to the list (above the selected point).
'*Delete point*'	Remove the selected point from the list.
'*Save list*'	Export the list of points to a file (e.g. may be imported to a spreadsheet program).
'*Clear list*'	Delete the entries of the list.

The measurement of a point is started either by pressing the button *Measure point* or by tilting over the Measurement Tool as defined in *Settings*. An active measurement is indicated by a blue rectangle in the Measurement Tool display.

If the Measurement Tool is not tracked a measurement cannot be performed!

4.3.6.7 Menu About

DTrack2 Offers information about the software version and release date of the ***DTrack2*** frontend software. By clicking on the button *Show details* you receive a list of every single software module with the respective software version.

Controller Offers information about the software version and release date of the ***DTrack2*** backend software. Additionally, name and serial number of the ***SMARTTRACK*** are shown.

About	*Shortcut*
DTrack2	
Controller	
What's new?	
What's this?	Shift + F1

Table 4.17: Menu *About*

What's new? Provides information about the new features that have been released with the respective version. By clicking on '*Show more*' you can access the history of introduced features during the last versions.

What's this? By clicking *What's this*, you may use our context-sensitive help function within ***DTrack2*** frontend software. Just use the mouse cursor to point on any feature of the ***DTrack2*** GUI and you will receive an information with a click on the left mouse button.

5 Interaction devices

5.1 Flystick2

The batteries must be removed before shipping the Flystick2, otherwise the radio transmitter could be started by shock or vibration.

Description The Flystick2 is a wireless input device for ***ART*** infrared optical tracking systems.

Figure 5.1: Flystick2

The Flystick2 has a trigger, four buttons and an analogue joystick with an additional button functionality. All interactions are transmitted wirelessly via a 2.4 GHz ISM radio connection. The software ***DTrack2*** takes up the Flystick2 button & joystick events and correlates them with the 6DOF output data. Tracking and interaction data are then transmitted to the application via Ethernet.

The Flystick2 has no power switch. It is activated automatically within a few seconds after any button event and is deactivated after several minutes without usage.
The Flystick2 is tracked via passive markers which are covered by an acrylic housing. This means that 6DOF tracking is still valid when the Flystick2 electronics is off.

Top view		
status LEDs	green pulse	→ button pressed or joystick position successfully transmitted
	yellow pulse	→ button pressed or joystick position could not be transmitted
	yellow flashing	→ low battery, recharge soon
trigger, button and joystick	press the trigger or any button to invoke an interaction which can be defined in the user application (e.g. drag objects while button trigger pressed, open a menu dialogue, . . .)	

Table 5.1: Description of the Flystick2

The output data consists of:

- position and orientation of the Flystick,
- status of buttons and joystick,
- number of used Flysticks.

Please refer to chapter B for more information about the format of the output data.

Control elements The numbering sequence of the buttons is as follows:

- # 1 trigger
- # 2 - # 4 blue buttons, right to left
- # 5 pressing the joystick

Figure 5.2: Flystick2 control elements

In neutral position the joystick transmits x=0, y=0.

- Moving left creates negative x values, moving right positive x values.
- Moving down creates negative y values, moving up positive y values.
- Full extension into any direction creates values of 1.0 or -1.0.

The Flystick2 device provides all functions (buttons, trigger and joystick) simultaneously.

In case you need to carry out a factory reset for the Flystick2 you just have to plugin the charger into the charging jack.

Radio module The Flystick2 uses a radio module in the 2.4GHz band. This band is standardized internationally and can be used without a license. Range with line of sight is more than 7m but can be reduced when passing material, e.g. projection screens.

The *SMARTTRACK* comes with an integrated radio transceiver. There is no need to plug in an additional USB Radio Transceiver (RT2)

Battery pack The battery compartment is at the lower end of the handle. It is fixed with a single screw which can be opened with the supplied 2mm hexagon key. Remove the screw and take off the cover of the battery compartment.

(a) Step 1 (b) Step 2 (c) Step 3

Figure 5.3: Flystick2 - inserting the battery pack

Insert the battery pack taking care of the polarity - also note the imprinting "<<INSERT<<" on the battery pack. Apply the cover of the battery compartment again and fix the screw.

The battery pack includes 3 standard AAA rechargeable batteries.

The polarity of the batteries is indicated inside the battery pack. The rechargeable batteries must be inserted into the battery pack in the indicated polarity.
Dispose used batteries according to governmental regulations (life cycle approximately 2 years).

Risk of explosion if battery is replaced by an incorrect type!

Charging jack The charging jack is at the bottom of the handle and has to be connected with the supplied battery charger.

Figure 5.4: Charging the battery of the Flystick2

By connecting the battery charger the Flystick2 electronics are disconnected to prevent damage. Thus the Flystick2 cannot be used during the the charging process.

The rechargeable batteries may only be charged with the supplied charger. To ensure long battery life, do not let the batteries become discharged completely. Recharge whenever convenient. Do not charge for > 24 h.

Battery charger A battery charger is supplied with the delivered Flystick2 and must be used for charging the batteries. For your convenience, the battery pack may remain inside the Flystick2 for charging. However, during the charging process the Flystick2 cannot be used.

As soon as the battery pack is connected to the charger the initialisation starts (status LED: Yellow). After a few seconds the charger switches to the fast-charge mode (status LED: Orange).

Once the battery pack is fully charged (approx. 1 h) the charger switches to the top-off charge mode to balance the cells inside the battery pack (status LED: Green with intermittent yellow flash). This helps to extend battery life. Hereafter the charger goes into trickle charge mode automatically (status LED: Green). Now, the battery pack may be used again.

Please also refer to table 5.2 for an overview of the status LEDs on the battery charger.

MultiUser option The MultiUser option is an enhancement especially for VR/AR applications when working with more than one Flystick2. Up to ten users can be equipped with

status LED colour	Description
Yellow	No battery pack connected or initialisation
Orange	Fast charge
Green with Yellow flash	Top-off charge (balancing)
Green	Trickle charge (charging completed)
Flickering Orange - Green	Error (disconnect !)

Table 5.2: Status LEDs quick reference

a Flystick2 and a head target (usually mounted on glasses). The software ***DTrack2*** is able to track them all but only the data pair (Flystick2 and head target) of one user is available as output data. Switching between the single users can be done by just pressing one of the Flystick buttons.

Depending on how many Flysticks you are using, you have to configure the *number of Flysticks* (max. 10) in *Settings* → *Flystick*. Tick the checkbox '*activate MultiUser function*'. If you want to use a Flystick2 and a head target as data pair then you have to tick the checkbox '*use head targets*' as well. Please refer to chapter B on page 121 for more details on the output format.

Body calibration First, configure the number of Flystick2 you are using: select *Settings* → *Flystick* and configure the *number of Flysticks*. You have to assign your Flystick2 to a '*Flystick ID*' by selecting, for example, '*F1*' and selecting your Flystick2 out of the '*available Flysticks*' list.
Now, press *Select* to finalize the assignment.

If the '*available Flysticks*' list doesn't contain your Flystick2 although it is already present, just press any button of the Flystick2 to register it at the radio transceiver.

Then, select *Calibration* → *Body calibration*.
In the appearing dialogue the body to be selected is named '*Flystick body 01*'. Please define the orientation of the body coordinate system relative to the body (default setting is '*due to body*'). Make sure that all markers of the Flystick2 are seen by the cameras using the *Monitor 2DOF display* which appears in the background.

Press *Calibrate* and the calibration starts within 5 seconds. Please refer to page 50 for more information concerning *body calibration*.

Output settings Please define where the Flystick data has to be sent to. In ***DTrack2*** frontend software, select *Settings* → *Output*. You can either select *this computer* (= remote PC) or enter an IP address of another computer you want to send data to. By ticking the checkbox '*6df2*' you can define the Flystick data to be transmitted.
Please refer to chapter 4.3.6.3 on page 68 for more details.

Press *Start* to start the measurement. In order to see the tracking data you have to enable the Flystick display by clicking *Display* → *Flystick*.

5.2 Flystick3

The batteries must be removed before shipping the Flystick3, otherwise the radio transmitter could be started by shock or vibration.

Description The Flystick3 is a lightweight input device for ***ART*** infrared optical tracking systems.

(a) active target (discontinued) (b) passive target (standard)

Figure 5.5: Flystick3

Top view		
status LEDs	green pulse	→ button pressed or joystick position successfully transmitted
	yellow pulse	→ button pressed or joystick position could not be transmitted
	yellow flashing	→ low battery, recharge soon
trigger, button and joystick	press the trigger or any button to invoke an interaction which can be defined in the user application (e.g. drag objects while button trigger pressed, open a menu dialogue, . . .)	

Table 5.3: Description of the Flystick3

It is equipped with an active[1] or passive target, a trigger, three buttons and an analogue joystick for wireless interaction in a virtual environment. Like with the Flystick2, all interactions are transmitted wirelessly via a 2.4 GHz ISM radio connection. Synchronization

[1] discontinued in December 2011

of the Flystick3 is provided wirelessly with a modulated flash by one camera.

The software ***DTrack2*** takes up the Flystick3 button and joystick events and correlates them with the 6DOF output data. Tracking and interaction data are then transmitted to the application via Ethernet.

☞ **The radio transmission and the active target are switched off after 15 minutes without usage. Press any button to reactivate the Flystick3 and, therefore, tracking.**

The output data consists of:

- position and orientation of the Flystick,
- status of buttons and joystick,
- number of used Flysticks.

Please refer to chapter B on page 121 for more information about the format of the output data.

Control elements The numbering sequence of the buttons is as follows:

- # 1 trigger
- # 2 - # 4 blue buttons, right to left

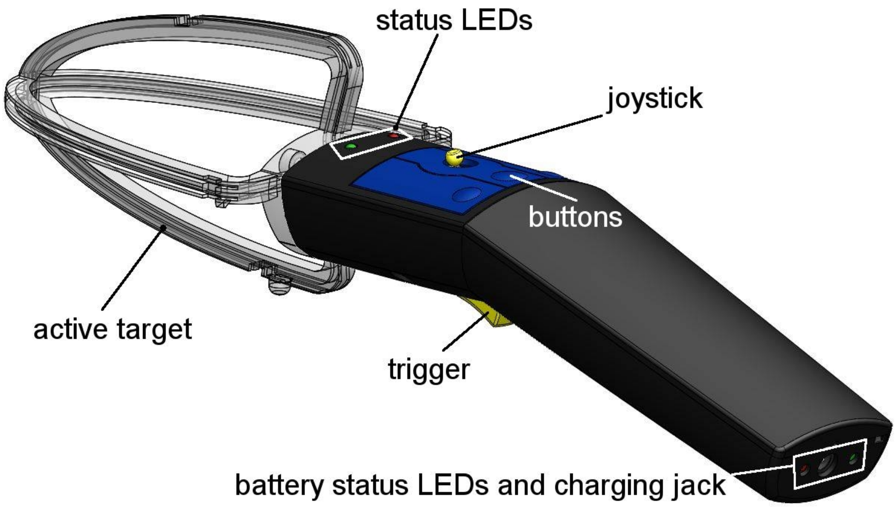


Figure 5.6: Flystick3 control elements

In neutral position the joystick transmits x=0, y=0.

- Moving left creates negative x values, moving right positive x values.
- Moving down creates negative y values, moving up positive y values.

- Full extension into any direction creates values of 1.0 or -1.0.

The Flystick3 device provides all functions (buttons, trigger and joystick) simultaneously.

In case you need to carry out a factory reset for the Flystick3 you will find the reset button just on top of the charging jack. You may use a paper clip to press the reset button.

The *SMARTTRACK* comes with an integrated radio transceiver. There is no need to plug in an additional USB Radio Transceiver (RT2)

Battery charger A battery charger is supplied with the delivered Flystick3 and must be used for charging the batteries. For your convenience, the battery pack may remain inside the Flystick3 for charging. During the charging process you may continue using your Flystick3.

As soon as the battery pack is connected to the charger, the red LED ("Charge") is switched on. Once the battery pack is fully charged the charger switches off the "Charge" LED, the green "Ready" LED is switched on. Now, the battery pack may be used again.

The rechargeable batteries may only be charged with the supplied charger.

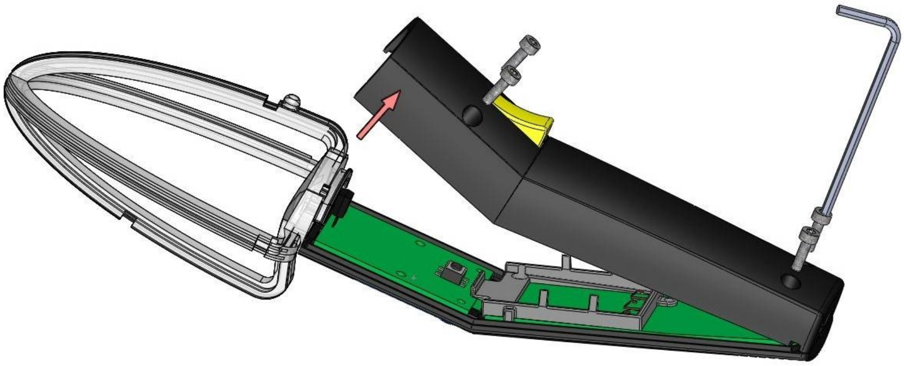
An error during charging occured, in case the green LED is switched on permanently and the red LED is flashing at the same time. This indicates for example that either the battery isn't inserted correctly or it is defective.

Inserting the battery For inserting the battery into the Flystick3, you have to take off the back cover completely.

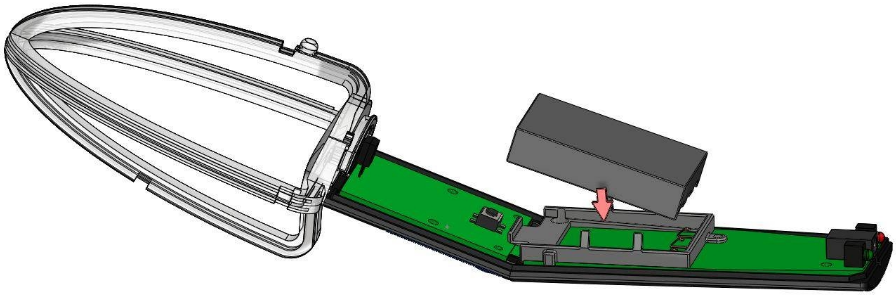
Risk of explosion if battery is replaced by an incorrect type!

Dispose used batteries according to governmental regulations.

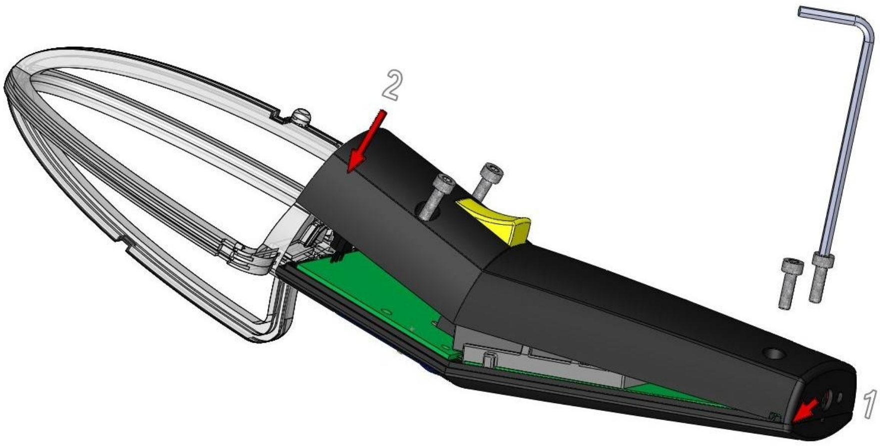
Therefore, loosen the four screws using the 2.5mm hexagon key and remove the back cover.



Place the battery correctly within the cut-out.



Apply the back cover again and tighten the screws carefully.



Wireless synchronization (only for active variant) The receiver for the modulated infrared signal which is used for synchronization is located in the middle of the joint between transparent target and handpiece (see figure 5.6).

☞ **Active targets need synchronization in order to make sure that the IR LEDs are flashing at the proper time. To ensure wireless synchronization the following points should be observed:**

- **Note that the synchronization will not work near plasma screens.**
- **If two or more tracking systems using wireless synchronization are in the same room, then external synchronization of the systems might be necessary (e.g. at tradeshows).**

The modulated flash is adjustable in *Settings* → *Cameras*. Just tick the checkbox '*modulated flash*' and select one camera (which is in syncgroup # 1) from the dropdown list. Press *OK* to apply the changed settings.

MultiUser option The MultiUser option is an enhancement especially for VR/AR applications when working with more than one Flystick. Up to ten users can be equipped with a Flystick and a head target (usually mounted on glasses). The software ***DTrack2*** is able to track them all but only the data pair (Flystick and head target) of one user is available as output data. Switching between the single users can be done by just pressing one of the Flystick buttons.

Depending on how many Flysticks you are using, you have to configure the *number of Flysticks* (max. 10) in *Settings* → *Flystick*. Tick the checkbox '*activate MultiUser function*'. If you want to use a Flystick and a head target as data pair then you have to tick the checkbox '*use head targets*' as well. Please refer to chapter B for more details on the output format.

Body calibration First, configure the number of Flystick3 you are using: select *Settings* → *Flystick* and configure the *number of Flysticks*. You have to assign your Flystick3 to a '*Flystick ID*' by selecting, for example, '*F1*' and selecting your Flystick3 out of the '*available Flysticks*' list.
Now, press *Select* to finalize the assignment.

If the '*available Flysticks*' list doesn't contain your Flystick3 although it is already present, just press any button of the Flystick3 to register it at the radio transceiver.

Then, select *Calibration* → *Body calibration*.
In the appearing dialogue the body to be selected is named '*Flystick body 01*'. Please define the orientation of the body coordinate system relative to the body (default setting is '*due to body*'). Make sure that all markers of the Flystick3 are seen by the cameras using the *Monitor 2DOF display* which appears in the background.

Press *Calibrate* and the calibration starts within 5 seconds. Please refer to page 50 for more information concerning *body calibration*.

Output settings Please define where the Flystick data has to be sent to. In ***DTrack2*** frontend software, select *Settings* → *Output*. You can either select *this computer* (= remote PC) or enter an IP address of another computer you want to send data to. By ticking the checkbox '*6df2*' you can define the Flystick data to be transmitted.
Please refer to chapter 4.3.6.3 on page 68 for more details.

Press *Start* to start the measurement. In order to see the tracking data you have to enable the Flystick display by clicking *Display* → *Flystick*.

5.3 Measurement Tool

Introduction The ***ART*** Measurement Tool is a pointing device for measurement or medical applications. In this specialized field it is very important to measure positions of points in high accuracy. For that reason the Measurement Tool is equipped with a measurement tip. The position of the tip can be measured with the optical tracking system.

Figure 5.7: Measurement Tool

Description The Measurement Tool is an add-on to the ***ART*** tracking system and is integrated into ***DTrack2*** by entering a license code, which can be supplied by ***ART*** . For the creation of the license code we need the serial number of the synccard. Click *DTrack2* → *Licenses* and *Hardware Info* to find out the serial number. Go back to license overview and add the license key delivered by ***ART*** for your Measurement Tool (refer to chapter 4.3.6.2 on page 59).

The pointing device carries a target that was developed to get optimal tracking quality for the use with two IR cameras. You will get the best measurement results, when the pointing device is facing the cameras as shown in figure 5.7 (i.e. markers have to be

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oriented towards the cameras). Typically, the position of the tool's tip is measured in the ***DTrack2*** room coordinate system which was fixed during room calibration.

Optionally, the ***ART*** Measurement Tool can calculate the position relative to a "reference body". Then, the Measurement Tool is measuring distances to the origin of the reference body coordinate system, and not to the origin which was defined during room calibration.

The output data consists of:

- position and orientation of the tool's tip,
- number of the Measurement Tool ,
- rotation matrix of the target.

Please refer to chapter B on page 121 for more information about the format of the output data.

Body calibration The calibration of the Measurement Tool is separated into two steps:

1. body calibration of the Measurement Tool and
2. calibration of the tip.

First of all, you have to define how many Measurement Tools you want to use. Therefore, please select *Settings → Measurement Tool* and define the '*number of Measurement Tools* '.

Now, please calibrate the Measurement Tool with a standard body calibration (see chapter 4.3.3 on page 50): select *Calibration → Body*. In the appearing dialogue the body to be selected is named '*Measurement Tool body 01*'. Please define the orientation of the body coordinate system relative to the body (default setting is due to body). Make sure that all markers of the Measurement Tool are seen by the cameras using the Monitor 2DOF display which appears in the background.
If you are working with a reference body you would have to calibrate it as well. This is done by a standard body calibration. Just select the body named '*Measurement Tool reference body 01*'.

Press "Calibrate" and the calibration starts within 5 seconds.

Tip calibration After successful body calibration, you have to calibrate the tip of the Measurement Tool : select *Calibration → Measurement Tool* .
Place the Measurement Tool in front of the cameras with the tip fixed at exactly one position.
Press *Calibrate* to start the calibration process. Gently move the Measurement Tool while keeping the tip still at exactly one position (i.e. tilt around its tip).
DTrack2 is calculating the position of the tip relative to the markers of the Measurement Tool , i.e. the origin of the body coordinate system is tranformed into the Measurement

Tool 's tip.

☞ **Note that the progress bar is not continuing if the pointing device is not moved sufficiently.**

If the tip calibration has been successful the result is presented in the dialogue *Measurement Tool Tip Calibration Result*. Please check the information displayed and either '*Accept*' or '*Cancel*' the tip calibration.

Output settings Please define where the Measurement Tool data has to be sent to. In ***DTrack2*** frontend software, select *Settings* → *Output*. You can either select *this computer* (= remote PC) or enter an IP address of another computer you want to send data to. By ticking the checkboxes '*6dmt*' and '*6dmtr*' you can define the Measurement Tool data to be transmitted. Please refer to chapter 4.3.6.3 on pag 68 for more details.

Press *Start* to start the measurement. In order to see the tracking data you have to enable the Measurement Tool display by clicking *Display* → *Measurement Tool*.

6 Frequently asked questions (FAQ)

Within this FAQ chapter we are offering solutions for easy-to-solve questions that our support encounters from time to time. The questions are grouped into specific topics to make it more convenient for you to find a solution.

In case you do not find a proper solution for your specific problem, please do not hesitate to contact us.
Our goal is to offer the best support possible. Therefore, we ask you to have the system running and that you have internet access when you call us. Sometimes, it might be possible to locate your problem if you deliver the following files:

- the configuration export file:
  Go to *DTrack2 → Configurations* and press '*log settings*'. Save this file to a location of your choice and mail it to us.

- the event log file:
  - Windows:
    Go to "*C:\Documents and Settings\username\.ART\DTrack2\version*" and mail the file "*events-yyyy-mm-dd.log*" to us.
  - Linux:
    In your home directory, go to "*.ART/DTrack2/version/*" and mail the file "*events-yyyy-mm-dd.log*" to us.

6.1 Backup

➪ How do I create a backup of important configurations?

From ***DTrack2*** v2.8.1 it is possible to export and import configurations. *DTrack2 → Configurations* → '*Save*' will export the complete active configuration. In case of an accidental deleting of a configuration it will be possible to restore the configuration presuming that an export has been carried out before. Then, it could even be a replacement Controller to '*Load*' the exported configuration on.

Please note that a room calibration might be necessary especially in case the number of cameras or the cameras themselves have changed.

6.2 Cameras

➪ One of my cameras recognizes a reflection which I can't eliminate. What can I do?

You may enable the suppression of static reflexes within ***DTrack2*** . But carefully read the notes on page 62.

6.3 Controller

➪ What are the possibilities to start the controller?

The controller is equipped with a switch that you have to press for the initial start-up. If you want to power up your controller remotely, you may either use Wake On LAN (WOL) or wake-on-power (WOP).

➪ I cannot find my controller. What can I do?

- Please make sure that the controller is connected properly to the Ethernet network.
- Switch on the controller.
- It is possible that your controller has become unreachable due to wrong IP settings (wrong IP address or IP address area, etc.). Please refer to chapter 4.1.2 on page 26.
- In case you are using a firewall, please do not block ***DTrack2*** communication.

For more information, please also refer to chapter 4.1.1 (page 25).

➪ What is the IP address of my controller?

You may use a standard USB stick and plug it in to the controller at any time. If not running yet, please switch on the controller. Its settings (IP address, etc.) will be saved to a setup file on the USB stick. This file may be opened and modified in any editor.

Please refer to chapter 4.1.2 on page 26 for more information.

➪ How can I assign a specific IP address to my controller?

There are two options to do this:

1. Modify the setup file (i.e. enter the IP address), save it to a USB stick and plug it in the controller. Please refer to chapter 4.1.2 on page 26 for more information.
2. Within ***DTrack2*** go to *Settings* → *Controller*. On the *General* tab, untick the check-box '*DHCP client*' and enter the desired '*IP address*' and '*subnet mask*'. Please refer to chapter 4.3.6.3 on page 72 for more information.

Chapter 6

6.4 *DTrack2* and shutter glasses

➪ What types of shutter glasses can be used with the *ART* tracking system

- RealD CrystalEyes 1, 2, 3 and 5
- NuVision APG6000 and APG6100
- XPand X101, X103 (with NuVision Long-Range Emitter), X104LX
- NVidia 3D Vision Pro (RF sync'ed)
- Volfoni EDGE (with Volfoni or NuVision LR Emitter)
- Virtalis ActiveWorks 500

➪ When I start tracking, the shutter glasses don't work correctly.

Most shutter glasses use infrared signals to synchronize the glasses with the image. The tracking cameras produce a strong infrared flash, which interferes with this communication. By synchronizing both systems, the cameras emit their flash in a way that does not interfere.

Please refer to chapter 4.1.1 on page 25.

➪ When I connect the "ExtIn", the shutter emitters stop working.

Some projectors create only a weak sync signal (TTL), which is not strong enough to drive the Synccard2. Please contact ***ART*** to get a special high-impedance version or synchronize against the video signal (if available).

➪ Tracking stops when no stereo image is displayed

Some graphics adapters only create the shutter image when a stereo image is displayed. If available, use video synchronization. Known behavior for NVidia adapters.

6.5 *DTrack2* and interfaces

➪ I'm using VRPN. Which output identifiers have to be activated?

It is absolutely mandatory that you activate at least the '*6d*' and '*6dcal*' output identifiers (refer to table 4.10 on page 69). Activate other output identifiers depending on your application (e.g. if you're using a Flystick you have to activate '*6df2*').

➪ I'm using VRPN and TrackD but I only succeed in receiving data via just one of them.

Please make sure that you are using two separate output channels with different port numbers.

➪ **I'm having problems with the Flystick2 or Flystick3 data transmission via TrackD.**

Please make sure that you are using the latest version of the TrackD module - ***ART*** will provide information upon request. Versions of trackd 5.5 which are older than February 2007 do not support data transmission for Flystick2 or Flystick3.

If you don't want to change the module you may also use the '*old output format*' in *Settings* → *Flystick*.

6.6 Software *DTrack2*

➪ **Where do I get the software *DTrack2* from?**

The software ***DTrack2*** is delivered on a USB flash drive with the tracking system. Furthermore, you may register for the ***ART*** Download Center (`http://www.ar-tracking.com/support/`) in order to always have access to the latest release of ***DTrack2*** .

➪ **Why is my frontend not starting up?**

- Please refer to chapter A.3 on page 119 for a list of supported operating systems.
- If using Windows XP: please check, that you have installed Service Pack 3 (SP3).
- If using Linux: some newer Linux distributions don't install the library `libpng12.so.0` as default, although it's part of the distribution. Please install it using an appropriate package installer.
- If using 64-bit Linux: please be sure, that you have installed the 64-bit ***DTrack2*** package. To run 32-bit ***DTrack2*** on 64-bit Linux, you might have to install the 32-bit version of several libraries (depending on your Linux distribution).

➪ **Some of my menu items are missing. What can I do?**

- Please check if the latest updates for your operating system are installed.
- Please refer to chapter A.3 on page 119 for a list of supported operating systems.

➪ **Where is the Monitor 2DOF display?**

- Please check if the latest updates for your operating system are installed.
- Please make sure that your firewall is not blocking ***DTrack2*** , even partly.
- Please refer to chapter A.3 on page 119 for a list of supported operating systems.

⇨ **My target is not visualized within the Monitor 2DOF display.**

- Please make sure that the target is inside the tracking volume and within tracking range of the cameras.
- Double-check the settings for the flash intensities of the cameras (refer to chapter 4.3.6.3 on page 62).
- In case you are using active targets, please make sure that you have activated the modulated flash. The camera to emit the modulated flash has to be on syncgroup #1. When using a Flystick3 you have to doublecheck additionally how many syncgroups are activated for the Flystick3 active target (*Settings → Flystick*).

⇨ **How do I define the number of targets to be tracked?**

Go to *Settings → Body Administration* and change the '*number of 6DOF bodies*'.

⇨ **What is the maximum number of targets?**

The maximum number of targets (including Flysticks and Fingertracking hand devices) is depending on the license type:

- Basic and Extended license: 4
- Full-featured license: 50

Starting with ***DTrack2*** version v2.10 a new license model has been established.
You may activate and calibrate 4, 10, 30 or up to 50 targets depending on the license purchased.

Please refer to table 4.1 on page 43 for a complete license overview.

⇨ **Where do I get a license code from?**

You may purchase additional licenses for your system. Please contact us in case you need consultation.

For creating a new license code we will need some information from you:
Go to *DTrack2 → Licenses*, select the license you want to add and click on *Hardware Info*.
Contact ***ART*** and tell us the synccard number. If you are using a ***TRACKPACK*** system (discontinued) please tell us the MAC address of the Ethernet adapter.

⇨ **Where do I enter a new license code?**

Go to *DTrack2 → Licenses* and enter the code in line '*new license code*'.

⇨ **Where do I get a software update from?**

The latest release of ***DTrack2*** is always available at the ***ART*** Download Center (`http://www.ar-tracking.com/support/`).

➪ I want to run a software update. How do I preserve my data and my configurations?

Your data and your configurations are automatically preserved when running a software update. But it is recommended to regularly create backups of your configuration(s).

➪ How do I run a software update?

Please contact ***ART*** to receive the latest software release and follow the instructions in chapter 4.3.1.3 on page 39.

➪ Do I have to update the *DTrack2* frontend software and the software of the controller at the same time?

We recommend to do so.

➪ My specific settings have been lost.

Please check if the correct configuration is selected:
go to *DTrack2* → *Configurations* and select the correct configuration.

➪ Is it possible to automatically start the measurement after booting the controller?

Yes, go to *Settings* → *Tracking* and tick the checkbox '*automatic start of measurement after booting*'.

➪ May I close the *DTrack2* frontend software window after starting the measurement?

Yes, the measurement continues even if the ***DTrack2*** frontend software is not active.

➪ What's the version of my *DTrack2* software?

Go to *About* → *DTrack2* to find out the version of your ***DTrack2*** frontend software. The software version of your controller is shown when you select *Controller*.

➪ There are greyish areas in my Monitor 2DOF display. What do they indicate?

The static reflex suppression is currently active. This is indicated with these greyish areas. Markers in these areas will not contribute to tracking.

Please refer to chapter 4.3.6.3 on page 62 for more information.

➪ What do the abbreviations "SR", "DR" and "UD" mean?

SR ... static reflex suppression active
DR ... dynamic reflex suppression active
UD ... display orientation is upside down

Please refer to chapter 4.3.6.5 on page 78 for more information.

➪ The display bar in the Monitor 2DOF display is indicating very high radiation intensities, although no markers are illustrated. Where's the radiation coming from?

Furthermore, remove other strong IR radiation sources from the tracking volume or, at least, prevent them from interfering with the tracking system.

6.7 Calibration

➪ How can I find out when the room has been calibrated last time?

Please go to *Calibration* → *Room* and click *Show details*. The date of the last room calibration is shown.

➪ How do I define position and orientation of the room coordinate system?

The calibration angle defines position and orientation of the room coordinate system depending on how you place it within the tracking volume. Please refer to table 4.2 on page 46.

DTrack2 offers a limited possibility to adjust the room coordinate system after the room calibration. Please refer to chapter 4.3.6.4 on page 74 for more information.

➪ How do I have to move the wand?

Move the wand gently within the measurement volume, in order to generate a virtual point cloud. This point cloud should fill at least about two thirds of the measurement volume. Please refer to chapter 4.3.2 on page 44 for more information.

➪ I do not succeed in performing a room calibration.

- Please make sure that the calibration angle is placed within the measurement volume such that it is seen completely by at least two cameras (→ verify with *Monitor 2DOF* display). If not all cameras see the angle be sure that a sufficient volume connects each camera to the others. No other marker except for the ones belonging to the calibration angle should be visible.
- Please make sure that the correct calibration set ('*Room Calibration Set TP*', '*Room Calibration Set 410*' or '*Room Calibration Set 710*') is selected in the settings for

room calibration.

- Please make sure that no reflections are seen by the cameras. If it is not possible to eliminate the reflections you may use static suppression of reflections to remove them.
- Please make sure that the markers positioned on the calibration angle are not damaged or misarranged.
- Increase the flash intensities of the cameras until all markers are of good quality (i.e. at least yellow).

Restart the room calibration. Use the wand to create the virtual point cloud within the measurement volume. Avoid rapid and hectic movement.

➪ I cannot cover two thirds of the measurement volume within the set time for the room calibration. How do I extend the time for the calibration process?

Please open the dialogue room calibration from the Calibration menu and press the button Show Details. There you can extend the time for the calibration process.

➪ How shall I evaluate the room calibration results?

The value '*Used Frames*' represents the percentage of valid (i.e., used for room calibration) data for each camera. It should be as high as possible for all cameras. Values under 50% indicate poor room calibration quality. The number of valid frames should be greater than 70% for each camera.

Please note that percentages of more than 70% may not be possible when chain calibration is executed.

➪ *DTrack2* reports the error message "*no angle tool detected*". What went wrong?

First of all, please double-check if all markers are visible and that there are no disturbing reflexes. Sometimes, it might help to move the calibration angle a little bit.
Please always verify the settings for the room calibration before repeating:

- wand length is printed on a label on the wand,
- select the correct calibration set and

➪ The progress bar of the room calibration stopped.

Please double-check in the *Monitor 2DOF* display whether the calibration wand is recognized by the cameras during its movement.

➩ What is a "re-calibration" and when do I have to perform one?

DTrack2 provides simplified room and body calibrations, called room and body re-calibration. The main advantage of a re-calibration is that ***DTrack2*** preserves the origin and the orientation of your coordinate system.

You may perform a room re-calibration from time to time or if a camera moved slightly (e.g. due to mechanical instabilities). If your body fell down and the structure bent you should carry out a body re-calibration.

Please refer to chapter 4.3.2 on page 47 and chapter 4.3.3 on page 54 for more information.

➩ What does '*scaling factor*' mean?

Performing a room calibration results in a certain scaling error. This might be a problem when applications do have very high accuracy requirements (e.g. when performing measurements with the Measurement Tool).
The scaling error can be determined, for instance, by measuring points on a defined scale (e.g. tape measure). The determined scaling error can thus be adjusted with the ***DTrack2*** '*scaling factor*' (refer to chapter B.1.1.1).

Please contact ***ART*** if you require further information.

➩ I cannot calibrate my target.

- Please check if the markers of the target are seen by the cameras in good quality (i.e. at least yellow) - a slight change of the target position might help. If necessary increase the flash intensities of the cameras. Therefore, go to *Settings* $\rightarrow$ *Cameras*.
- Make sure that when starting the body calibration every marker of the target is visible to the cameras.
- A body calibration can be carried out only if a valid room calibration has been carried out before. Otherwise, the button *Calibrate* is grey and cannot be clicked. Check in the *Event Display* if there is a warning saying "no valid room calibration".
  In that case, please carry out a new room calibration.
- Please make sure using the *Monitor 2DOF* display that no marker is overlapped (i.e. merged) by another one. If necessary rearrange the target and restart the body calibration.
- Try to carry out the body calibration with a moving target. Therefore, shift the starting position of the target for calibration (often a shift of 10 or 20cm is enough to enable calibration again).
- Make sure that no other markers or targets but the one you want to calibrate, are inside the tracking volume.

- Please carry out a new room calibration.

➪ I'd like to save all my body files for backup reasons but I receive less files than configured bodies.

DTrack2 only creates body files for calibrated bodies. For example: if you configured 15 targets for tracking but only 4 of them are calibrated, you will only receive 4 calibration files.

➪ I'd like to calibrate a body but the body calibration dialogue is greyed out.

Please ensure that you have performed and accepted a valid room calibration prior to body calibration.
You may only calibrate bodies if you have the "Extended" or the "Full-featured" license. With a "Basic" license you are only able to calibrate bodies using a calibration file.
Starting with ***DTrack2*** version v2.10 a new license model has been established. Thus you are always allowed to manually calibrate up to 4 bodies at least.

Go to *DTrack2* → *Licenses* to see which license you have.

➪ What is the difference between '*due to body*' and '*due to room*'?

When selecting '*due to body*', the body coordinate system is fixed by the markers of the rigid body. The origin of the body coordinate system is set to the center of gravity of all markers building the rigid body when '*due to room*' is used.

Please refer to chapter 4.3.3 on page 50 for more information.

➪ Do I have to move the target while performing a body calibration?

If possible we recommend to perform moderate movements because accuracy can be improved doing so. However, the body has to be visible to the cameras all the time.

➪ May I change the position and the orientation of the body coordinate system later on?

Yes, you may use the dialogue *Body adjustment* to alter position and orientation of the body coordinate system. Please refer to chapter 4.3.6.4 on page 75 for more information.

➪ How do I define a name for a target?

Go to *Settings* → *Body Administration (F8)*. Double-click into the name field and enter a name for the respective body.

⇨ I cannot increase the number of targets anymore.

The maximum number of targets (including Flysticks and Fingertracking hand device) to be tracked depends on the license code that is installed. With the "Basic" and the "Extended" license you may only use 4 targets at the same time - the "Full-featured" license supports 50 targets.
Starting with ***DTrack2*** version v2.10 a new license model has been established. You may activate and calibrate 4, 10, 30 or up to 50 targets depending on the license purchased.

Please refer to table 4.1 on page 43 for more information.

⇨ How shall I evaluate the body calibration results?

Verify that all markers of the target have been recognized during the ***DTrack2*** body calibration. Further, you may check if the single distances between the markers are correct (refer to chapter 4.3.3 on page 50).

As a special service you may send us the calibration file and we are going to check it.

6.8 Tracking

⇨ My target (active or passive) is not recognized sporadically or only partly or even not at all.

- Go to *Settings → Cameras* and tick the checkbox '*modulated flash*'. The camera that sends out the modulated flash has to be on syncgroup # 1.
- Also, take into account that the distance between active target and cameras should not exceed 2.5 m
- Deactivate the dynamic reflex suppression. Go to *Settings → Cameras* and untick the checkbox '*dynamic reflex suppression*'.
- Active targets cannot be used near or in front of plasma screens. The IR emission of the plasma screen overdrives the IR receiver in the active target.
- Please perform a new room calibration.
- Double-check if the marker surface is not dirty or dusty and that it doesn't appear to be worn out.

⇨ Tracking does not work.

- Please make sure that the measurement has been started and that the target is within tracking range of the cameras.
- If marker recognition is poor then increase the flash intensity.

- Check number of markers that are used for calculation. If all markers of the target are seen by the cameras, but partly not used for calculation, then execute a new room calibration.
- Go to *Settings* → *Output*. Define a receiver for the tracking data and configure the type of data to be transmitted.
- Activate the tracking functionality within your graphics application.

➪ **I'm having too many heavy reflections.**

- Please double-check that the flash intensities of the cameras are not too high. In general, a flash intensity of 3-4 might be sufficient.
- Make sure that no other strong infrared radiation sources (e.g. sunrays or halogen lamps) are present in the tracking volume. If they cannot be removed you may use the reflex suppression feature of ***DTrack2*** .

➪ **Does *DTrack2* send data if no target is being tracked?**

No tracking data is sent except for the frame number ('*fr*').

➪ **The application PC does not receive tracking data.**

- Go to *Settings* → *Output*. Define a receiver for the tracking data and configure the type of data to be transmitted.
- Check the network connection physically and try to address the controller with a 'Ping'.
- Double-check with a UDP receiver if data is being sent by the controller.
- Activate the tracking functionality within your graphics application.

➪ **May I use passive and active targets at the same time?**

Yes, of course, there a no restrictions on using passive and active targets simultaneously.

➪ **I am moving my target upwards but within the Monitor 2DOF display it moves downwards.**

The camera is set to display data upside down. In the Monitor 2DOF display, right-click on the respective camera window and disable *Display upside down*.

6.9 Flystick

➩ **My Flystick is not presented within the available Flysticks list.**

- Make sure that the battery is charged. Press any button of the Flystick and the orange status LED should be switched on.

➩ **Why is the pressing of the Flystick buttons not recognized (within *DTrack2*)?**

- Make sure that the battery is charged. Press any button of the Flystick and the orange status LED should be switched on.
- Double-check whether the button pressed events are recognized by ***DTrack2*** . Therefore:
  - enable the Flystick Display (*Display* → *Flystick*)
  - blue rectangles should light up on each button pressed event in the Flystick Display.
- Go to *Settings* → *Flystick* and assign your Flystick (to be found in the available Flysticks list) to any '*Flystick ID*'.

➩ **Why is the pressing of the Flystick buttons not recognized (within the graphics application)?**

- Make sure that the battery is charged. Press any button of the Flystick and the orange status LED should be switched on.
- Go to *Settings* → *Flystick* and assign your Flystick (to be found in the available Flysticks list) to any '*Flystick ID*'.
- Go to *Settings* → *Output* and check if the data output is configured correctly:
  - data receiver defined ('*send to*'),
  - identifier '*6df2*' selected,
  - if you are using the old output format: identifier '*6df*' selected.

➩ **What is the maximum number of Flysticks to be used simultaneously?**

type	**max. number**
Flystick2	5
Flystick3	1

Please double-check that the targets of the Flysticks, that are used simultaneously, are not identical. If doubts remain please contact ***ART*** .

➪ **What is the MultiUser option for Flysticks?**

The MultiUser option is an enhancement especially for VR/AR applications when working with more than one Flystick.

Please refer to chapter 5.1 on page 86 for more information.

➪ **The Flystick output data is not transmitted.**

Go to *Settings* → *Output* and check if the data output is configured correctly:

- data receiver defined ('*send to*'),
- identifier '*6df2*' selected,
- if you are using the old output format: identifier '*6df*' selected.

6.10 Measurement Tool

➪ **I'm using the Measurement Tool demo but I cannot measure any points.**

Please check whether both, the Measurement Tool and the Measurement Tool reference body (if assigned), are tracked.

➪ **It is not possible to perform a tip calibration.**

Please check whether both, the Measurement Tool and the Measurement Tool reference body (if assigned), are tracked.
Then, try to keep the tip in the same position while doing the tip calibration. Therefore, tilt the Measurement Tool in both room directions, not only in one direction (i.e. left and right, as well as back and forth). When rotating around one axis only, a tip position cannot be defined.

6.11 Active Targets

➪ **Operation near plasma screen**

A plasma screen is a very strong IR source which overdrives the IR receiver in the active target (e.g. Flystick3, Fingertracking). Thus, active targets may not work properly near plasma screens. If possible use passive targets as alternative.

6.12 *ART* tracking and 3D TVs

➪ **Synchronization**

3D TVs are primarily consumer products which have not been designed to fulfill the requirements of professional users. In fact, this especially applies when it comes to synchronizing the 3D TV and the tracking system. Typically, there's no defined synchronization output which could be used easily. In some rare cases, ***ART*** might be able to assist.

⇨ Shutter glasses

IR synchronized shutter glasses might not work with ***ART*** tracking systems. Due to the increasing variety, ***ART*** only validated a few of these shutter glasses. However, we may support customers who are performing tests with not validated shutter glasses.
Please contact us to receive information on this issue.

6.13 Radio transceivers used in *ART* products

⇨ Can *ART* radio transceivers pose any security issue ?

Radio transceivers for Flysticks, Measurement Tool or Tactile Feedback use a protocol based on IEEE 802.15.4 which was developed in-house at ***ART*** specifically for these devices. There are no other devices which can understand this protocol. The design of the ATC ensures that use of this protocol is limited to transfering measurement data (like button-pressed events) and configuring devices.

7 General Information

7.1 Service

It is recommended to maintain the equipment every three years. If you experience any problems please do not hesitate to contact our support.

Never try to repair anything yourself!!

Opening the equipment implies risks for health and environment as well as loss of warranty and liability.

7.2 Cleaning of the equipment

Only the housing of the cameras may be cleaned. Before cleaning shut down the system and disconnect the power cords.
Never use water or any chemicals. Just use a dry, lint-free and antistatic tissue like lens-cleaners for optical equipment.

Do not open the housings!

Opening the housings implies risk for health and environment, as well as loss of warranty and liability.

7.3 Warranty and liability

Hardware ***ART*** warrants the hardware to be free from defects in workmanship and material under normal use and service and in its original, unmodified condition, for a period of 24 months from the time of purchase. The time of purchase is defined as the day when the end-user takes possession of the equipment. If ***ART*** or any company authorized by ***ART*** installs the system, the time of purchase is the time of the first installation.
In case of defects during the warranty period, ***ART*** will repair or replace any defective parts. Replaced parts become property of ***ART*** .

Software Software supplied either on the tracking-PC or in cameras is furnished on a tested "As Is" basis. ***ART*** explicitly does not warrant that the software is error (bug) free.

If the users detect bugs, ***ART*** will provide a workaround or bug fix as soon as possible after the notification.

Liability ***ART*** products are not authorized for use in any circumstances where human life might be endangered by malfunction, measurement errors or interrupted operation of the system without written approval of a managing director of ***ART*** .
It is the user's sole responsibility to check the results of the measurement data and to protect any consecutive system against malfunction, measurement errors or interrupted operation of the systems supplied by ***ART*** . Under no circumstances ***ART*** can be held liable for consequential damages or incidental costs, including production downtimes, whether arising from measurement errors, interrupted operation or any other malfunction of the system.

Warranty restrictions All warranty and liability is void, if the system

- is not operated according to the manual,
- shows damages or signs of abuse,
- has been opened by non-authorized people (non-members of ***ART*** and companies not authorized by ***ART***),
- has been modified by the user or any third party,
- has not been used according to the specifications of this manual.

7.4 Declaration of conformity

ART
Advanced Realtime Tracking

CE

EUROPEAN DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

SMARTTRACK

to which this declaration relates is in conformity to the following standard(s) or other normative document(s)

2006/95/EC (Low Voltage Directive):	IEC 60950-1/A1:2009 EN 60950-1/A2:2013
2004/108/EC (EMC Directive):	EN 55022:2010 EN 55024:2010 EN 61000-3-2:2006 + A2:2009 EN 61000-3-3:2008

Weilheim i. OB, 08.09.2014

Dr. A. Weiss (Managing Director)

Advanced Realtime Tracking GmbH Am Öferl 6 82362 Weilheim i. OB Germany

ART
Advanced Realtime Tracking

FCC

MANUFACTURER'S FEDERAL COMMUNICATION COMMISSION DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

SMARTTRACK

to which this declaration relates is in conformity to the following standard:

FCC 47 CFR Part 15, Subpart B
Class B digital device

Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.

Weilheim i. OB, 08.09.2014

Dr. A. Weiss (Managing Director)

Advanced Realtime Tracking GmbH Am Öferl 6 82362 Weilheim i. OB Germany

CERTIFICAT ◆ CERTIFICADO ◆ CERTIFICAT ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ 認証証書 ◆ CERTIFICATE ◆ CERTIFIKAT

TÜV SÜD

Product Ser

CERTIFICATE

No. Z1A 14 04 52228 007

Holder of Certificate:	**Advanced Realtime Tracking GmbH** Am Öferl 6 82362 Weilheim GERMANY
Factory(ies):	52228
Certification Mark:	TÜV SÜD Production monitored Safety tested; TÜV SÜD GS geprüfte Sicherheit
Product:	**Scanner (IR-Tracking Camera)**
Model(s):	**SMARTTRACK**

Parameters:

	SMARTTRACK
Rated voltage:	5 VDC
Rated power:	max. 20 W
Protection class:	III

Tested according to: EN 60950-1/A2:2013
ZEK 01.4-08

The product meets the safety and health requirements of the German Product Safety Act section 20 to 22 ProdSG. The certification marks shown above can be affixed on the product. It is not permitted to alter the certification marks in any way. In addition the certificate holder must not transfer the certificate to third parties. This certificate is valid until the listed date, unless it is cancelled earlier. See also notes overleaf.

Test report no.:	028-713035476-000
Valid until:	2019-04-08

Date, 2014-04-11

(Ralph Fischer)

Page 1 of 1

TIFIKAT • CERTIFICATE • 認証証書 • СЕРТИФИКАТ • CERTIFICADO • CERTIFICAT

CERTIFICATE

No. U8 14 04 52228 008

Holder of Certificate: **Advanced Realtime Tracking GmbH**
Am Öferl 6
82362 Weilheim
GERMANY

Production Facility(ies): 52228

Certification Mark:

C TÜV SÜD NRTL US

Product: **Scanner (IR-Tracking Camera)**

Model(s): **SMARTTRACK**

Parameters:

	SMARTTRACK
Rated voltage:	5 VDC
Rated power:	max. 20 W
Protection class:	III

Tested according to: UL 60950-1:2007
CAN/CSA-C22.2 No. 60950-1-07

The product was voluntarily tested according to the relevant safety requirements noted above. I can be marked with the certification mark above. The mark must not be altered in anyway. This product certification system operated by TÜV SÜD America Inc. most closely resembles systen 3 as defined in ISO/IEC Guide 67. Certification is based on the TÜV SÜD "Testing and Certification Regulations". TÜV SÜD America Inc. is an OSHA recognized NRTL and a Standards Council of Canada accredited certification body.

Test report no.: 028-713035476-000

Date, 2014-04-10

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A Technical specifications

☞ **The specifications are subject to change without notice.**

A.1 *SMARTTRACK*

Power supply

Nominal voltage	5V DC
Maximal current	4A
Maximal power	20W
Ext. power supply	5V / 4A / 20W

Protection category

Ext. power supply	I
Camera	III

Interface connectors

data	RJ45
synchronization	BNC
power	external
Flystick2 and 3	internal Radio Transceiver, no external USB Radio Transceiver is allowed

Operating conditions

Temperature	0 .. 35°C
Relative humidity	5 .. 50%
	non-condensing
Cooling system	active (fan)

Dimensions

Length	approx. 420mm
Width	approx. 105mm
Height	approx. 55mm
Weight	approx. 1300g

Performance

Frame rate	max. 60fps (adjustable)
IR flash	850nm

Max. tracking distance with 12mm passive markers (F .. focal length in mm).

@ F = 2.1mm	2.5m

Maximum number of 6DOF targets (simultaneously)

@ 60fps	> 4

Field of view (FoV for each lens, horizontal × vertical)

@ F = 2.1mm	100° × 84°

A.2 Flysticks

	Flystick2	Flystick3
Power supply		
Rechargeable battery [1]	3 standard AAA batteries	lithium battery (850mAh / 3.7V) integrated in the handheld
Continuous operation[2]	at least 10 hours	at least 8 hours
Battery charging duration		
Operation possible with connected charger	no	yes
USB transmitter		
Connection to the PC	USB	USB
Radio range (depending on setup location, e.g. walls)	at least 7m	at least 7m
Radio module		
Type ID	IEEE 802.15.4	IEEE 802.15.4
Frequency	2.4 GHz	2.4 GHz
Transmission power	1	1
Operating conditions		
Operating temperature	0 .. 40°C	0 .. 38°C
Relative humidity	5 .. 50%, non-condensing	5 .. 50%, non-condensing
General features		
Target type	passive markers	passive or active markers (IR-LEDs @ 880nm)
Tracking range (@ 3.5mm focal length)	approx. 4m	approx. 4.5m
Weight	250g	120g
Size	220mm x 180mm x 100mm	245m x 90mm x 75mm

[1] replacement after a period of 2 years is recommended
[2] only valid for new batteries

A.3 Overall system

Compatible shutter glasses

NuVision APG6000	×
NuVision APG6100	×
NVidia 3D Vision Pro	×, radio synchronization
RealD CE1	×
RealD CE2	×
RealD CE3	×
RealD CE4	-
RealD CE5	×
Volfoni EDGE	×, with Volfoni or NuVision Long-Range Emitter
XPand X103	×, with NuVision Long-Range Emitter
XPand X101	×
XPand X104LX	×
Virtalis ActiveWorks 500	×

***DTrack2* frontend software**

System requirements	
- Free disk space	≥ 200MB
- Processor	Intel: ≥ P4 2GHz
	AMD: ≥ K6 1.6Ghz
- RAM	≥ 1GB
Operating systems	Windows XP 32/64 Bit, with Service Pack 3 (SP3)
	Windows 7 32/64 Bit
	Windows 8/8.1 32/64 Bit
	Linux openSUSE ≥ 12.3 32/64 Bit
	Linux Ubuntu ≥ 10.04 32/64 Bit
	Linux CentOS ≥ 6.6 32/64 Bit
Settings firewall (remote PC)	
- used ports	50105 (for UDP & TCP)
	50110 (for UDP)

Appendix A

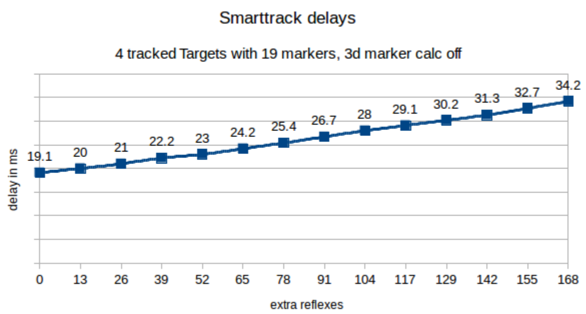
A.4 System latency

System Latency

Definition of the system latency:
The system latency is defined as the time delay between sending out the IR flash by the cameras and the availability of the tracking data at the Controller's Ethernet output. The latency is a function of the number of cameras, the number of targets, enabled or disabled 3DOF tracking and additional reflexes (e.g. single markers). Another dependency, which is quite important, can be found in the software version of ***DTrack2*** being used (here: v2.8.6). We recommend to always use the latest version in order to have the most recent features.

For ***SMARTTRACK*** : The ***SMARTTRACK*** is triggered externally with an arbitrary function generator at 60 Hz. The network package with the tracking results can be triggered with an oscilloscope.

SMARTTRACK



B Technical Appendix

B.1 Definition of Coordinates and Rotations

B.1.1 Room Calibration

The calibration angle defines origin and axes of the coordinate system. This can be done in two different ways:

Type	longer arm	shorter arm
'*normal*'	+X axis	+Y axis
'*powerwall*'	+X axis	-Z axis

For example, a room calibration of type '*normal*' would result in a coordinate system like the following:

1. The marker located in the crossing point of the two arms is defining the origin of the coordinate system.
2. The longer arm of the calibration tool defines the +X axis.
3. The shorter arm of the calibration tool defines the +Y axis. (i.e., the tool markers define the X/Y plane.)
4. The Z axis is added in order to give a right-handed coordinate system.

B.1.1.1 Room Adjustment

DTrack2 allows to modify the room coordinate system by specifying these seven values:

- l_x, l_y, l_z for a translational offset (denoted x, y, z in the GUI),
- η, θ, ϕ for a rotation (denoted rx, ry, rz in the GUI).
- s for a scaling factor.

These offsets are defined as a shift and/or rotation and/or scaling of the room coordinate system relative to the original one. Mathematically a point $\vec{x}_{orig}$ in the original room is transformed into a point $\vec{x}_{mod}$ in the modified room coordinate system by:

$$\vec{x}_{mod} = (R^T \cdot \vec{x}_{orig} - \vec{l}) \cdot s$$

where the rotation matrix R is calculated from η, θ and ϕ like defined in section B.1.3.

Appendix B

B.1.2 Body Calibration

During the body calibration ***DTrack2*** is fixing a local coordinate system (body coordinate system) for each rigid body. Both coordinate systems define the later 6DOF output (see chapter B.1.3 on page 123). The calibration can be done in three different ways (to be selected in the menu *Calibrate / Body* of the body calibration):

B.1.2.1 Definition of the Coordinates by the Body itself

Body calibration setting *due to body*:

The body coordinate system is fixed by the markers of the rigid body according to a set of rules:

1. Search the biggest distance between two markers of the rigid body. These two markers (#1 and #2) will define the X axis.
2. Search for a third marker (#3) that has the smallest distance to one of the two markers #1 and #2. The marker that has smallest distance to marker #3 becomes marker #1. It will define the coordinate origin. The other marker will be #2. The positive X axis is directed from marker #1 to marker #2.
3. Marker #3 defines the X/Y plane, together with markers #1 and #2. Marker #3 has a positive Y coordinate.
4. The Z axis is already defined by these rules, resulting in a right-handed coordinate system.

B.1.2.2 Definition of the Coordinates by the Room Coordinate System, with Origin in the Center of the Markers

Body calibration setting *due to room*:

The origin of the body coordinate system is set to the center (center of gravity) of all markers building the rigid body. The axes of the body coordinate system are parallel to the axes of the room coordinate system in the beginning of the body calibration.
I.e., the result of a body calibration will depend on the angular position of the target during calibration. A 6DOF measurement, following calibration without having moved the body, will give the angular coordinates 0° / 0° / 0°.
If the target was moved during calibration, the angular position of the target at the beginning of the calibration will be taken.

B.1.2.3 Definition of the Coordinates by the Room Coordinate System, with Origin in a Marker

Body calibration setting *due to room (zero in marker)*:

A combination of the first two methods. The direction of the axes of the body coordinate system will be set parallel to the room coordinate system in the moment of body calibration - like done with setting *due to room*. The origin of the body coordinate system is given by one marker of the body, according to the rules given for setting *due to body*.

B.1.2.4 Coordinate System Definition for 5DOF Targets (with and without cylinder markers)

Body calibration setting *x*/*y*/*z*:

In the body coordinate system all markers of the target are on the selected axis. The origin is in the middle between the two markers with the largest distance to each other. The orientation is defined by the marker with the smallest distance to the origin. Its position has a negative sign. The other two directions are undetermined due to the one degree of freedom.

B.1.2.5 Coordinate System Definition for two 5DOF Targets with cylinder markers

Body calibration setting *xy*/*yx*/*yz*/*zy*/*zx*/*xz*:

The body is expected to consist of two about perpendicularly connected 5DOF targets. These are placed on the two axes. The origin is placed at the position where the two 5DOF targets intersect. The first axis is assigned to the 5DOF target which includes the marker with the largest distance to the origin. The other 5DOF target is placed in the plane created by the two axes.

B.1.3 6DOF Results

Position and Orientation

Position and orientation of a target are expressed by an affine transformation ($\vec{s}$, R) that transforms a vector $\vec{x}$ from the body coordinate system to the room coordinate system:

$$\vec{x}_{room} = R \cdot \vec{x}_{body} + \vec{s}$$

I.e., the coordinates $\vec{s}$ give the position of the origin of the body coordinate system (marker #1 or center of gravity, as described above), measured in room coordinates.
The 3×3 rotation matrix R describes the rotation part of the transformation. The columns of the matrix R are the axes (X, Y, Z) of the body coordinate system, expressed in room coordinates.

Description by Rotation Angles

The rotation matrix can be replaced by three consecutive rotations $R_i(\chi)$ (rotation angle χ, rotation axis i). The angles, as given in the ***DTrack2*** data output, are defined by the equation:

$$R = R_x(\eta) \cdot R_y(\theta) \cdot R_z(\phi)$$

Expressed in trigonometric functions, that means:

$$R = \begin{pmatrix} \cos\phi\cos\theta & -\sin\phi\cos\theta & \sin\theta \\ \sin\phi\cos\eta + \cos\phi\sin\theta\sin\eta & \cos\phi\cos\eta - \sin\phi\sin\theta\sin\eta & -\cos\theta\sin\eta \\ \sin\phi\sin\eta - \cos\phi\sin\theta\cos\eta & \cos\phi\sin\eta + \sin\phi\sin\theta\cos\eta & \cos\theta\cos\eta \end{pmatrix}$$

Note that per definitionem the angles can only have the values:

$$-180^\circ \leq \phi \leq 180^\circ, -90^\circ \leq \theta \leq 90^\circ, -180^\circ \leq \eta \leq 180^\circ$$

☞ **Note: rotation angles can show strange behaviour at certain orientations. In particular, for orientations close to $\theta = \pm 90°$ the other two angles can experience large odd-looking changes.**

When connecting ***DTrack2*** to an application, often problems appear caused by different definitions of rotation angles. To avoid that, we recommend to use rotation matrices.

B.1.4 3DOF Data

Besides the tracking of 6DOF bodies, ***DTrack2*** is able to calculate the coordinates of single markers, i.e. markers that can not be recognized as part of a rigid body. The output values are the coordinates of these markers, measured in room coordinates.
In some situations, a rigid body within the measurement volume is (temporarily) not correctly recognized by the software. In these cases, its markers appear as 3DOF objects.
3DOF markers are tracked (as long as possible) and labeled with an ID number. When a 3DOF marker vanishes (or is recognized as part of a 6DOF body), its ID number will not be used any more, as long as the tracking is active.

B.1.5 Flystick devices

DTrack2 is supporting the following input devices:

- Flystick2 and
- Flystick3.

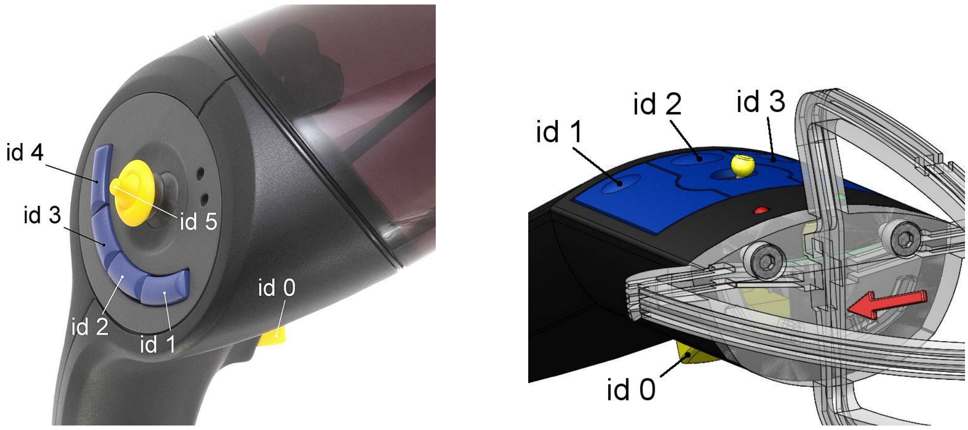
Each of the afore mentioned devices is equipped with buttons (4 - 8) and a small joystick. Input transactions are transmitted wirelessly to the controller and added to the 6DOF tracking result of the Flystick body.
There are two types of output formats available, called `6df` and `6df2` (details see chapter B.2.5 on page 129 and chapter B.2.6 on page 130); they differ in the number of carried input controls. Only the newer `6df2` format is capable of processing analogue values (or controllers) as produced by a joystick. Both formats use the same order of buttons (details see below):

Output Format	Number of Buttons	Order of Buttons	Number of Controllers
`6df`	8 (fix)	“right to left”	—
`6df2`	device dependent	“right to left”	device dependent

B.1.5.1 Flystick2

Each Flystick2 is equipped with six switches (buttons) and a small joystick, that produces two analogue values, one for horizontal and one for vertical movement. When using the old output format `6df`, the joystick values are transferred into hat switch actions; two of the buttons cannot be accessed.

Switch	labelled as (in figure B.1)	`6df` Output	`6df2` Output
front switch (yellow)	id 0	code 01 (hex)	button code 01 (hex)
outer right switch on backside (blue)	id 1	code 02 (hex)	button code 02 (hex)
inner right switch on backside (blue)	id 2	code 04 (hex)	button code 04 (hex)
inner left switch on backside (blue)	id 3	code 08 (hex)	button code 08 (hex)
outer left switch on backside (blue)	id 4	–	button code 10 (hex)
switch on joystick (yellow)	id 5	–	button code 20 (hex)
joystick (yellow) to the left	–	code 20 (hex)	first controller up to 1.0
joystick (yellow) to the right	–	code 80 (hex)	first controller up to -1.0
joystick (yellow) up	–	code 40 (hex)	second controller up to 1.0
joystick (yellow) down	–	code 10 (hex)	second controller up to -1.0



(a) Flystick2 (b) Flystick3

Figure B.1: Allocation of ID number to the Flystick buttons

B.1.5.2 Flystick3

Each Flystick3 is equipped with four switches (buttons) and a small joystick, that produces two analogue values, one for horizontal and one for vertical movement. When using the old output format `6df`, the joystick values are transferred into hat switch actions.

Switch	labelled as (in figure B.1)	`6df` Output	`6df2` Output
bottom switch (yellow)	id 0	code 01 (hex)	button code 01 (hex)
top right switch (blue)	id 1	code 02 (hex)	button code 02 (hex)
top middle switch (blue)	id 2	code 04 (hex)	button code 04 (hex)
top left switch (blue)	id 3	code 08 (hex)	button code 08 (hex)
joystick (yellow) to the left	–	code 20 (hex)	first controller up to 1.0
joystick (yellow) to the right	–	code 80 (hex)	first controller up to -1.0
joystick (yellow) up	–	code 40 (hex)	second controller up to 1.0
joystick (yellow) down	–	code 10 (hex)	second controller up to -1.0

Appendix B

B.1.6 Measurement Tools

Only available, if the Measurement Tool license is present for *DTrack2* (available since version v2.2.0)

The Measurement Tool license allows the use of Measurement Tools , i.e. pointing devices with a special target geometry. While tracking, the module calculates position and orientation of the tip of the tool. It is necessary to perform an additional calibration procedure (called tip calibration) to provide the module with information about the tip.

B.1.6.1 Orientation of a Measurement Tool

The module modifies the local coordinate system (i.e. the body coordinate system) of the tool's body as follows:

1. The tip becomes the origin of the coordinate system.
2. The marker with the largest distance to the tip defines the +Z axis.
3. The marker, that is closest to the tip, defines the Y/Z plane.

This definition shall ease the use of the tip orientation. For instance, the orientation of all ***ART*** Measurement Tools is approximately along the -Z axis.

B.1.6.2 Using a reference body

When using a reference body for a Measurement Tool , the module calculates the position of the tip $\vec{x}^S_{ref}$ within the local coordinate system of the reference body:

$$\vec{x}^S_{room} = R_{ref} \cdot \vec{x}^S_{ref} + \vec{s}_{ref}$$

where $\vec{x}^S_{room}$ is the position of the tip in room coordinates, and $(\vec{s}_{ref}, R_{ref})$ position and orientation (see B.1.3) of the reference body. The orientation of the Measurement Tool is transformed in an analogous way.

B.2 Output of Measurement Data via Ethernet

DTrack2 uses ethernet (UDP/IP datagrams) to send measurement data to other applications. The IP address and the port of the application (and the computer it runs on) can be configured in *Settings → Output*.
Each datagram carries all the results of a single measurement, coded in ASCII format. One datagram is sent after each measurement of the cameras, i.e. following the synchronization frequency. The '*send data divisor*' in *Settings → Output* offers the possibility to decrease the data output frequency ($f_{output} = f_{sync}/d_{divisor}$).

All data are given in units millimeter (`mm`) or angular degree (`deg` / °).

ART provides free sample source code ('DTrack2SDK', in C++) to receive and parse the output data. Please contact ***ART*** to get it.

A UDP datagram in ASCII format contains several lines separated by CR/LF (hex `0D 0A`). Each line carries data of a specific type and starts with an identifier. In *Settings → Output* you may configure which lines or data types should be included in the output:

Identifier	Type of data	enable/disable in
`fr`	frame counter	always enabled
`ts`	timestamp	*Settings → Output* ('*ts*')
`6dcal`	additional informations	*Settings → Output* ('*6dcal*')
`6d/6di`	standard bodies (6DOF)	*Settings → Output* ('*6d / 6di*')
`3d`	additional markers (3DOF)	*Settings → Output* ('*3d*')
`6df/6df2`	Flysticks (6DOF + buttons)	*Settings → Output* ('*6df / 6df2*')
`6dmt`	Measurement Tools (6DOF + tip trafo)	*Settings → Output* ('*6dmt*')
`6dmtr`	Measurement Tool references (6DOF)	*Settings → Output* ('*6dmtr*')
`6dmt2`	Measurement Tool with sphere tip (6DOF + tip trafo + sphere radius)	*Settings → Output* ('*6dmt2*')

B.2.1 Frame Counter

Identifier `fr`.

This line is always the first one. It carries a frame counter (counting with synchronization frequency).
Example:

```
fr 21753
```

B.2.2 Timestamp

Identifier `ts`.

A timestamp can be added to each datagram. It shows the time at the measurement of this frame, i.e. the time when the infrared flash of the cameras is fired. The timestamp uses the internal clock of the controller, giving back the seconds (with an accuracy of $1\mu s$) since 00:00 UTC[1] (midnight). This implies that the timestamp value is reset to zero when passing midnight (UTC)!

The timestamp typically shows an accuracy of better than $\Delta t_{err} \sim \pm 0.01ms$ with a Synccard2 (used in *ARTTRACK* systems). With a SynccardTP (used in *TRACKPACK* systems) one can only expect an accuracy of $\Delta t_{err} \sim \pm 0.5ms$.

Example:

```
ts 39596.024831
```

B.2.3 Standard 6DOF Bodies

Identifier `6d`.

Measurement data of all tracked standard 6DOF bodies (i.e. all 6DOF bodies except Flysticks, Measurement Tools . . .). Bodies, that are not tracked by the system at that moment, don't appear in the output.

[1] Coordinated Universal Time = Greenwich Mean Time

Appendix B

- The first number gives the number of tracked bodies (less or equal to the number of calibrated bodies).
- The data of each tracked body show up in blocks (three consecutive `[]`) like:

$$\texttt{[id qu]}\,\texttt{[}s_x\ \ s_y\ \ s_z\ \ \eta\ \ \theta\ \ \phi\texttt{]}\,\texttt{[}b_0\ \ b_1\ \ b_2\ \ b_3\ \ b_4\ \ b_5\ \ b_6\ \ b_7\ \ b_8\texttt{]}$$

  They contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, unused),
  2. Position (s_i), orientation angles ($\eta\ \theta\ \phi$) and
  3. Rotation matrix (b_i) of the Body's orientation.

  All numbers are separated by spaces (hex `20`). Nine values $b_0 \dots b_8$ form the rotation matrix R:

$$R = \begin{pmatrix} b_0 & b_3 & b_6 \\ b_1 & b_4 & b_7 \\ b_2 & b_5 & b_8 \end{pmatrix}$$

  To avoid problems with different definitions of the angles, we recommend to only use rotation matrices.

Example (one line):

```
6d 1 [0 1.000][326.848 -187.216 109.503 -160.4704 -3.6963
-7.0913][-0.940508 -0.339238 -0.019025 0.333599 -0.932599 0.137735
-0.064467 0.123194 0.990286]
```

B.2.4 Standard 6DOF Bodies (extended format)

Identifier `6di`.

The `6di` format is only available when hybrid targets are being used.

Measurement data of all tracked standard 6DOF bodies (i.e. all 6DOF bodies except Flysticks, Measurement Tools ...) and all hybrid bodies. Bodies, that are not tracked by the system at that moment, do appear in the output.

- The first number gives the number of tracked bodies.
- The data of each tracked body show up in blocks (three consecutive `[]`) like:

$$\texttt{[id st er]}\,\texttt{[}s_x\ \ s_y\ \ s_z\texttt{]}\,\texttt{[}b_0\ \ b_1\ \ b_2\ \ b_3\ \ b_4\ \ b_5\ \ b_6\ \ b_7\ \ b_8\texttt{]}$$

  They contain:

  1. ID number (`id`, starting with 0), status of the tracking (`st`, 0: not tracked, 1: inertial tracking, 2: optical tracking, 3: inertial and optical tracking), drift error estimate (`er`, 10 degree per minute when tracking inertially)

2. Position (s_i) and
3. Rotation matrix (b_i) of the Body's orientation.

All numbers are separated by spaces (hex 20). Nine values $b_0 \ldots b_8$ form the rotation matrix R:

$$R = \begin{pmatrix} b_0 & b_3 & b_6 \\ b_1 & b_4 & b_7 \\ b_2 & b_5 & b_8 \end{pmatrix}$$

To avoid problems with different definitions of the angles, we recommend to only use rotation matrices.

Example (one line):

```
6di 2 [0 1 2.135][326.848 -187.216 109.503][-0.940508 -0.339238
- -0.019025 0.333599 -0.932599 0.137735 -0.064467 0.123194 0.990286] [1 0
0.000][0.000 0.000 0.000][0.000000 0.000000 0.000000 0.000000 0.000000
0.000000 0.000000 0.000000 0.000000]
```

B.2.5 Flysticks

Identifier `6df2`.

☞ **Note: this format version replaces the older `6df` format (see B.2.6). Use it whenever possible.**

The newer format for Flysticks is quite similar to the format of standard 6DOF bodies. It provides tracking data for all Flysticks and other ***ART*** radio devices (see B.1.5):

- The first number after the identifier `6df2` gives the number of defined (i.e. calibrated) Flysticks.
- The second number gives the number of Flystick data, that are following in the line.
- The data of each Flystick show up in blocks (four consecutive `[]`), like:

  `[id qu nbt nct]`[s_x s_y s_z][b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7 b_8][bt_0 ... ct_0 ct_1 ...]

  The four blocks contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, see below) and the number of available buttons and controllers (`nbt` and `nct`).
  2. Position of the Flystick (s_i).
  3. Orientation of the Flystick, given as rotation matrix (b_i, like standard bodies).
  4. Status of buttons (bt_i, see below) and controllers (ct_i, see below).

- The quality (`qu`) can (so far) just get the values 1.000 or -1.000. -1.000 means that the target of the Flystick is not visible at the moment. Even in that case a Flystick appears in the output data. Then dummy values are used for position (zero) and orientation (zero matrix!). Informations about buttons and controllers are valid as long as the wireless transmission is active.

- When buttons of the Flysticks are pressed the (decimal) numbers bt_i change. They are coded binary (i.e. switch 1 activated = bit 0 set, switch 2 activated = bit 1 set, ...) with a maximum of 32 buttons per bt_i number.

  ☞ **Note that the number of bt_i numbers in the block can vary with different Flystick hardware! If the device isn't equipped with buttons, the output won't contain any bt_i number!**

- Controller elements are transferred into floating point numbers ct_i, reaching from -1.00 to 1.00. In the output line they follow the button informations (one number for each controller).

  ☞ **Note that the number of ct_i numbers in the block can vary with different Flystick hardware! If the device isn't equipped with controller elements, the output won't contain any ct_i number!**

Example (one line) for two devices, one Flystick2 (ID 0) and one Flystick1 (ID 1):

```
6df2 2 2 [0 1.000 6 2][-228.992 270.818 92.561][0.758006 -0.652230 0.004807 -0.651759
-0.757133 0.044271 -0.025236 -0.036691 -0.999008][5 0.13 -1.00] [1 -1.000 4 2][0.000
0.000 0.000][0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000
0.000000][1 1.00 0.00]
```

B.2.6 Flysticks (Old Format)

Identifier `6df`.

☞ **Note: supported just for compatibility. It is recommended to use the newer Flystick format `6df2` (see chapter B.2.5 on page 129) whenever possible.**

ℹ **Refer to chapter B.1.5.1 on page 124 to find out which buttons of the Flystick2 are NOT transmitted when using the old output format `6df`.**

This older format for Flysticks is quite similar to the format of standard 6DOF bodies:

- The first number gives the number of defined Flysticks.
- The data of each Flystick show up in blocks (three consecutive `[]`) like:

  $$\texttt{[id qu bt][}s_x\ s_y\ s_z\ \eta\ \theta\ \phi\texttt{][}b_0\ b_1\ b_2\ b_3\ b_4\ b_5\ b_6\ b_7\ b_8\texttt{]}$$

  They contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, see below) and button information (`bt`, see below),
  2. Position (s_i) and orientation angles ($\eta\ \theta\ \phi$) and
  3. Orientation (b_i) of the Flystick.

- The quality (`qu`) can (so far) just get the values 1.000 or -1.000. -1.000 means that the target of the Flystick is not visible at the moment. Even in that case a Flystick appears in the output data. Then dummy values are used for position (zero) and orientation (zero matrix!). Informations about buttons are valid as long as the wireless transmission is active.

- When buttons of the Flysticks are pressed the (decimal) number bt changes. It is coded binary (i.e. switch 1 activated = bit 0 set, switch 2 activated = bit 1 set, . . .).

Example (one line):

```
6df 1 [0 1.000 2][261.103 116.520 41.085 19.6522 -57.3530 116.5992]
[-0.241543 0.968868 -0.054332 -0.482366 -0.168461 -0.859619
-0.842010 -0.181427 0.508039]
```

B.2.7 Measurement Tools

Identifier 6dmt.

Only available, if the Measurement Tool license is present for *DTrack2* (available since version v2.2.0)

The output for Measurement Tools is similar to the format for Flysticks:

- The first number gives the number of defined Measurement Tools .
- The data of each tool show up in blocks (three consecutive []), like:

  [id qu bt][s_x s_y s_z][b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7 b_8]

  They contain:

  1. ID number (id, starting with 0), quality value (qu, see below) and button information (bt, unused),
  2. Measured position (s_i) of the tip,
  3. Rotation matrix (b_i) of the tip's orientation.

- The quality (qu) can (so far) just get the values 1.0 and -1.0. -1.0 means that the target of the Measurement Tool is not visible at the moment.
- The protocol is prepared for future Measurement Tools equipped with buttons (like Flysticks). Until then bt is set to zero.
- $b_0 \dots b_8$ form a rotation matrix R according to the scheme described in chapter B.2.3 on page 127.

Example (one line):

```
6dmt 1 [0 1.000 0][326.848 -187.216 109.503][0.911812 -0.038421
0.408806 0.095040 0.988324 -0.119094 -0.399457 0.147444 0.904817]
```

B.2.8 Measurement Tools with sphere tip

Identifier 6dmt2.

Only available, if the Measurement Tool license is present for *DTrack2* (available since version v2.9.1).

To use the 6dmt2 output first deactivate the old output format 6dmt in *Settings → Measurement Tool → use old output format*. Then activate *Settings → Output → 6dmt2*.

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The output for Measurement Tool *with sphere tip* is defined as follows:

- The first number gives the number of calibrated Measurement Tools .
- The second number gives the number the following target data.
- The data of each tool show up in blocks (five consecutive []), like:

  [id qu nbt rd][s_x s_y s_z][b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7 b_8][bt][c_{11} c_{12} c_{13} c_{22} c_{23} c_{33}]

  They contain:

  1. ID number (id, starting with 0), quality value (qu, see below) number of buttons (nbt) and the radius of the Measurement Tool tip sphere (rd).
  2. Measured position (s_i) of the tip
  3. Rotation matrix (b_i) of the tip orientation.
  4. Button (bt), binary coded (0x01 measurement of a point is active; 0x02, 0x04, ... designate buttons of the Measurement Tool)
  5. Covarianz matrix (c_{ij}) of the position of the tool tip (in mm^2)

- The quality (qu) can (so far) just get the values 1.0 and -1.0. -1.0 means that the target of the Measurement Tool is not visible at the moment.
- $b_0 \ldots b_8$ form a rotation matrix according to the scheme described in chapter B.2.3 on page 127.
- The protocol is prepared for the future when the covariance matrix of the measurement tool tip is calculated. Until then c_{ij} is set to zero.

Example (one line):

```
6dmt2 1 1 [0 1.000 4 2.000][326.848 -187.216 109.503][0.911812 -0.038421
0.408806 0.095040 0.988324 -0.119094 -0.399457 0.147444 0.904817][0]
[0.000e-00 0.000e-00 0.000e-00 0.000e-00 0.000e-00 0.000e-00]
```

B.2.9 Measurement Tool references

Identifier 6dmtr.

Only available, if the Measurement Tool license is present for *DTrack2* (available since version v2.2.0)

The output for Measurement Tool references is defined as follows:

- The first number gives the number of defined Measurement Tool references.
- The second number gives the number of tracked Measurement Tool references.
- The data of each tracked reference show up in blocks (three consecutive []), like:

  [id qu][s_x s_y s_z][b_0 b_1 b_2 b_3 b_4 b_5 b_6 b_7 b_8]

  They contain:

1. ID number (id, starting with 0), quality value (qu, see below),
2. Measured position (s_i) of the Measurement Tool reference,
3. Rotation matrix (b_i) of the Measurement Tool reference.

- The quality (qu) can (so far) just get the values 1.0 and -1.0. -1.0 means that the Measurement Tool reference is not visible at the moment.
- $b_0 \ldots b_8$ form a rotation matrix R according to the scheme described in chapter B.2.3 on page 127.

Example (one line):

```
6dmtr 1 1 [0 1.000][-485.245 -67.217 -38.328][0.681257 -0.315034
0.660790 -0.477531 -0.875410 0.074967 0.554845 -0.366620 -0.746817]
```

B.2.10 Additional 3DOF Markers

Identifier 3d.

The format of additional markers (all markers that don't belong to a 6DOF object) looks like a reduced format of standard bodies:

- The first number is the number of tracked additional markers.
- Blocks (two consecutive []) follow for each marker:

  [id qu][s_x s_y s_z]

  They contain ID number (id, starting with 1) and a quality value (qu, still unused), and the position (s_i).

Example (one line):

```
3d 6 [79 1.000][210.730 -90.669 -108.554] [83 1.000][61.235 -165.625
3.217] [87 1.000][123.633 -107.836 0.110] [88 1.000][212.383 -133.640
77.199] [90 1.000][326.455 -187.055 109.589] [91 1.000][303.185
-239.771 114.861]
```

B.2.11 Additional Informations

Identifier 6dcal.

Optionally, the number of the adjusted bodies (not only of the tracked ones) can be included in a data set. This is done within an additional line like:

```
6dcal 3
```

☞ **Note that this number does not include all calibrated bodies. In particular, it counts the calibrated bodies that show up in the output lines 6d, 6df and 6dmt.**

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