ART
Advanced Realtime Tracking

System user manual

ARTtrack®, TRACKPACK & DTrack®

version 2.14
July 2018

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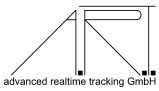		×	×	×

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What's new in version v2.14?

Following, a short overview of the main new features in ***DTrack2*** version v2.14:

- Integration of optical-inertial hybrid tracking (sensor fusion)
- Minor features (e.g. display IP address using DHCP, display ATC's CPU temperature)

What's new in version v2.13?

Following, a short overview of the main new features in ***DTrack2*** version v2.13:

- Support of FINGERTRACKING2 Tactile. Based on the vibro-tactile Fingertracking prototype the product version offers tactile feedback for the fingertips and compatibility to the high frame rates of ***ARTTRACK5*** & ***TRACKPACK/E*** cameras.
- Integration of new 'Fingertracking Administration' GUI. It facilitates and streamlines the configuration of all Fingertracking devices.
- Detailed export functionality of system-configuration and event-log for tech support

What's new in version v2.12?

Following, a short overview of the main new features in ***DTrack2*** version v2.12:

- Easier addition of cameras: To add a camera, simply re-calibrate the room without losing the origin and orientation of the original coordinate system and continue tracking. A similar procedure applies when removing cameras from the system.
- Integration of 'COOTrans', our co-ordinate adjustment utility. This means that the room adjustment can now be used to transform the tracking coordinate system into the coordinate system of specific 3rd party objects, provided that the reference points are known and can be measured (license-based)
- Support of bodies with up to 30 markers each
- Support of bodies with visibility restrictions including display of emission cones within 'Body Adjustment'
- Additional information dialog regarding cylindrical markers within 'Body Calibration Result Dialog'
- New function to remove unused markers from a rigid body within 'Body Adjustment'
- Radio channel settings are saved persistently when choosing a specific channel number

What's new in version v2.11?

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

- Support of new ***TRACKPACK/E*** cameras with Controllers including Synccard3 (see e.g. chapter 4.3 on page 35)
- Support of new ***ARTTRACK5/C*** cameras for cave installations with Controllers including Synccard3 (see e.g. chapter 4.2 on page 32)
- Improvements of usability of Hybrid Motion Capture (see chapter 7 on page 106)

What's new in version v2.10?

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

- Support of ***ARTTRACK5*** cameras with Controllers including Synccard3 (see e.g. chapter 4.1 on page 29)
- Support of external sync source 'TTL signal, both edges' (see e.g. chapter 8.5.2 on page 151)
- New license model. (see e.g. table 8.6 on page 141)

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)
ART Controller	calculates tracking data and generates the data output stream (compatible to ***ARTTRACK2*** , ***ARTTRACK3*** , ***ARTTRACK5*** , ***ARTTRACK5/C*** , ***TRACKPACK/E***)
ARTTRACK Controller (discontinued)	calculates tracking data and generates the data output stream (compatible to ***ARTTRACK1*** , ***ARTTRACK2*** , ***ARTTRACK3***)
ARTTRACK 2 & 3 (discontinued)	infrared camera
ARTTRACK5	infrared camera
ARTTRACK5/C	infrared camera dedicated for multi-sided projections
body calibration	teach the system the geometry of a rigid body
body, rigid body	rigid arrangement of multiple markers intended for 6DOF tracking (see also "target")
calibration angle (410mm or 710mm)	belongs to the room calibration set and defines origin and orientation of the room coordinate system
ceiling suspension	equipment to mount an infrared camera to the ceiling
DTrack2	
backend software	software running on the controller doing all necessary calculations
frontend software	graphical user interface running on customer's computer to control the controller
Field of View (FoV)	is the area of interest captured on the camera's image
finger thimble	a fixture for the finger tip to hold the active marker(s)
Fingertracking	tracks the orientation of the hand and the position of the fingers
Flystick	wireless interaction device for virtual reality (VR) applications
hand geometry	describes the dimensions of your hand and fingers
hybrid tracking	sensor fusion of optical and inertial data into one consolidated output
inertial sensor	an inertial measurement unit simultaneously measures 9 physical properties, namely angular rates, linear accelerations (unused) and magnetic field components (unused) along all 3 axes. This is achieved using solid state gyroscopes for measurement of roll, pitch and yaw and optical tracking for drift correction.
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 tracking system
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
motion capture	track movements of a human body
mutual blinding	one camera sees disturbing reflections caused by the infrared flashes of another one
prediction	predicts output for the specified time in the future to compensate tracking and rendering latency
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

term	definition
syncgroup	cameras being in one syncgroup receive the sync signal at the same time. Syncgroups are distinguished by a short time delay between their sync signals (i.e. mutual blinding may be avoided).
synccard (Synccard2/3 or SynccardTP)	plug-in card for the controller which serves for synchronizing the cameras
Tactile Feedback	system for finger-based interactions in immersive virtual reality applications (wires touch the inside of the finger tips and provide an impression when they are shortened)
target	rigid arrangement of several single markers (= rigid body)
tracking	position measurement of bodies that move in a defined space
TRACKPACK (discontinued)	infrared camera
TRACKPACK/C (discontinued)	infrared camera dedicated for multi-sided projections
TRACKPACK/E	infrared camera
TRACKPACK Controller (discontinued)	calculates tracking data and generates the data output stream (compatible to ***TRACKPACK*** and ***TRACKPACK/C***)
USB radio transceiver (RT2, RT3)	exchange data with Flystick or Tactile Feedback
virtual point cloud	used for calculating the relative positions of the IR cameras
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 cameras emit infrared light. 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.
- 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 ***ARTTRACK2*** camera 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 236. The appliance rating plates are on the equipment's housing (***ARTTRACK1*** on the lower side of the housing; ***ARTTRACK2*** / ***ARTTRACK3*** on external power supply, ***ARTTRACK5*** & ***ARTTRACK5/C*** / ***TRACKPACK/E*** on camera housing, all controllers 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 cameras due to mechanical strain,
  - the line of sight of the cameras 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 29, 5 on page 54 and 6 on page 71. Only use the originally provided external power supply for operating the camera ***ARTTRACK2*** and ***ARTTRACK3*** and, if applicable, only the provided PoE+ switch for ***ARTTRACK5*** & ***ARTTRACK5/C*** .
- 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 10.2 on page 218.
- 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

ART tracking systems are infrared (IR) optical tracking systems. In this user manual we are going to perceive "tracking" as measurement of positional and rotational information (i.e. orientation) of objects or individuals that move in a defined space.

Concept of tracking The simultaneous measurement of spatial position (X, Y, Z) and orientation (three independent angles) is called "six degrees of freedom" (6DOF) tracking. If only the spatial position (X, Y, Z) is to be measured it is called "three degrees of freedom" (3DOF) tracking.
Single markers are sufficient if only 3DOF coordinates are needed, but single markers cannot be identified. ***DTrack2*** will assign an ID to a tracked 3DOF marker as long as it can be followed, but after losing the tracking (e.g. due to occlusions) it will not be able to re-identify the marker and thus assign a new ID.
For 6DOF tracking, however, a target is mandatory. Targets are unique and rigid arrangements of markers (=rigid bodies) and thus can be identified by their relative marker position. Figure 2.1 on page 17 shows the concept of infrared optical tracking with a two-camera system and a standard target.

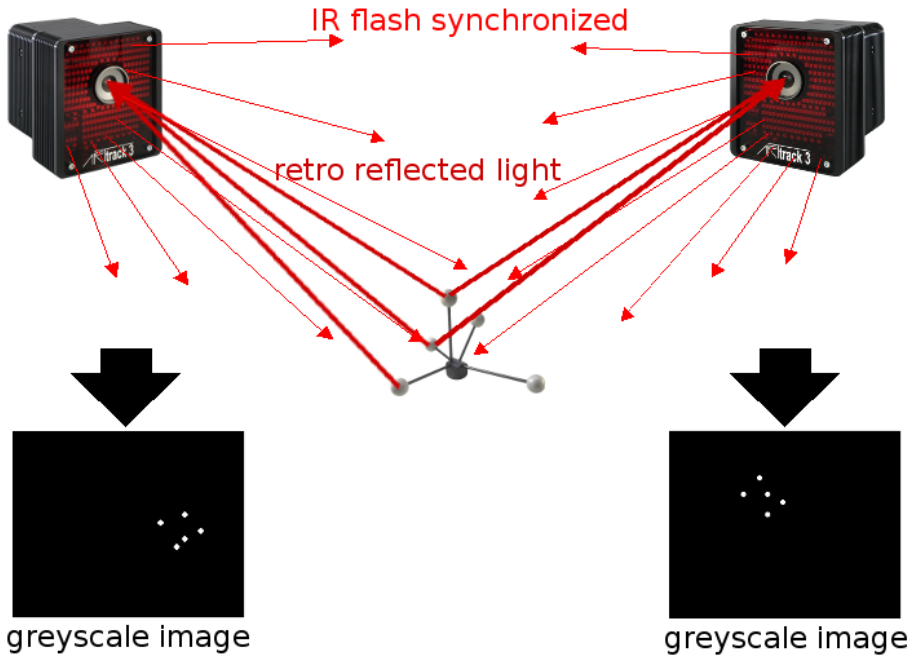


Figure 2.1: Concept of optical tracking (stereo vision)

Marker types 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 (see chapter 3 on page 20).

Tracking in detail The cameras send out synchronized IR flashes which are reflected back into the lens by retro-reflective material covering the markers of the target. The 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. During preprocessing the intelligent cameras calculate the 2DOF marker positions with high accuracy using pattern recognition algorithms.
Then the 2DOF data are being sent to a controller via ethernet which calculates 3DOF or 6DOF information. 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 is made known to the system during 'room calibration', while during 'body calibration' ***DTrack2*** identifies the unique arrangements of markers as targets. Based upon these two teaching steps, ***DTrack2*** is able to calculate 6DOF data and, finally, knows position and orientation of the target and therefore of the object or individual to be tracked.

Note: In pure optical tracking systems tracking is only possible as long as

- objects or individuals to be tracked are equipped with single markers or targets
- the target is not occluded by any other objects in the cameras' line of sight, which could even be the object itself
- the target is positioned inside the tracking range of the cameras
- at least four markers of a target are visible to at least two cameras (in more detail: to enable tracking).

Hybrid tracking In addition to tracking by a pure optical system it is possible to utilize data from inertial measurement units (IMU). These devices usually consist of several components such as gyroscopes, accelerometers and magnetometers. The underlying principle is the combination of solid-state microelectromechanical systems with integrated circuits and analog or digital outputs to achieve 6DOF rotational information.

Some of the most important advantages of hybrid tracking are:

- tracking data from IMUs offers low noise-levels while running at very high frequencies in combination with low latencies
- IMUs deliver tracking data (i.e. rotational information) even when the optical target is not inside the tracking volume or if the target cannot be tracked due to viewing limitations or occlusions

- drifting of IMUs (i.e. mostly from the 3-axis gyroscope) is compensated by fusing the inertial data with position measurements calculated from the optical tracking system

A hybrid target is basically an optical target additionally equipped with an IMU, which itself is connected to the controller. There the tracking data from both worlds (i.e. hybrid) is combined, which also leads to the term 'sensor fusion'. By nature the IMU contains an independent coordinate system which needs to be aligned to the optical tracking system axes. This additional teaching process is called hand-eye calibration or 'hybrid body calibration' in ***DTrack2*** .

3 Markers and targets (rigid bodies)

3.1 Passive markers

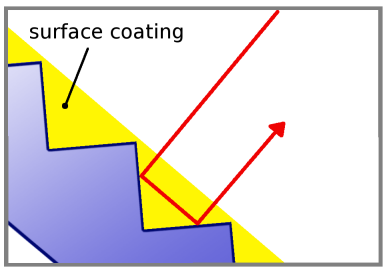
Passive markers used in ***ART*** tracking systems are retro-reflective, which means they reflect a high fraction of the incoming light in a small cone around the incoming light's direction (cat's eye effect). More precise: the IR radiation is reflected into a narrow range of angles around the (opposite) 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:
   + low price,
   + flat targets possible,
   + robust surface because cover may be applied,
   - the angular range of visibility is limited to approx. $\pm 45^{\circ}$.
3. ring markers:
   + low price,
   + cylindrically shaped targets possible,
   + robust surface,
   - the angular range of visibility is limited to approx. $\pm 45^{\circ}$.

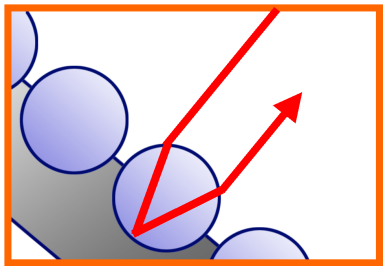
Passive markers are mostly spheres covered with retro reflecting foils. However, they can also be stickers made from retro reflecting material.

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

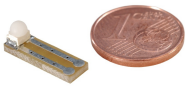
Basics Active markers are light (i.e. infrared light) emitting elements, usually LEDs.

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

1. Single LEDs without diffusor sphere:

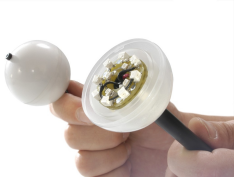
+ can be covered with acrylic protection film,
+ results in simple and robust markers providing visibility up to high distances (up to 10m),
- the angular range of visibility is limited to approx. ±60°.

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:



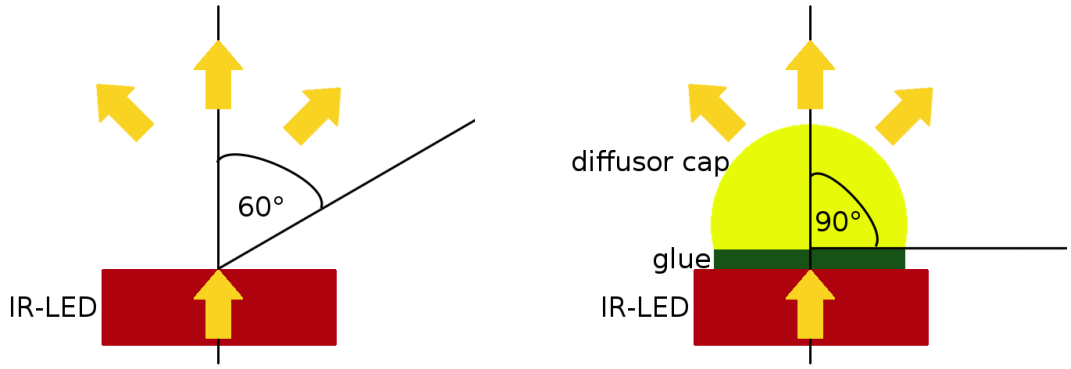
+ several single LEDs per marker, covered with light scattering spheres,
+ provide visibility from all sides and up to very high distances (approx. 20m),
+ suitable for outdoor tracking,
- diameter: 50mm,
- weight: 50g.

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 The easiest way to create an active marker is to have it emit IR light continuously. However, this would be inefficient in respect to energy dissipation and would yield low signal-to-noise ratios. ***ART*** tracking cameras have very short exposure times, i.e. narrow time slots of sensitivity. Most of the light emitted by the markers would hit the cameras sensors at times when it is inactive rendering the light useless for tracking. As a consequence, the range between cameras and marker would become significantly shorter. Additionally the active markers can be configured to emit high power intensities by flashing just like the camera flash. This also helps with energy dissipation due to an upper limit allowed for each single LED. Therefore, most active



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

Figure 3.1: Angular range of visibility

markers supplied by ***ART*** are synchronized with the cameras to emit radiation only during exposure times. This allows both more robust and longer ranging targets.

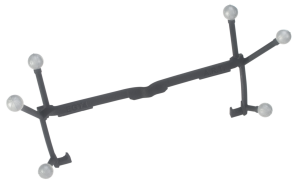
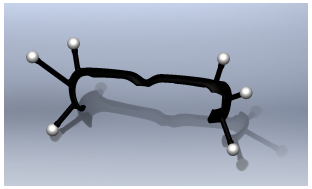
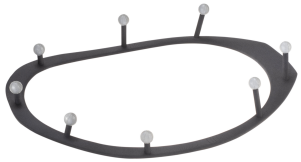
Synchronization can be done either by a wired connection between the tracking system and the pc-board controlling the active markers but also in a wireless way. For wireless synchronization a coded (i.e. modulated) IR flash is being sent out by a tracking camera. The active marker's PC board recognizes the coded flash and activates the LEDs.

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 × 80 × 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 × 120 × 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 × 110 × 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

Type	Description	Weight	approx. Dimension	Marker size
Motion capture targets 	***ART*** provides a complete set of targets for motion capture purposes. All targets are 6DOF targets and can be identified by the tracking system. A full ***ART*** MoCap target set consists of (subsets can be generated):			
	1 Glasses target (AGT4)	28g / 1.0oz	(225 × 180 × 95)mm	12mm
	2 Shoulder targets (UT)	44g / 1.55oz	(90 × 75 × 35)mm	12mm
	1 Dorsal target (DT)	84g / 2.96oz	(150 × 65 × 35)mm	12mm
	2 Upper arm targets (HBT)	52g / 1.83oz	(150 × 70 × 35)mm	12mm
	2 Forearm targets (UBT)	50g / 1.76oz	(150 × 65 × 35)mm	12mm
	2 Hand targets (HT)	25g / 0.9oz	(110 × 80 × 28)mm	12mm
	1 Waist target (WT, one-piece)	195g / 6.9oz	(390 × 140 × 50)mm	14mm
	1 Waist target (WT, multi-part), each	30g / 1.1oz	(90 × 60 × 50)mm	16mm
	2 Upper leg targets (FBT)	99g / 3.49oz	(220 × 120 × 40)mm	16mm
	2 Lower leg targets (TBT)	58g / 2.05oz	(205 × 70 × 35)mm	16mm
	2 Foot targets (FT)	65g / 2.29oz	(95 × 105 × 70)mm	16mm

Table 3.3: Standard targets overview

4 *ART* Tracking Cameras

4.1 *ARTTRACK5*

Keep a distance of min. 20 cm when operating the camera ! The camera 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 ***ARTTRACK5*** infrared camera is intended for working environments with distances between camera and markers of up to 7.5 metres. By default the ***ARTTRACK5*** is equipped with a 3.5 mm lens. Depending on the application and the setup the ***ARTTRACK5*** can be equipped with other lenses (i.e. with different focal lengths). Refer to A.1 on page 236 for a list of available focal lengths and the respective FoV.

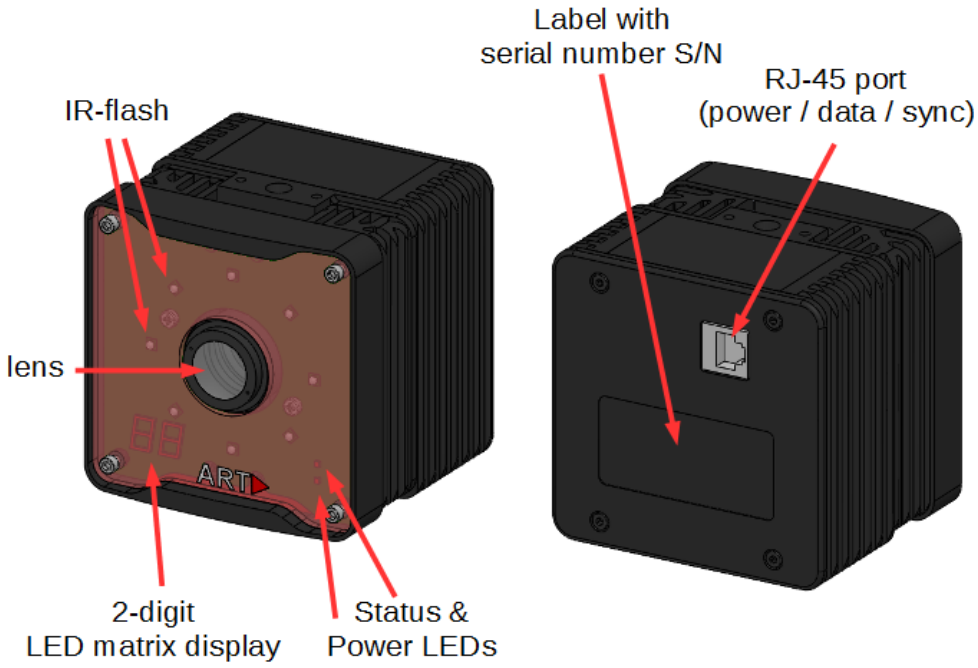


Figure 4.1: Camera ***ARTTRACK5***

Mounting The ***ARTTRACK5*** cameras are optimized for a predefined range of measurement volumes. System operation in smaller or bigger measurement volumes can lead to reduced accuracy. The measurement volume can be adjusted within certain limits simply

by changing the flash intensity of the ***ART*** infrared cameras (see chapter 8.5.1 on page 146).

The flash intensities should not be too high. In general, a flash intensity of 50-60 might be sufficient.

Major changes of the measurement volume may require different lenses and thus a new determination of camera parameters. These changes have to be done at the ***ART*** labs.

Be aware that a tracking system is very sensitive to camera movements. Therefore the cameras have to be mounted in a way that camera movements (especially vibrations) are reduced as much as possible.

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

The ***ARTTRACK5*** camera is equipped with UNC 1/4" threads on both sides and can thus directly be mounted to tripod heads.
The carrier for the ***ARTTRACK5*** can be attached on both bottom and top side of the camera. Attach the carrier to the camera as shown in figure 4.2 on page 30. For more flexibility, the T-piece can be mounted pointing forward or backward. Note, the ceiling suspension is already connected to the carrier in figure 4.2.

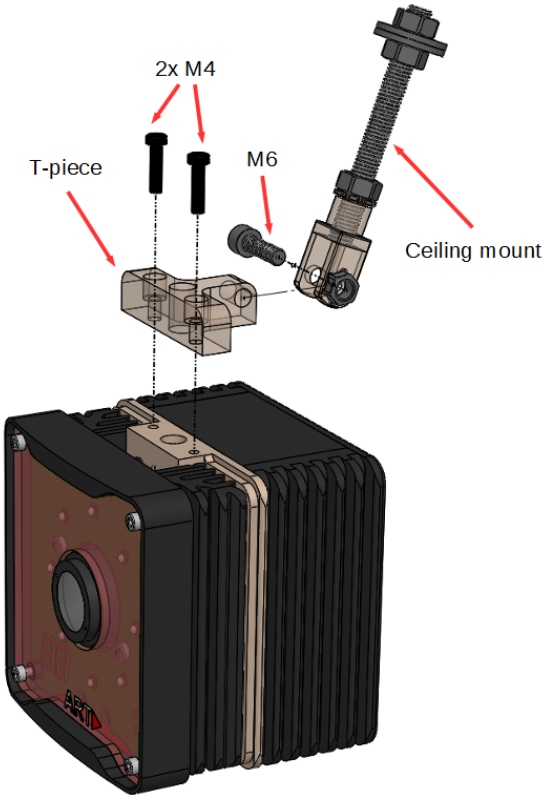


Figure 4.2: Attaching the ceiling mount to the ***ARTTRACK5*** camera

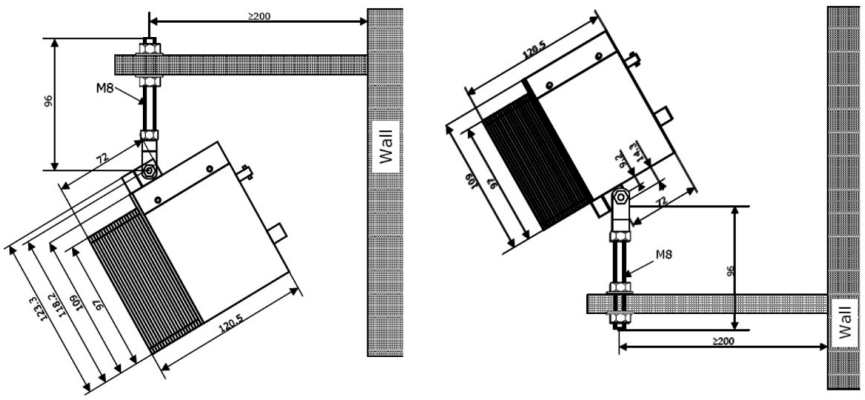


Figure 4.3: Mounting a camera to a wall or a ceiling (e.g. *ARTTRACK2* camera)

Only use screws supplied with the ceiling mount for mounting it. Also, use all the parts supplied with the ceiling mount - especially the toothed washer is quite important.

Never unfasten other screws on the cameras (see chapter 1.2 on page 14). Otherwise, the camera might be damaged and liability and warranty is void.

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

Make sure to install the system in a way that you can easily access the cameras and its cables. Be especially careful to mount the cameras firmly so they cannot fall down. Unsecured cameras may pose a serious hazard to health and safety.

Shock and vibration can permanently destroy the internal calibration of the cameras. De-calibrated cameras have to be recalibrated in the ART labs.

Figure 4.3 on page 31 shows the correct mounting for a camera to a wall with a carrier using the example of an *ARTTRACK2* camera. Make sure to not fall below minimal distance to the wall so enough room is left for the cables and to allow readjustment of the camera angles and maintenance. For easy adjustment, it is highly recommended to mount the ceiling mount in a way that the threaded bolt is vertical. This way heading and elevation of the camera view can be adjusted individually.
Use strong dowels and screws for mounting the cameras to walls or ceilings (see figure 4.3 on page 31).
If in doubt, ask a skilled craftsman for assistance. Use massive and long enough angle irons to provide the required stiffness and stability.

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. 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 install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the cameras due to mechanical strain,
- the line of sight of the cameras 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!

Please refer to chapter 5.2 on page 60 for more information.

4.2 *ARTTRACK5/C*

Keep a distance of min. 20 cm when operating the camera ! The camera 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 *ARTTRACK5* or *TRACKPACK/E* system may be combined with the *ARTTRACK5/C* camera in order to realize tracking in multi-sided projection environments (e.g. CAVE®, I-Space). In such an environment it is necessary to drill holes into the projections' corners as the camera cannot see through the screen. The *ARTTRACK5/C* camera has been designed to easily fit into such holes by separating the lens from the electronics part (see figure 4.4). With its 4.0 mm lens a large field of view (FoV) is covered. Refer to A.1 on page 236 for more information.

The 26-pin D-Sub connector between *ARTTRACK5/C* remote camera head and camera body employs proprietary design. Do not try to connect the remote head to any other port (e.g. COM port) !!!

The *ARTTRACK5/C* system either consists of *ARTTRACK5/C* cameras only or it can be mixed with standard *ARTTRACK5* or *TRACKPACK/E* cameras - both variants are limited to a total number of 50 cameras per system.

Mounting The *ARTTRACK5/C* cameras are optimized for a predefined range of measurement volumes. System operation in smaller or bigger measurement volumes can lead to reduced accuracy. The measurement volume can be adjusted within certain limits simply by changing the flash intensity of the *ART* infrared cameras (see chapter 8.5.1 on page 146).

The flash intensities should not be too high. In general, a flash intensity of 50-60 might be sufficient.

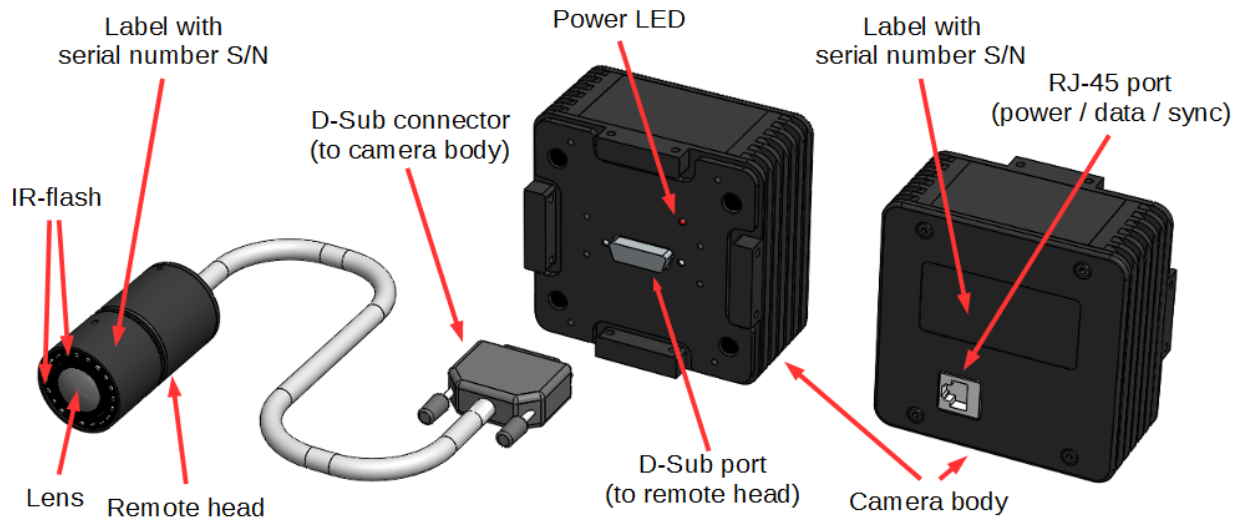


Figure 4.4: Camera *ARTTRACK5/C*

Major changes of the measurement volume may require different lenses and thus a new determination of camera parameters. These changes have to be done at the *ART* labs.

Be aware that a tracking system is very sensitive to camera movements. Therefore the cameras have to be mounted in a way that camera movements (especially vibrations) are reduced as much as possible.

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

If you want to mount the camera on a tripod just mount the carrier on any side of the camera body and then the remote camera head on the opposite side using a ceiling mount.

The carrier for the *ARTTRACK5/C* can be attached on all 4 sides of the camera body. Attach the carrier with the T-piece pointing to the back of the camera in a similar way to figure 4.2 on page 30. Note, the ceiling suspension is already connected to the carrier in figure 4.2. The *ARTTRACK5/C* remote camera head should be installed using the M6 mounting threads on its back as shown in figure 4.5 on page 34.

☞ **The *ARTTRACK5/C* remote head has to be connected to its corresponding camera body. During mounting please ensure matching serial numbers for both parts !**

Only use screws supplied with the ceiling mount for mounting it. Do not use standard screws for connection of the remote camera head due to limited space between thread and cable. Also, use all the parts supplied with the ceiling mount - especially the toothed washer is quite important.

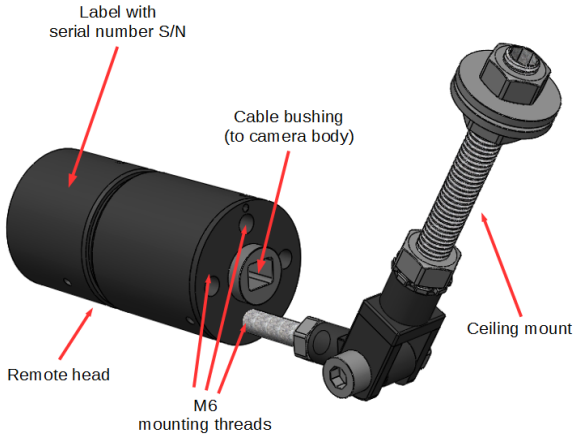


Figure 4.5: Camera ***ARTTRACK5/C*** remote head (back)

Never unfasten other screws on the cameras (see chapter 1.2 on page 14). Otherwise, the camera might be damaged and liability and warranty is void.

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

Make sure to install the system in a way that you can easily access the cameras and its cables. Be especially careful to mount the cameras firmly so they cannot fall down. Unsecured cameras may pose a serious hazard to health and safety.

Shock and vibration can permanently destroy the internal calibration of the cameras. De-calibrated cameras have to be recalibrated in the ART labs.

Figure 4.3 on page 31 shows the correct mounting for a camera to a wall with a carrier using the example of an ***ARTTRACK2*** camera. Make sure to not fall below minimal distance to the wall so enough room is left for the cables and to allow readjustment of the camera angles and maintenance. For easy adjustment, it is highly recommended to mount the ceiling mount in a way that the threaded bolt is vertical. This way heading and elevation of the camera view can be adjusted individually.
Use strong dowels and screws for mounting the cameras to walls or ceilings (see figure 4.3 on page 31).
If in doubt, ask a skilled craftsman for assistance. Use massive and long enough angle irons to provide the required stiffness and stability.

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. 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 install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the cameras due to mechanical strain,
- the line of sight of the cameras 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!

Please refer to chapter 5.2 on page 60 for more information.

4.3 TRACKPACK/E

Keep a distance of min. 20 cm when operating the camera ! The camera 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 *TRACKPACK/E* infrared camera is intended for working environments with distances between camera and markers of up to 4.5 metres. With its 3.5 mm lens a large field of view (FoV) is covered. Refer to A.1 on page 236 for the respective FoV.

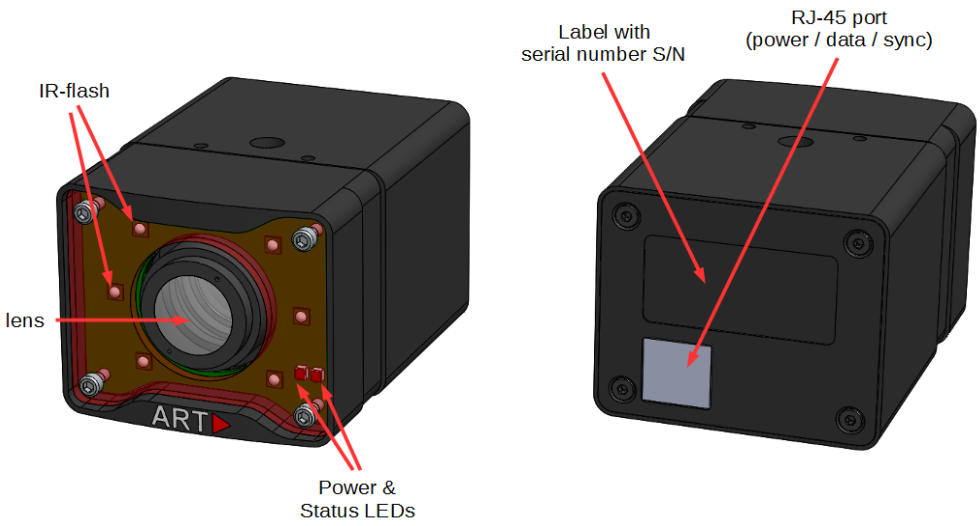


Figure 4.6: Camera *TRACKPACK/E*

Mounting The *TRACKPACK/E* cameras are optimized for a predefined range of measurement volumes. System operation in smaller or bigger measurement volumes can lead to reduced accuracy. The measurement volume can be adjusted within certain limits

simply by changing the flash intensity of the *ART* infrared cameras (see chapter 8.5.1 on page 146).

The flash intensities should not be too high. In general, a flash intensity of 50-60 might be sufficient.

Major changes of the measurement volume may require different lenses and thus a new determination of camera parameters. These changes have to be done at the *ART* labs.

Be aware that a tracking system is very sensitive to camera movements. Therefore the cameras have to be mounted in a way that camera movements (especially vibrations) are reduced as much as possible.

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

The *TRACKPACK/E* camera is equipped with UNC 1/4" threads on both sides and can thus directly be mounted to tripod heads.
The carrier for the *TRACKPACK/E* can be attached on both bottom and top side of the camera. Attach the carrier to the camera in a similar way to figure 4.2 on page 30. For more flexibility, the T-piece can be mounted pointing forward or backward. Note, the ceiling suspension is already connected to the carrier in figure 4.2.

Only use screws supplied with the ceiling mount for mounting it. Also, use all the parts supplied with the ceiling mount - especially the toothed washer is quite important.

Never unfasten other screws on the cameras (see chapter 1.2 on page 14). Otherwise, the camera might be damaged and liability and warranty is void.

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

Make sure to install the system in a way that you can easily access the cameras and its cables. Be especially careful to mount the cameras firmly so they cannot fall down. Unsecured cameras may pose a serious hazard to health and safety.

Shock and vibration can permanently destroy the internal calibration of the cameras. De-calibrated cameras have to be recalibrated in the ART labs.

Figure 4.3 on page 31 shows the correct mounting for a camera to a wall with a carrier using the example of an *ARTTRACK2* camera. Make sure to not fall below minimal distance to the wall so enough room is left for the cables and to allow readjustment of the camera angles and maintenance. For easy adjustment, it is highly recommended to mount the ceiling mount in a way that the threaded bolt is vertical. This way heading and elevation of the camera view can be adjusted individually.
Use strong dowels and screws for mounting the cameras to walls or ceilings (see figure 4.3 on page 31).

If in doubt, ask a skilled craftsman for assistance. Use massive and long enough angle irons to provide the required stiffness and stability.

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. 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 install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the cameras due to mechanical strain,
- the line of sight of the cameras 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!

Please refer to chapter 5.2 on page 60 for more information.

4.4 *ARTTRACK2* (discontinued)

Keep a distance of min. 20 cm when operating the camera ! The camera 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 *ARTTRACK2* infrared camera is intended for working environments with distances between camera and markers of up to 4 metres. By default the *ARTTRACK2* is equipped with a 3.5 mm lens. Depending on the application and the setup the *ARTTRACK2* can be equipped with other lenses (i.e. with different focal lengths). Refer to A.1 on page 236 for a list of available focal lengths and the respective FoV.

Mounting The *ARTTRACK2* cameras are optimized for a predefined range of measurement volumes. System operation in smaller or bigger measurement volumes can lead to reduced accuracy. The measurement volume can be adjusted within certain limits simply by changing the flash intensity of the *ART* infrared cameras (see chapter 8.5.1 on page 146).

The flash intensities should not be too high. In general, a flash intensity of 3-4 might be sufficient.

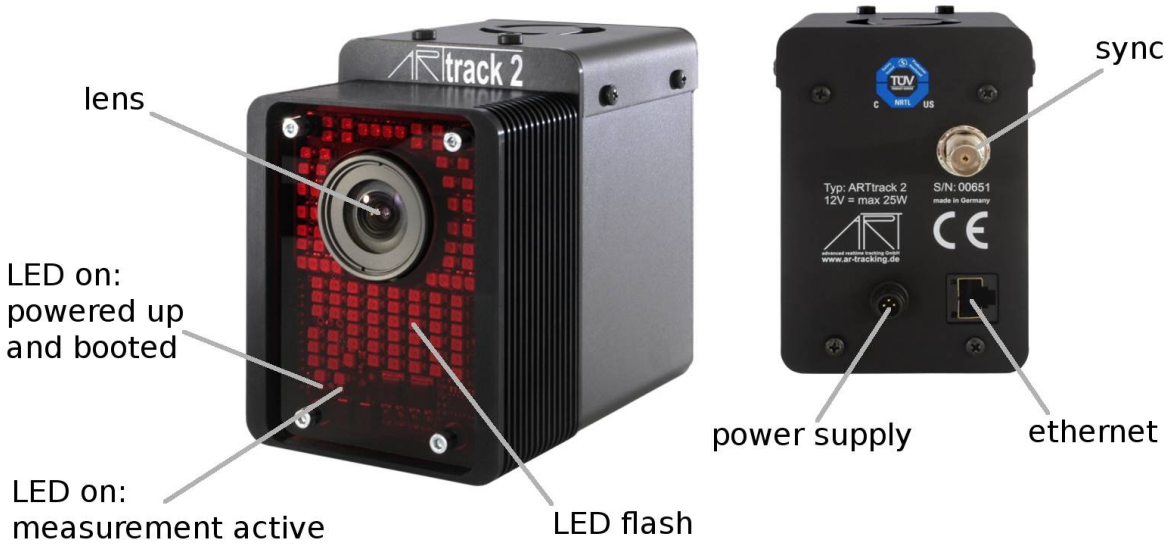


Figure 4.7: Camera ***ARTTRACK2***

Major changes of the measurement volume may require different lenses and thus a new determination of camera parameters. These changes have to be done at the ***ART*** labs.

Be aware that a tracking system is very sensitive to camera movements. Therefore the cameras have to be mounted in a way that camera movements (especially vibrations) are reduced as much as possible.

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

If you want to mount the camera on a tripod just mount the carrier on the bottom of the camera.
The carrier for the ***ARTTRACK2*** can be attached on both bottom and top side of the camera. To attach the carrier remove the screws from the holes 1 and 2 and attach the carrier with the T-piece pointing to the back of the camera in a similar way to figure 4.2 on page 30. Note, the ceiling suspension is already connected to the carrier in figure 4.2.

Only use screws supplied with the ceiling mount for mounting it. The screws used for sealing the housings are not sufficiently long for fixing the carrier. Also, use all the parts supplied with the ceiling mount - especially the toothed washer is quite important.

Never unfasten other screws on the cameras (see chapter 1.2 on page 14). Otherwise, the camera might be damaged and liability and warranty is void.

Feel free to contact ***ART*** in case you want to realise a more complex installation. We will assist you in your planning.
It is recommended to install the power supply for the cameras in a way that enables the

switching of all cameras by one main switch. If this is done, the system can be easily turned off and on without changing camera positions.

Make sure to install the system in a way that you can easily access the cameras and its cables. Be especially careful to mount the cameras firmly so they cannot fall down. Unsecured cameras may pose a serious hazard to health and safety.

Shock and vibration can permanently destroy the internal calibration of the cameras. De-calibrated cameras have to be recalibrated in the ART labs.

Figure 4.3 on page 31 shows the correct mounting for a camera to a wall with a carrier using the example of an ***ARTTRACK2*** camera. Make sure to not fall below minimal distance to the wall so enough room is left for the cables and to allow readjustment of the camera angles and maintenance. For easy adjustment, it is highly recommended to mount the ceiling mount in a way that the threaded bolt is vertical. This way heading and elevation of the camera view can be adjusted individually.
Use strong dowels and screws for mounting the cameras to walls or ceilings (see figure 4.3 on page 31).
If in doubt, ask a skilled craftsman for assistance. Use massive and long enough angle irons to provide the required stiffness and stability.

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. 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).
Furthermore, please make sure the ventilator holes are not covered. For thermal reasons the ventilator always has to be on the upper side of the ***ARTTRACK2*** camera. That means, if the camera is to be mounted hanging the carrier must be mounted on top (ventilator side). If it is to be mounted standing the carrier has to be on the bottom side of the housing.

Please install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the cameras due to mechanical strain,
- the line of sight of the cameras 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!

Please refer to chapter 5.2 on page 60 for more information.

4.5 *ARTTRACK3* (discontinued)

Keep a distance of min. 20 cm when operating the camera ! The camera 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 *ARTTRACK3* camera is the successor of *ARTTRACK1* which is no longer produced. Due to its larger IR flash it can be used for measurements in higher distances (up to 6 metres). And, because of its passive cooling system (i.e. without fan), the *ARTTRACK3* is also suitable for dirty or noise sensitive environments.
By default the *ARTTRACK5/C* is equipped with a 4.5 mm lens. Depending on the application and the setup the *ARTTRACK3* can be equipped with other lenses (i.e. with different focal lengths). Refer to A.1 on page 236 for a list of available focal lengths and the respective FoV.

Figure 4.8: Camera *ARTTRACK3*

Mounting The *ARTTRACK3* cameras are optimized for a predefined range of measurement volumes. System operation in smaller or bigger measurement volumes can lead to reduced accuracy. The measurement volume can be adjusted within certain limits simply by changing the flash intensity of the *ART* infrared cameras (see chapter 8.5.1 on page 146).

The flash intensities should not be too high. In general, a flash intensity of 3-4 might be sufficient.

Major changes of the measurement volume may require different lenses and thus a new

determination of camera parameters. These changes have to be done at the *ART* labs.

Be aware that a tracking system is very sensitive to camera movements. Therefore the cameras have to be mounted in a way that camera movements (especially vibrations) are reduced as much as possible.

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

If you want to mount the camera on a tripod just mount the carrier on the bottom of the camera.
The carrier for the *ARTTRACK3* can be attached on both bottom and top side of the camera. Attach the carrier with the T-piece pointing to the back of the camera in a similar way to figure 4.2 on page 30. Note, the ceiling suspension is already connected to the carrier in figure 4.2.

Only use screws supplied with the ceiling mount for mounting it. The screws used for sealing the housings are not sufficiently long for fixing the carrier. Also, use all the parts supplied with the ceiling mount - especially the toothed washer is quite important.

Never unfasten other screws on the cameras (see chapter 1.2 on page 14). Otherwise, the camera might be damaged and liability and warranty is void.

Feel free to contact *ART* in case you want to realise a more complex installation. We will assist you in your planning.
It is recommended to install the power supply for the cameras in a way that enables the switching of all cameras by one main switch. If this is done, the system can be easily turned off and on without changing camera positions.

Make sure to install the system in a way that you can easily access the cameras and its cables. Be especially careful to mount the cameras firmly so they cannot fall down. Unsecured cameras may pose a serious hazard to health and safety.

Shock and vibration can permanently destroy the internal calibration of the cameras. De-calibrated cameras have to be recalibrated in the ART labs.

Figure 4.3 on page 31 shows the correct mounting for a camera to a wall with a carrier using the example of an *ARTTRACK2* camera. Make sure to not fall below minimal distance to the wall so enough room is left for the cables and to allow readjustment of the camera angles and maintenance. For easy adjustment, it is highly recommended to mount the ceiling mount in a way that the threaded bolt is vertical. This way heading and elevation of the camera view can be adjusted individually.
Use strong dowels and screws for mounting the cameras to walls or ceilings (see figure 4.3 on page 31).
If in doubt, ask a skilled craftsman for assistance. Use massive and long enough angle irons to provide the required stiffness and stability.

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. 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 install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the cameras due to mechanical strain,
- the line of sight of the cameras 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!

Please refer to chapter 5.2 on page 60 for more information.

4.6 *TRACKPACK* (discontinued)

Keep a distance of min. 20 cm when operating the camera ! The camera 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 *TRACKPACK* is a two or four camera infrared optical tracking system for use in medium-sized working volumes. It is the best solution for Head- and Flystick-tracking in multi-sided projection environments (max. 3 m x 3 m x 2 m), or in front of medium-sized projection screens (up to 4.5 m wide). The system consists of two or four *TRACKPACK* cameras and a *TRACKPACK* Controller.
By default the *TRACKPACK* is equipped with a 3.5 mm lens. Depending on the application and the setup the *TRACKPACK* camera can be equipped with other lenses (i.e. with different focal lengths). Refer to A.1 on page 236 for a list of available focal lengths and the respective FoV.

The RJ45 connection between *TRACKPACK* camera and controller is used for power supply and synchronization signal. It is not a standard Ethernet connection! That is why connecting the RJ45 connector to any other than the equivalent port of the controller may damage the camera or the connected partner.

Figure 4.9: Camera *TRACKPACK*

Mounting The *TRACKPACK* cameras are optimized for a predefined range of measurement volumes. System operation in smaller or bigger measurement volumes can lead to reduced accuracy. The measurement volume can be adjusted within certain limits simply by changing the flash intensity of the *ART* infrared cameras (see chapter 8.5.1 on page 146).

The flash intensities should not be too high. In general, a flash intensity of 3-4 might be sufficient.

Major changes of the measurement volume may require different lenses and thus a new determination of camera parameters. These changes have to be done at the *ART* labs.

Be aware that a tracking system is very sensitive to camera movements. Therefore the cameras have to be mounted in a way that camera movements (especially vibrations) are reduced as much as possible.

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

If you want to mount the camera on a tripod just mount the carrier on the bottom of the camera.

The carrier for the *TRACKPACK* can be attached on both bottom and top side of the camera. Attach the carrier with the T-piece pointing to the back of the camera in a similar way to figure 4.2 on page 30. Note, the ceiling suspension is already connected to the carrier in figure 4.2.

Only use screws supplied with the ceiling mount for mounting it. The screws used for sealing the housings are not sufficiently long for fixing the carrier. Also, use all the parts supplied with the ceiling mount - especially the toothed washer is quite important.

Never unfasten other screws on the cameras (see chapter 1.2 on page 14). Otherwise, the camera might be damaged and liability and warranty is void.

Please keep the distance between the cameras in a range of 1 to 2 metres. Depending on the lens and the focal length it may be possible to achieve other range values. Please contact *ART* for more information.

Make sure to install the system in a way that you can easily access the cameras and its cables. Be especially careful to mount the cameras firmly so they cannot fall down. Unsecured cameras may pose a serious hazard to health and safety.

Shock and vibration can permanently destroy the internal calibration of the cameras. De-calibrated cameras have to be recalibrated in the ART labs.

Figure 4.3 on page 31 shows the correct mounting for a camera to a wall with a carrier using the example of an *ARTTRACK2* camera. Make sure to not fall below minimal distance to the wall so enough room is left for the cables and to allow readjustment of the camera angles and maintenance. For easy adjustment, it is highly recommended to mount the ceiling mount in a way that the threaded bolt is vertical. This way heading and elevation of the camera view can be adjusted individually.
Use strong dowels and screws for mounting the cameras to walls or ceilings (see figure 4.3 on page 31).
If in doubt, ask a skilled craftsman for assistance. Use massive and long enough angle irons to provide the required stiffness and stability.

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. 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 install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the cameras due to mechanical strain,
- the line of sight of the cameras 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!

Please refer to chapter 5.3 on page 63 for more information.

4.7 *TRACKPACK/C* (discontinued)

Keep a distance of min. 20 cm when operating the camera ! The camera 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 *TRACKPACK* system may also be combined with the *TRACKPACK/C* camera in order to realize tracking in multi-sided projection environments (e.g. CAVE®, I-Space). In such an environment it is necessary to drill holes into the projections' corners as the camera cannot see through the screen. The *TRACKPACK/C* camera has been designed to easily fit into such holes by separating the lens from the electronics part (see figure 4.10).
With its 3.5 mm lens a large field of view (FoV) is covered. Refer to A.1 on page 236 for the respective FoV.

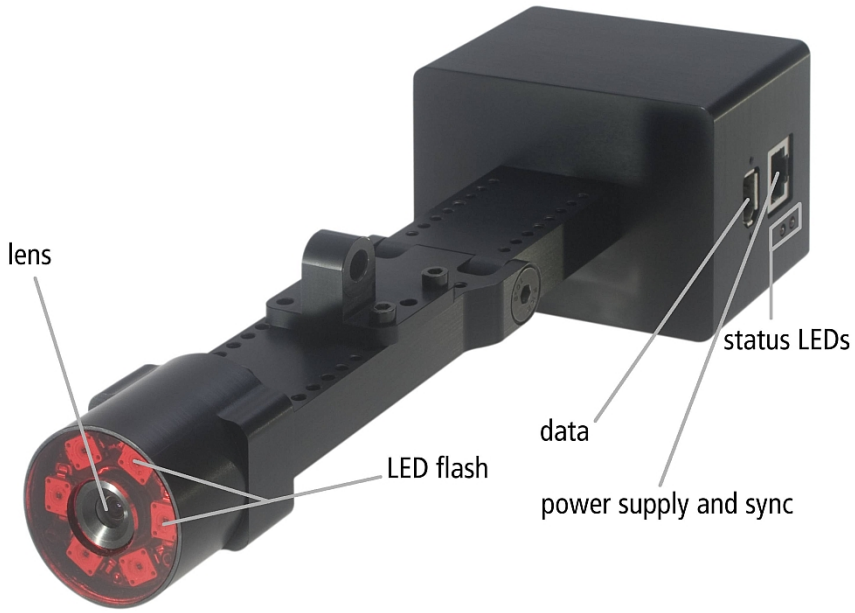


Figure 4.10: Camera *TRACKPACK/C*

The *TRACKPACK* system either consists of *TRACKPACK/C* cameras or it can be mixed with standard *TRACKPACK* cameras - both variants are limited to a total number of four cameras per system and come with a *TRACKPACK* Controller.

The RJ45 connection between *TRACKPACK/C* camera and controller is used for power supply and synchronization signal. It is not a standard Ethernet connection! That is why connecting the RJ45 connector to any other than the equivalent port of the controller may damage the camera or the connected partner.

Mounting The *TRACKPACK/C* cameras are optimized for a predefined range of measurement volumes. System operation in smaller or bigger measurement volumes can lead to reduced accuracy. The measurement volume can be adjusted within certain limits simply by changing the flash intensity of the *ART* infrared cameras (see chapter 8.5.1 on page 146).

The flash intensities should not be too high. In general, a flash intensity of 3-4 might be sufficient.

Major changes of the measurement volume may require different lenses and thus a new determination of camera parameters. These changes have to be done at the *ART* labs.

Be aware that a tracking system is very sensitive to camera movements. Therefore the cameras have to be mounted in a way that camera movements (especially vibrations) are reduced as much as possible.

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

The carrier for the *TRACKPACK/C* can be attached to the camera as shown in figure 4.11.

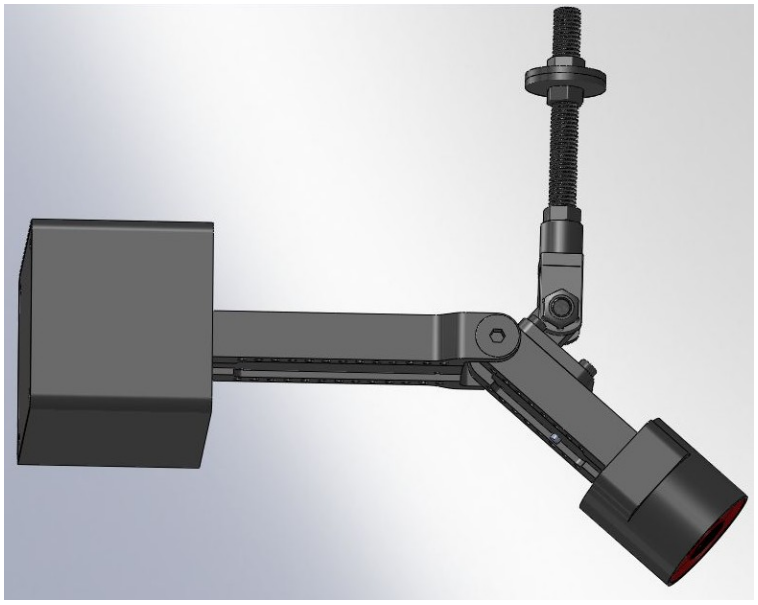


Figure 4.11: Camera *TRACKPACK/C* with attached carrier

Only use screws supplied with the ceiling mount for mounting it. The screws used for sealing the housings are not sufficiently long for fixing the carrier. Also, use all the parts supplied with the ceiling mount - especially the toothed washer is quite important.

Never unfasten other screws on the cameras (see chapter 1.2 on page 14). Otherwise, the camera might be damaged and liability and warranty is void.

Please keep the distance between the cameras in a range of 2 to 3 metres. Please contact *ART* for more information.

Make sure to install the system in a way that you can easily access the cameras and its cables. Be especially careful to mount the cameras firmly so they cannot fall down. Unsecured cameras may pose a serious hazard to health and safety.

Shock and vibration can permanently destroy the internal calibration of the cameras. De-calibrated cameras have to be recalibrated in the ART labs.

Use strong dowels and screws for mounting the cameras to walls or ceilings (see figure 4.3 on page 31).
If in doubt, ask a skilled craftsman for assistance. Use massive and long enough angle irons to provide the required stiffness and stability.

To avoid measurement problems, no light sources or highly reflecting areas should be visible to the camera. 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 install the cables such that

- no one can stumble over the cords,
- the cords cannot be damaged,
- the cords cannot damage the cameras due to mechanical strain,
- the line of sight of the cameras 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!

Please refer to chapter 5.3 on page 63 for more information.

4.8 Setting up the cameras

4.8.1 Camera orientation

After mounting and connecting the cameras to the controller, the next step is to adjust the orientation of each camera such that the measurement volume is covered completely by the field of view (FoV) of all cameras. On the one hand camera mounting has to ensure that tracking is possible over the entire measurement volume. On the other hand attention has to be paid to the fact that the calibration angle (for room calibration) can be seen completely by at least two cameras. Moreover, the FoV of all cameras has to overlap sufficiently to enable the calculation of the photogrammetric orientation of all cameras in a common coordinate system, especially if the calibration angle can not be seen by each camera.
Additionally this step is important for removing disturbing reflections (refer to 4.8.2 on page 48) as well as ruling out mutual blinding of the cameras, i.e. the IR flash of one camera is inside the FoV of another(refer to 4.8.2.1 on page 49). Therefore, as part of its GUI ***DTrack2*** provides the *Monitor 2DOF display* which is essentially a 2-dimensional graphical display of all markers / flashes or other IR sources that can be seen inside the FoV of the cameras. At this point, you will probably find it most useful to become acquainted with the graphical user interface and the main window of ***DTrack2*** . Please refer to chapter 8.3 on page 132.

4.8.2 Localizing and removing of disturbing reflections

Possible sources of disturbing reflections may be diverse. Still all of them may be detected when starting the *Monitor 2DOF display* in ***DTrack2*** . They are illustrated the same way as markers, i.e. with small coloured crosses or circles, depending on the distance to the camera (see figure 4.12 on page 48).

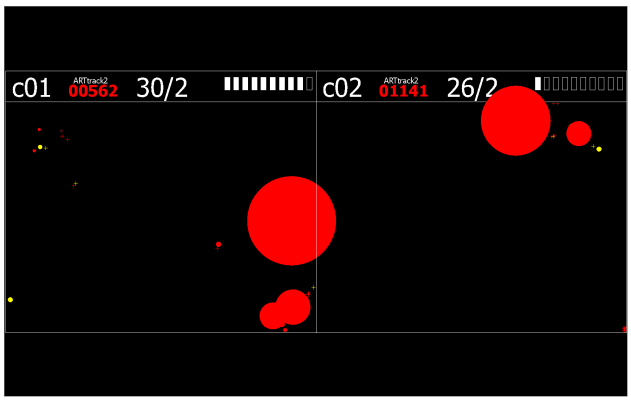


Figure 4.12: Typical situation arising from reflections through sunlight

Typically the reflections arise from one (or more) of the following points:

- active or passive targets that are inside the FoV / tracking range of the cameras,

- strong IR sources (e.g. sunlight or sunrays, halogen lamps, ...),
- mutual blinding of opposing or adjacent cameras
- any kind of reflective material on clothes or shoes (e.g. reflective tape on safety vests),
- blank metal surfaces that act as mirrors, especially curved surfaces and polished surfaces with 90° angles,
- some types of packaging foils.

For localising and removing disturbing reflections follow this simple approach:

- active targets or IR sources: reduce the flash intensity of all cameras to '0'
  Try to localize and remove the remaining markers / reflections which originate from infrared radiation sources (e.g. sunlight, halogen lamps, ...).
- mutual blinding: reduce the flash intensity of all cameras to '0', then set each camera's flash intensity to full one after the other
  Corresponding / opposing cameras can be easily identified. Re-mount the relevant cameras until *Monitor 2DOF display* does not show markers and the LED bar does not indicate levels of intensity. You may also assign different syncgroups at this stage. Please refer to chapter 8.5.1 on page 146 for further information.
- other non-specific reflections:set the flash intensity of all cameras to '50'
  Try to localize the reflection by moving a target or reflective marker towards the origin of the reflection (use the *Monitor 2DOF display*) and remove it.

If, by any means, reflections cannot be eliminated completely you may use the static reflex suppression of ***DTrack2*** (please refer to chapter 8.6.1 on page 165).

Be aware that reflex suppression leads to decreased FoV / effective measurement volume by blocking the area in which the reflection originated.

4.8.2.1 Mutual blinding

One possible source of disturbing reflections is mutual blinding of adjacent or opposing cameras that are inside the FoV of each other. This can be well observed in the *Monitor 2DOF display* as the cameras falsely identify the IR flashes as numerous flickering markers (i.e. clusters of crosses or circles). Tracking will be severely affected in the involved areas of the measurement volume / FoV. The intensity of the simulated LED bar next to the number of markers seen / used for tracking may serve as another indicator.
In order to distinguish from targets or other reflections please remove all reflective markers from the measurement volume in the first step. Then check whether the *Monitor 2DOF display* still shows the presence of markers and whether the LED bar shows high levels of intensity. Try to re-arrange or re-adjust the cameras (i.e. position and orientation).

Rarely there may also be mutual blinding that is not fully illustrated in the *Monitor 2DOF display*. Then only the simulated LED bar will indicate high levels of intensity whereas the presence of markers is missing (see figure 4.13 on page 50).

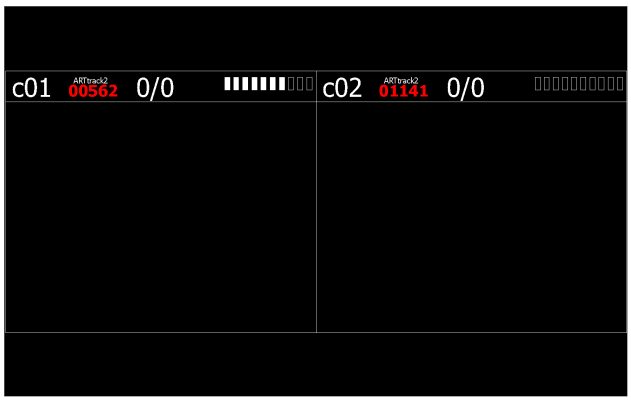


Figure 4.13: Mutual blinding without reflex illustration

This is a known behaviour of some ***ARTTRACK2*** cameras, which can be easiliy addressed by updating the firmware. Please contact ***ART*** in case you experience alike problems.

Assigning syncgroups If reorienting the cameras seems not feasible, the cameras can also be assigned to different syncgroups, i.e. setting individual time delays for each camera in order to shift the IR flash / measurement of one camera in time from the measurement recording of another camera. In other words, a short time delay (typically < 1ms) is introduced between the measurements of two cameras which are assigned to different syncgroups. Thus the IR flash of one camera cannot be detected by the other and vice versa.

Recommendation Assign opposing or adjacent cameras within the FoV of each other to different syncgroups (e.g. '*Channel 1*' and '*Channel 2*'). Cameras, that are outside of the FoV of each other (e.g. mounted on the same wall) should be assigned to the same syncgroup. For ***ARTTRACK5*** , ***ARTTRACK5/C*** and ***TRACKPACK/E*** systems it is possible to configure the syncgroups via software. Please refer to chapter 8.5.1 on page 146 for further information. For ***ARTTRACK2*** , ***ARTTRACK3*** (discontinued) please refer to chapter 5.2 on page 60 for installation instructions.

Static reflex suppression You may also take advantage of the functionality of static reflex suppression, i.e. blocking individual areas of the FoV / measurement volume to eliminate mutual blinding. ***DTrack2*** and all ***ART*** cameras are able to suppress all reflections in certain areas of the image sensor. Scanning for static reflections allows searching the measurement FoV for unwanted reflections. Areas are defined on top of the visible reflections, where all data on the image sensor is neglected during measurements. This is especially important for setups in multisided projections: these cameras are mounted in

the corners of the multisided projection and usually get a lot of unwanted reflections from the nearby walls. To gain good tracking results, these reflections should be suppressed. Be aware that the FoV / effective measurement volume will be decreased, which is why reflex suppression should always be the last option to be considered. If possible, try adjusting the cameras in order to minimize reflections.
Please refer to chapter 8.6.1 on page 165 for further details.

☞ **Be aware that reflex suppression leads to decreased FoV / effective measurement volume by blocking the area in which the reflection originated.**

4.8.3 Room Calibration overview

Before you can start tracking, a so called room calibration has to be carried out. During this calibration, the system identifies the position of the cameras inside the measurement volume and determines the three-dimensional coordinate system. Carrying out a room calibration is always the first step. Without it, body calibration and tracking will not be possible.
In principle, it is recommended to perform a room (re-)calibration on a regular basis (e.g. after a certain operating time of the system) and especially if the system setup does not rule out camera movements over time (these camera movements may also be thermal drifts!).

☞ **Example: If a camera with 3.5mm lenses (standard for *ARTTRACK5* or *TRACKPACK/E*) is rotated by one tenth of a degree it will cause aberrations of the optical rays that are as high as 5 millimetres in 3 metres distance from the camera.**
This will result in unacceptable errors in the measurement results, hence, *DTrack2* will exclude data from such a camera and it will not contribute to tracking.

In summary room calibration has to be carried out

- after the first system setup,
- after any changes of IR camera positions ($\rightarrow$ Room re-calibration),
- after any changes to the number of cameras,
- before a body calibration (when system has been setup initially),
- whenever any uncertainty regarding the mechanical stability or the thermal behaviour of the setup occurs.

Room calibration hardware For room calibration, the calibration angle (see figure 4.14 on page 52) of the "room calibration set" is put inside the tracking volume (i.e. into the FoV of the IR cameras). The position of the calibration angle defines the room coordinates. 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 relative positions of the IR cameras 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.

Figure 4.14: A room calibration set consisting of angle and wand

Room calibration process At least two IR cameras have to see all markers of the calibration angle while the two markers of the wand should be visible to all IR cameras as good as possible. Move the wand gently in all possible directions (up/down, left/reft, back/forth) and additionaly rotate it within the measurement volume in order to generate a virtual point cloud (see figure 4.15 on page 52). If possible, try to walk around to maximize the point cloud in all dimensions. It is used for calculation of IR cameras positions, so moving the wand in only a very small volume will result in reduced accuracy of calibration. Also avoid quick and jerky movements.
Please refer to chapter 8.6.3 on page 166 for further details of the procedure.

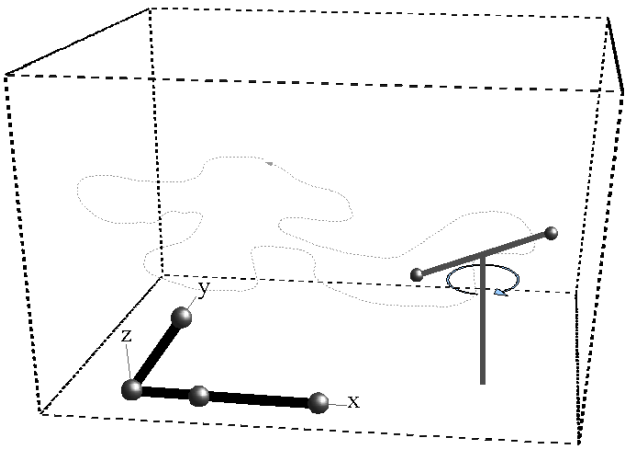


Figure 4.15: Room calibration process

The point cloud should fill at least two thirds of the measurement volume. Moving the wand in a restricted volume will result in reduced accuracy of calibration or failure.

If in a system setup no sufficient part of the measurement volume is seen by all IR cameras simultaneously, the point cloud created by the wand movement has to connect all cameras in a way that ensures the arrangement of all cameras in a common room coordinate system. This means cameras that see the calibration angle are oriented first. Then every additional camera has to be connected by a sufficient volume with at least two already oriented cameras. In this way, the calibration is stepping forward from camera to camera. (e.g.: cameras 1 and 2 are seeing the angle - camera 3 overviews a certain volume together with cameras 1 and 2 - camera 4, finally overviews a volume together with cameras 1 and 3).
Calibrating cameras which do not observe the angle directly is called "chain calibration". Chain calibrated cameras propagate inaccuracies from the previously calibrated cameras. It is recommended to place the calibration angle in a point where as many cameras as possible can see the angle.

5 *ART* Tracking Controllers

Starting with ***DTrack2*** , all ***ART*** systems are based on a controller – ***ART*** Controller, ***ARTTRACK*** Controller (discontinued) or ***TRACKPACK*** Controller (discontinued) – which operates cameras, interaction devices (optional) and targets respectively. The software ***DTrack2*** consists of frontend and backend software.
The frontend software is installed on a remote PC which is connected to the controller 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 controller and exchanging short command strings (refer to chapter 8.2.5 on page 129). Please contact ***ART*** if you are interested in using this feature.
The backend software runs on the controller - all necessary calculations (3DOF, 6DOF data, ...) are performed there. The data and control commands are interchanged via a TCP/IP connection between the controller and the ***DTrack2*** frontend software on the remote PC. Data output to the application or graphics workstation is done via a UDP connection. The cameras (refer to chapter 4 on page 29) and the interaction devices (refer to chapter 6 on page 71) have to be connected to the respective ports of the controller.

	ART Controller	***ARTTRACK*** Controller	***TRACKPACK*** Controller	***DTrack2*** [1]
ARTTRACK1	×	×		×
ARTTRACK2	×	×		×
ARTTRACK3	×	×		×
ARTTRACK5	×			× (from v2.10)
ARTTRACK5/C	×			× (from v2.11)
TRACKPACK			×	×
TRACKPACK/C			×	× (from v2.5)
TRACKPACK/E	×			× (from v2.11)
Flystick1	×	×	×	×
Flystick2	×	×	×	×
Flystick3	×	×	×	× (from v2.2)
Fingertracking [2]	×	×	×	×
FINGERTRACKING2	×	×	×	× (from v2.13)
Tactile [2]				
Measurement Tool	×	×	×	× (from v2.2)
Trivisio hybrid MoCap	×	×	×	× (from v2.9)
YEI wired inertial	×	×	×	× (from v2.14)

[1] an appropriate license may be necessary (refer to table 8.6)
[2] for Fingertracking it is recommended to use six cameras for ideal operation

Table 5.1: Compatibility of the ***ART*** cameras and interaction devices

5.1 Installation of the *ART* Controller (*DTrack2* since v2.10)

The *ART* Controller (*DTrack2* since v2.10) comes in a 19" inch housing compatible for rack mounting, see fig. 5.1 on page 55.
To turn on the controller flip the power switch to 'I', for restart from standby mode press the button 'soft power on'. All USB ports (front & back) can be used for plugging in the USB radio transceiver for the Flystick2/3 (refer to chapter 6.3.1 on page 80.

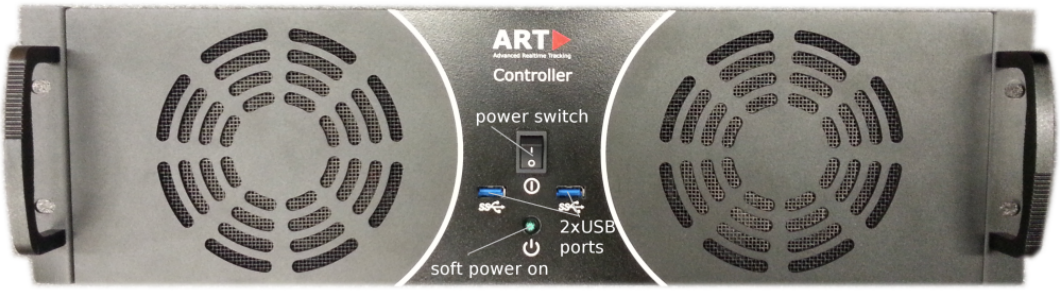


Figure 5.1: ART Controller front view

Please ensure unblocked airflow at all times for optimal operation of the *ART* Controller !

5.1.1 Ports & Plugs on the *ART* Controller

The following list gives a short overview of all ports accessible to the user. (see figure 5.2 on 55):

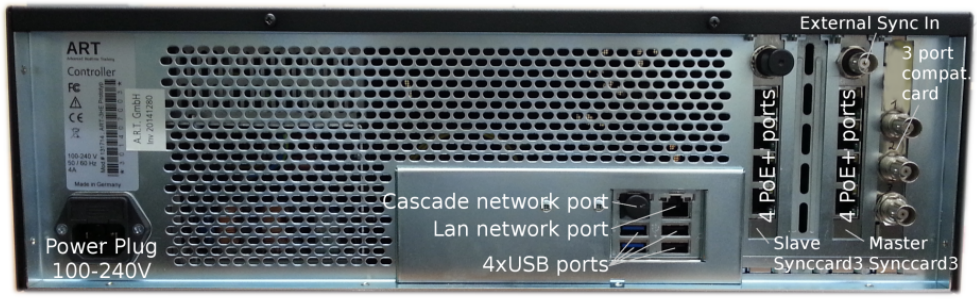


Figure 5.2: ART Controller back view

- *ART* Synccard3 (master & slave) :

  - ExtIn:
    Please plug in the external source (TTL or video signal) for synchronization here. Please use the accessible port without protective cap only. In cascaded systems please connect the external source to the master controller only. The slave controller is then synchronized by the master.
  - PoE+ ports:
    All ***ARTTRACK1*** , ***ARTTRACK2*** , ***ARTTRACK3*** , ***ARTTRACK5*** , ***ARTTRACK5/C*** and ***TRACKPACK/E*** cameras have to be plugged in here. In larger systems (> 8 ***ARTTRACK5*** and ***ARTTRACK5/C*** cameras only), please connect the external PoE+ switch to any of these ports.
  - OUT1-3 (optional):
    These ports are used as synchronization outputs (video signal) and are characterized by their respective time delay related to syncgroup # 1 on 'OUT1'. For cascaded systems please connect 'OUT1' to 'ExtIn' of a slave controller (see chapter 5.4 on page 66). For backwards compatibility, please connect ***ARTTRACK1*** – ***ARTTRACK3*** cameras here. Please refer to chapter 5.1.2 on page 58 for more detailed information.

    * OUT1:
      Defines syncgroup # 1. When using ***ARTTRACK1*** – ***ARTTRACK3*** cameras at least one camera has to be connected here if you are using active targets (e.g. Fingertracking, Flystick3). Refer to chapter 6.4 on page 83 for more information.
    * OUT2:
      Defines syncgroup # 2. The default time delay related to syncgroup # 1 is 480μs.
    * OUT3:
      Defines syncgroup # 3. The default time delay related to syncgroup # 1 is 960μs.

- USB port:
  Please plug in all USB based devices here (e.g. ***ART*** radio transceiver for Flystick2/3, Trivisio wireless transceivers, YEI wired inertial sensors, refer to chapter 6 on page 71).

- LAN network port:
  Please connect the ***ART*** Controller to your local network using an RJ45 cable.

- Cascaded network port:
  For cascaded systems please connect a slave controller to the ***ART*** Controller (master). Please refer to chapter 5.4 on page 66 for more detailed information.

- Power inlet:
  Please connect to mains (100 - 240V).

The power inlet is fuse-protected (2x4A, anti-surge type T) and features a line filter for EMV protection.

In order to replace the main fuse of the *ART* Controller always unplug the power cord. Two main fuses are existing since two power supplies are installed. So the device is possibly still under power although a fuse has blown.

PoE+ switch for larger systems In larger systems (> 8 *ARTTRACK5* and *ARTTRACK5/C* cameras **ONLY**), please use switches authorized by *ART* (e.g. Netgear Prosafe GSM7212P PoE+). It features 12 PoE+ Ports for connection to *ARTTRACK5* and *ARTTRACK5/C* cameras. Please use the accessible ports without protective caps only (see fig. 5.3 on page 57). To turn on the PoE+ switch, please connect it to mains.

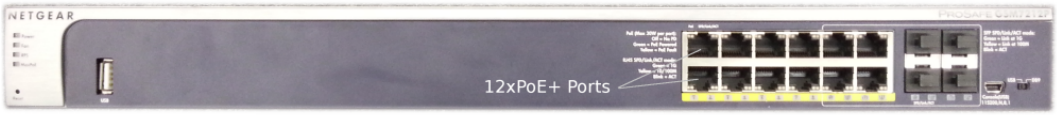


Figure 5.3: ART PoE+ switch front view

Please allow min. 3 minutes for booting prior to starting the *ART* Controller !

5.1.2 Connecting cameras

Connection of *ARTTRACK5* , *ARTTRACK5/C* or *TRACKPACK/E* cameras Mount the cameras at the desired position before connecting the cables.
The *ART* Synccard3 is designed as a single cable solution and is therefore used both for power and synchronization of the IR cameras. Therefore the *ARTTRACK5* , *ARTTRACK5/C* and *TRACKPACK/E* cameras have to be connected via twisted pair cables (min. Cat.5, max. length 100 m) to the internal *ART* Synccard3 of the *ART* Controller or to an external PoE+ switch for systems > 8 cameras (**ONLY** *ARTTRACK5* and *ARTTRACK5/C*). The external PoE+ switch itself is then to be connected to any port on the Synccard3.

Do not connect *TRACKPACK/E* cameras via external PoE+ switches ! In case of mixed systems connect all *TRACKPACK/E* cameras directly to the *ART* Controller.

The camera IP addresses are predefined - changes by the user are not possible:

- **IP address: 172.28.0.X**
- **subnet mask: 255.255.0.0**

Connection of *ARTTRACK1* , *ARTTRACK2* or *ARTTRACK3* cameras (backwards compatible systems) All sync signals are transferred via BNC connections. When connecting the synchronization cables it is important to correctly chain the cameras on the sync cable (see chapter 9.4 on page 195). There must be one continuous signal line terminated on both ends with 75Ω resistors, with the cameras and the synccard inserted by tee connectors. Do not extend the connection between the tee-connector and the camera nor branch the signal line (star wiring).
Typically all cameras are connected to the syncgroup #1 ('OUT1') of the synccard. If the cameras have to be grouped into different syncgroups, in order to avoid blinding, two or three BNC chains are used with syncgroups #1 and #2 or #1, #2 and #3 of the *ART* Synccard3 (compatibility ports) respectively.

☞ **_ARTTRACK2_ and _ARTTRACK3_ cameras have to be connected via any external ethernet switch or via the _ART_ PoE+ switch for larger systems. They shall not be connected directly to the PoE+ ports of the _ART_ Synccard3. Please refer to chapter 5.2 on page 60 for more detailed information.**

5.1.3 Dynamically adding / removing of cameras

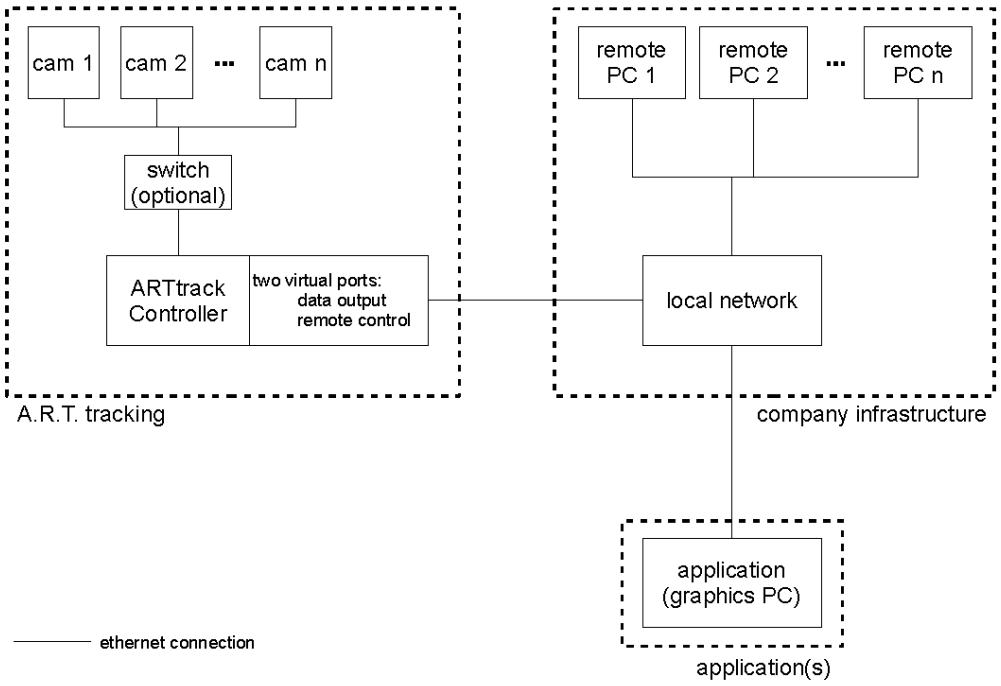
You can (dis-)connect additional cameras to the *ART* Controller without the need of restarting the controller. Please refer to chapter 8.4.4 on page 145 for details.

☞ **_DTrack2_ is able to operate when cameras have been added or removed; for best performance it is highly recommended to perform a recalibration**

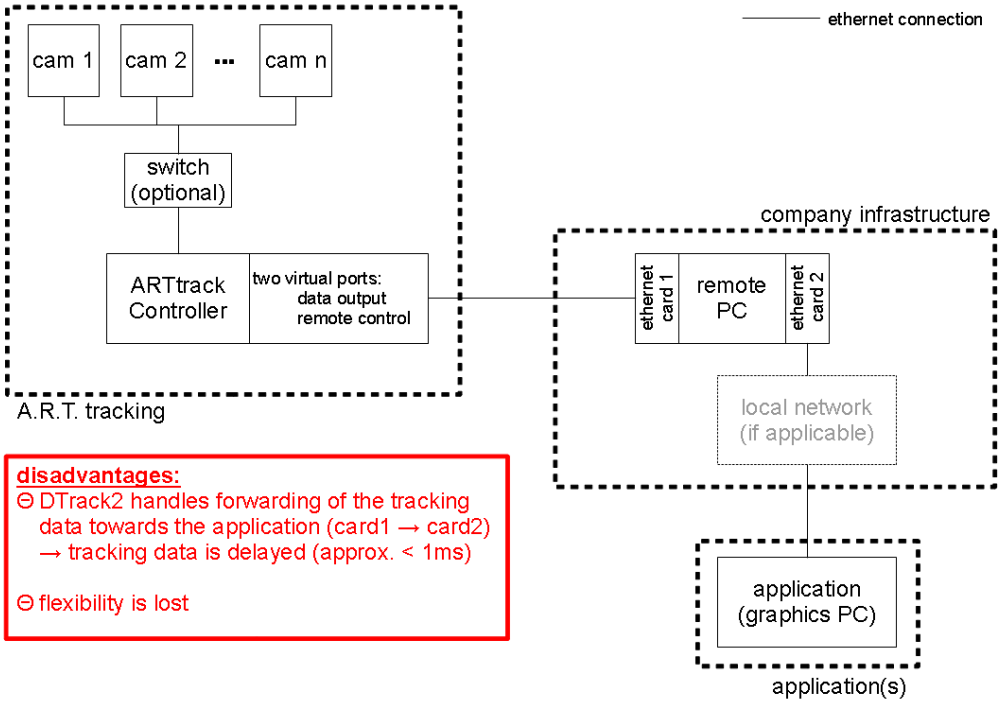
5.1.4 Connection to local network LAN

The controller uses the 'LAN network port' (1000 Base-TX) for data output to the remote PC or to any PC within the local network. Figure 5.4 on page 59 shows two possibilities of connecting the controller to a local network. You may either use the controller as a DHCP client within your network (figure 5.4(a)), i.e. the tracking data is transmitted directly via your local network. Or in case of security restrictions (e.g. company guidelines, that do not allow to connect the controller to your network), you may install two network cards in your remote PC - one is connected to the controller and the other one is connected to your local network (figure 5.4(b)). In this case, the *DTrack2* Frontend will act as a router for the tracking data.

By default the controller is set up to support DHCP. Therefore, it will acquire an IP address automatically given that a DHCP server is running.
Double-check that the cameras are connected properly to the controller (in case of *ARTTRACK1* , *ARTTRACK2* or *ARTTRACK3* verify that they are powered up), connect the 'LAN network port' to your local network and connect the power plug of the *ART* Controller to a power socket. Flip the power switch to 'I' on the front of the controller. Finally, start



(a) standard connection



(b) indirect connection

Figure 5.4: Connecting the *ARTTRACK* Controller to a local network

the *DTrack2* frontend software on the remote PC. Please refer to chapter 8 on page 121 for more details.

If the *ART* controller is not connected via an ethernet cable or no DHCP server is running, it will use its fall-back IP address (IP 192.168.0.1, subnet mask 255.255.255.0)

You may configure a static IP address the following ways:

- using *DTrack2* (refer to chapter 8.2.2 on page 125)
- without the *DTrack2* frontend (refer to chapter 8.2.4 on page 127)

Please note that these settings are not part of your personal configuration. Changes of the IP address will affect all users of your controller! Your controller may become unreachable with wrong IP settings! Refer to chapter 8.2.4 on page 127).

5.1.5 External synchronization

The *ART* Controller can be synchronized with an external source. On the back of the controller there is a BNC plug 'ExtIn' which serves as input for the external synchronization signal. The sync signal may be of type TTL (5V) or video. Using TTL you can select between rising and falling edge trigger and triggering on both edges (see also chapter 8.5.2 on page 151).
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 tee connector with an external 75 Ω terminating resistor should be used if the signal line ends at the controller.
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.

5.2 Installation of the *ARTTRACK* Controller (discontinued)

The following list introduces the ports of the *ARTTRACK* Controller with Synccard2:

- internal Ethernet switch:

the cameras have to be plugged in here. In larger systems, please connect the external switch to any of these ports.

- external Ethernet switch:
  the Allied Telesis AT-FS708 is an eco friendly switch which is designed to minimize power consumption (typical 3.5W) through the use of a high efficiency power supply and a low power chipset. It features an overnight mode (i.e. reduction in power during after-work hours) as well as other power saving features.
  Please refer to the Allied Telesis Installation Guide before connecting the power source.

- *ART* Synccard2 :
  - ExtIn:
    Please plug in the external source for synchronization here.
  - Out1:
    Defines syncgroup # 1. The three different syncgroups are characterized by their time delay related to syncgroup # 1. At least one camera has to be connected here if you are using active targets (e.g. Fingertracking, Flystick3). Refer to chapter 6.4 on page 83 for more information.
  - Out2:
    Defines syncgroup # 2. The time delay related to syncgroup # 1 is 480μs.
  - Out3:
    Defines syncgroup # 3. The time delay related to syncgroup # 1 is 960μs.

- USB port:
  Please plug in all USB based devices here (e.g. *ART* radio transceiver for Flystick2/3, Trivisio wireless transceivers, YEI wired inertial sensors, refer to chapter 6 on page 71).

- Ethernet port:
  Please connect the controller to your local network using an RJ45 cable.

Mount the cameras at the desired position before connecting the cables. The *ARTTRACK* cameras have to be connected via twisted pair cables either to the internal Ethernet switch of the controller or to an external Ethernet switch. The external switch itself has to be connected to the controller.

Older switches sometimes do have uplink ports which are not suitable for connecting to the camera. Only use the normal ports of the switch.

The controller is equipped with an internal switch (100 Base-TX) which serves for the connection to the cameras (suitable for small systems, i.e. $\leq$ 4 cameras). Larger systems (i.e. $>$ 4 cameras) have to be equipped with an external switch which must be connected to any port (except for the uplink port) of the internal switch of the controller.

The camera IP addresses are predefined - changes by the user are not possible:

- **IP address: 172.28.0.X**
- **subnet mask: 255.255.0.0**

The controller is equipped with a PCI card for synchronization of the IR cameras (***ART*** Synccard2). When connecting the synchronization cables it is important to correctly chain the cameras on the sync cable (see chapter 9.4 on page 195). There must be one continuous signal line from the BNC connector of the synccard to the 75Ω terminating resistor, with the cameras inserted to the line by T-junctions. It is neither allowed to extend the connection between the tee-connector and the camera, nor to branch the signal line.
Usually, all cameras are connected with the sync output no. 1 ("OUT1") of the synccard like a chain that is finished by a 75Ω terminating resistor. If the cameras have to be grouped into different syncgroups, in order to avoid blinding, two or three BNC chains are used at the sync outputs no. 1 and 2 or 1, 2 and 3, respectively, of the synccard. The settings of the Synccard2 are defined by software ***DTrack2*** . All sync signals are transferred via BNC connections.

Furthermore, the controller uses the single Ethernet plug (100 Base-TX) for data output to the remote PC or to any PC within the local network. Figure 5.4 on page 59 shows two possibilities of connecting the controller to a local network. You may either use the controller as a DHCP client within your network (figure 5.4(a)), 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 controller and the other one is connected to your local network (figure 5.4(b)). In this case, the ***DTrack2*** Frontend will act as a router for the tracking data.

The controller is controlled by a remote PC via ***DTrack2*** frontend software. When delivered, the controller is set up to support DHCP. Therefore, it will acquire an IP address automatically given that a DHCP server is running.
Double-check if the cameras are connected properly to the controller. Verify that power supplies are switched on and the cameras are running. Connect the Ethernet cable to your local network and connect the power plug of the ***ARTTRACK*** Controller to a power socket. If you want to set a specific static IP address before booting the controller please refer to chapter 8.2.4 on page 127 for more information.

Press the switch next to the power plug to start the controller. Finally, start the ***DTrack2*** frontend software on the remote PC. Please refer to chapter 8 on page 121 for more details.

If the controller is not connected via an ethernet cable or no DHCP server is running, it will use its fall-back IP address (IP 192.168.0.1, subnet mask 255.255.255.0)

You may configure a static IP address the following ways:

- using ***DTrack2*** (refer to chapter 8.2.2 on page 125)
- without the ***DTrack2*** frontend (refer to chapter 8.2.4 on page 127)

☞ **Please note that these settings are not part of your personal configuration. Changes of the IP address will affect all users of your controller! Your controller may become unreachable with wrong IP settings! Refer to chapter 8.2.4 on page 127).**

External synchronization Any ***ARTTRACK*** system controller can be synchronized with an external source. On the back of the controller there is a BNC plug ("ExtIn") which serves as input for the external synchronization signal. The sync signal may be of type TTL (5V) or video. Using TTL you can select between rising and falling edge trigger (see also chapter 8.5.2 on page 151).
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 tee-connector with an external 75 Ω terminating resistor should be used if the signal line ends at the controller.
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.

5.3 Installation of the *TRACKPACK* Controller (discontinued)

The following list introduces the ports of the ***TRACKPACK*** Controller:

- ***ART*** SynccardTP :
  The syncgroups for TRACKPACK systems can be configured in the ***DTrack2*** frontend software. Please refer to chapter 8.5 on page 146.
  - ExtIn:
    Please plug in the external source for synchronization here.
  - Output:
    The cameras have to be plugged in to the RJ45 connectors. Synchronization and power is supplied with this connection.
- Firewire:

Please connect the ***TRACKPACK*** cameras with the controller using the delivered Firewire cables.

- USB port:
  Please plug in all USB based devices here (e.g. ***ART*** radio transceiver for Flystick2/3, Trivisio wireless transceivers, YEI wired inertial sensors, refer to chapter 6 on page 71).

- Ethernet port:
  Please connect the controller to your local network using an RJ45 cable.

For connecting the ***TRACKPACK*** controller to your local network, please refer to figure 5.4 on page 59. You may either use the controller as a DHCP client within your network (figure 5.4(a)), i.e. the tracking data is transmitted directly via your local network. 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 controller and the other one is connected to your local network (figure 5.4(b)). In that case, the ***DTrack2*** Frontend will act as a router for the tracking data.
The controller is controlled by a remote PC via ***DTrack2*** frontend software. When delivered, the controller is set up to support DHCP. Connect the Ethernet cable to your local network and connect the power plug to a power socket. If you want to set a specific static IP address before booting the controller please refer to chapter 8.2.4 on page 127 for more information.

Press the switch next to the power plug to start the controller.Finally, start the ***DTrack2*** frontend software on the remote PC. Please refer to chapter 8 on page 121 for more details.

If the controller is not connected via an ethernet cable or no DHCP server is running, it will use its fall-back IP address (IP 192.168.0.1, subnet mask 255.255.255.0)

You may configure a static IP address the following ways:

- using ***DTrack2*** (refer to chapter 8.2.2 on page 125)
- without the ***DTrack2*** frontend (refer to chapter 8.2.4 on page 127)

Please note that these settings are not part of your personal configuration. Changes of the IP address will affect all users of your controller! Your controller may become unreachable with wrong IP settings! Refer to chapter 8.2.4 on page 127).

External synchronization The ***TRACKPACK*** system and therefore the ***TRACKPACK*** controller can be synchronized with an external source. On the back of the controller there is a BNC plug ("ExtIn") which serves as input for the external synchronization signal. The sync signal may be of type TTL (5V) or video. Using TTL you can select between rising and falling edge trigger (see also chapter 8.5.2 on page 151).
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 ***TRACKPACK*** 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 tee-connector with an external 75Ω terminating resistor should be used if the signal line ends at the controller.
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.

Be aware of the following specialty of the TrackPack system:
The *TRACKPACK* cameras get power supply and sync via the RJ45 cable!

Therefore, the status of the synchronization is indicated with two LEDs (orange and green) located on the synccard of the controller. Depending on the operating condition of the ***ART*** tracking system the LEDs are triggered respectively. Table 5.2 shows how the LEDs are triggered according to the type of synchronization.

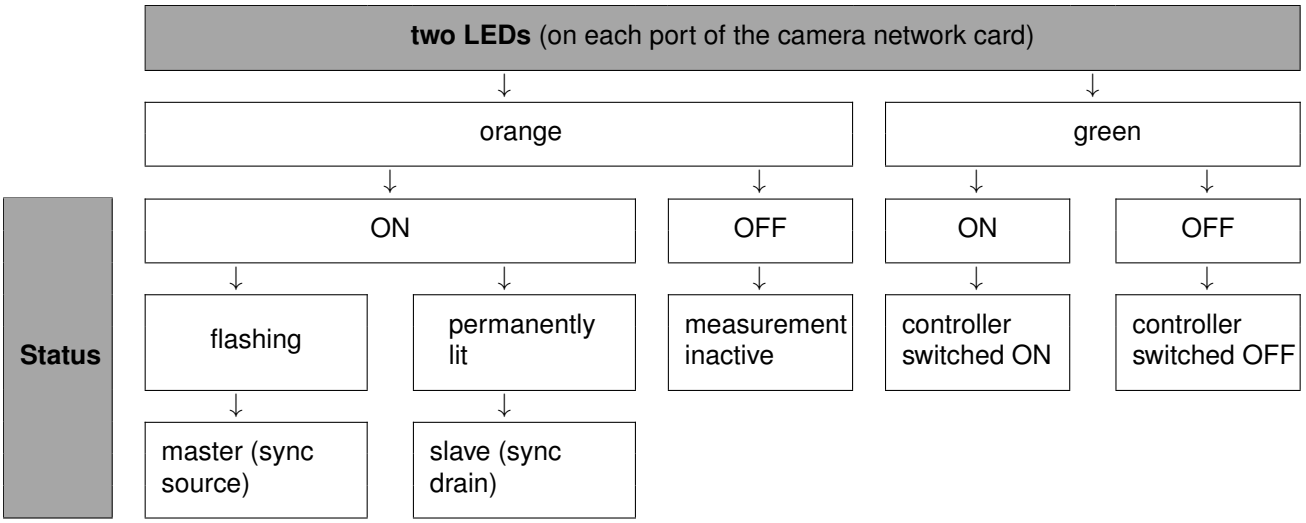


Table 5.2: Description of the LEDs on the back of the ***TRACKPACK*** Controller

5.4 Cascaded systems

Cascading means that two or more stand-alone tracking systems are combined to one large system in order to have only one consolidated data output. It is possible to cascade *TRACKPACK/E* systems with or without *ARTTRACK5* and *ARTTRACK5/C* and to build cascades out of *ARTTRACK* (discontinued) with *TRACKPACK* systems (discontinued). Therefore, the system is subdivided into one master and up to eight slaves. However, the total number of cameras in the cascaded system cannot exceed 16 for *TRACKPACK/E* only systems and 50 for combined *ARTTRACK5* & *ARTTRACK5/C* and *TRACKPACK/E* systems respectively.

The task of the master is to gather all single data outputs from all slaves and to merge them into one single data output. The *DTrack2* frontend connects to the master only and allows to configure (e.g. cameras, output, tracking, etc.) the entire tracking system as usual.

The master has to be an *ARTTRACK* Controller with "full-featured" license (< *DTrack2* 2.10) and a Synccard2.
Starting with *DTrack2* version v2.10 a new license model has been established. The master controller needs to have a dedicated "cascaded systems" license as well as a sufficient license for ALL cameras in the cascade, e.g. 4 *ARTTRACK5* + 4 *TRACKPACK/E* cameras = license for 8 cameras.

5.4.1 Connecting a cascade

Depending on your setup there are different options how to connect the single tracking systems within a cascade.

Option 1 - master: all *ART* and *ARTTRACK* Controllers, slave(s): *ART* Controllers with *TRACKPACK/E* or *TRACKPACK* controllers (discontinued) Connect the data output of the slave controller(s) and the one of the master to the same local area network LAN (e.g. application network, see option 1 in fig. 5.5 on page 67 and fig. 5.6 on page 68).

Option 2 - master: *ART* Controllers (*DTrack2* => v2.11), slave(s): *ART* Controllers with *TRACKPACK/E* or *TRACKPACK* controllers (discontinued) Connect the data output of the slave controller(s) to the cascaded network port of the master (see option 2 in fig. 5.5 on page 67). Please use a switch for two or more *TRACKPACK* slaves.

Option 3 - master: *ARTTRACK* controllers (discontinued), slave(s): *TRACKPACK* controllers (discontinued) Connect the data output of the slave controller(s) to the camera network of the master (see option 3 in fig. 5.6 on page 68).

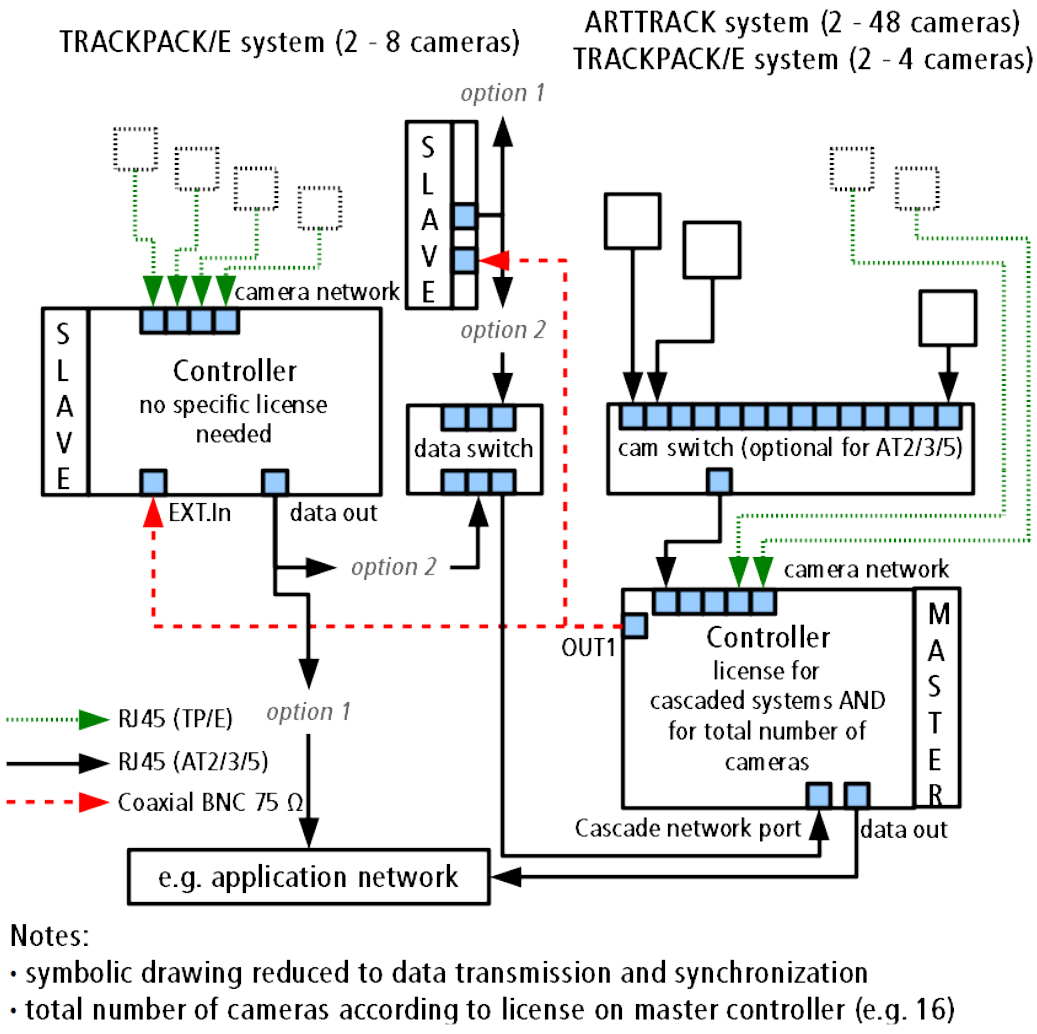


Figure 5.5: Principle of cascading using the LAN (option 1) or the cascaded network port (option 2 - master *ART* Controller & *DTrack2* => v2.11)

Additionally to the aforementioned figures, please proceed according to the following description:

1. mount the cameras as usual at the defined positions
2. connect all cameras to their corresponding controller as usual
3. establish a BNC connection between the master's OUT1 connector and the EXT.In of the slave(s) for synchronisation of cascade

☞ **The *ART* Radio Transceiver for Flystick2 and Flystick3 has to be connected to the master controller.**

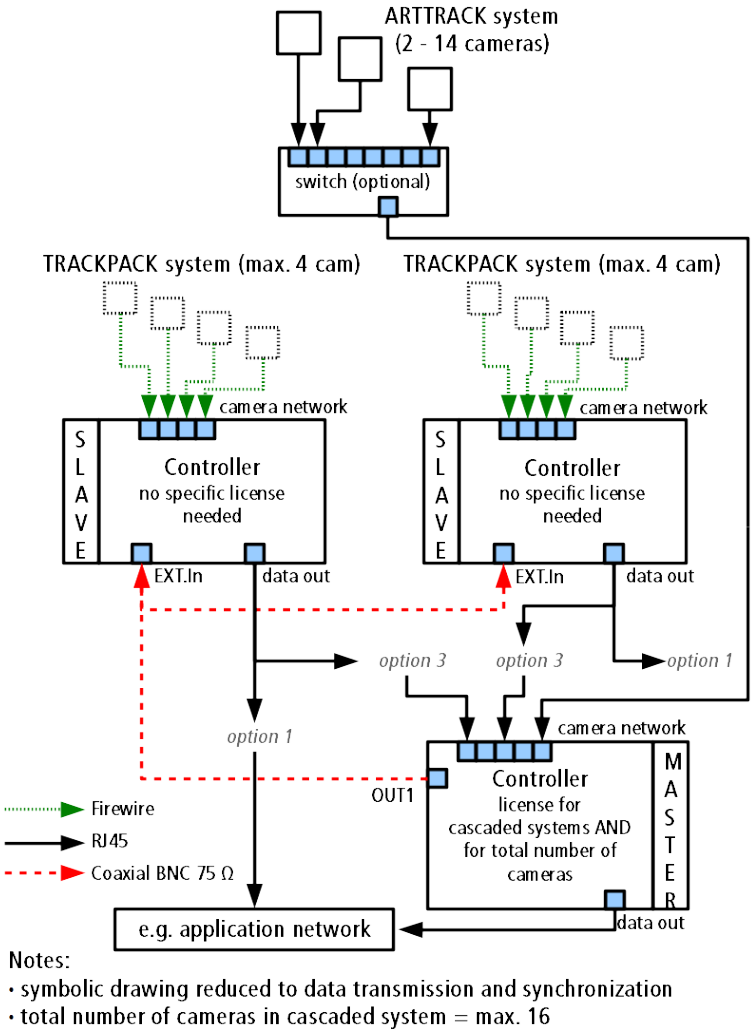


Figure 5.6: Principle of cascading using the LAN (option 1) or the internal camera network (option 3 - master *ARTTRACK* controller (discontinued))

5.4.2 Configuration of a cascade

Double-check if the cameras are connected properly to every controller. If applicable verify that all power supplies are switched on and the cameras are running (indicated by two LEDs at the front side of the cameras).
The master controller is controlled by a remote PC via *DTrack2* frontend software. When delivered, controllers are set up to support DHCP. When building cascades via LAN (option 1, see 5.5 on page 67) they will acquire an IP address automatically given that a DHCP server is running. If you want to set a specific static IP address before booting the controllers please refer to chapter 8.2.4 on page 127 for more information.

If the cascade is connected via the cascaded network port of the *ART* Controller (option 2, see 5.5 on page 67), all slave controllers must be set to a specific static IP address in the subnet 172.29.xxx.xxx with subnet mask 255.255.0.0 !

In case of using the internal camera network (option 3, see 5.6 on page 68), all slave controllers will acquire their IP addresses automatically.
Press the power switches (next to the power plug or on the front) to start the master and the slave controller(s). Make sure the controllers are booted up with all necessary ethernet connections, otherwise the fall-back IP address is applied.

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

Finally, start the *DTrack2* frontend software on the remote PC and establish a connection to the master.

We recommend creating a new configuration for all cascaded systems: *DTrack2* → *Configurations* → *'New'*

Now, go to *Settings* → *Cascaded System* to enter the configuration dialogue for the cascaded system (see figure 5.7 on page 69). There you have the possibility to select single tracking systems to join in the cascade. On the right-hand side of the dialogue you will be presented a list of '*Available*' controllers (i.e. which can become a slave in the cascaded system).

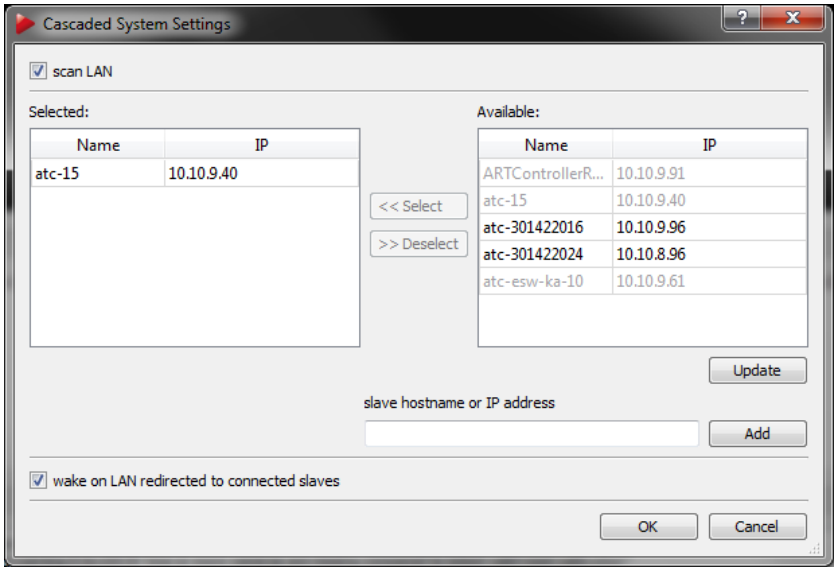


Figure 5.7: Cascaded System Settings

When you have set up your cascaded system using a direct link (Option 2 via Cascaded Network Port or Option 3 via Camera Network) between master and slave controller the list will be filles automatically. When using a connection via LAN (Option 1), you can tick the checkbox '*scan LAN*' and *DTrack2* will search automatically whether controllers are available to become slaves. The button '*Update*' refreshes the list.

You can also enter a '*slave hostname or IP address*' directly in case you have set a specific static IP address.

Mark the desired controller and press '*Select*' to assign this controller to the cascaded system. It will then appear on the left-hand side of the dialogue in the list of the '*Selected*' controllers. Repeat these steps if you want to add more single controllers to the cascade. To remove controllers from the cascaded system simply select the corresponding controllers in the list of the '*Selected*' controllers by left-clicking and press button '*Deselect*'.

The checkbox '*wake on LAN*' enables synchronized start-up of the master and all slave controllers. Starting of the cascade will take 3-4 minutes as the master has to boot up first and then wake up the slave(s). The changes will be accepted by the system if you press '*OK*'. Settings (e.g. flash intensity, sync groups) of all cameras inside the cascade can now be edited through the *Settings* → *Cameras* dialogue. The next time you start the measurement all cameras inside the cascade can be viewed through the *Monitor 2DOF display*.

☞ **Shutdown of master and slave controller(s) is always synchronized. Tick the option '*wake on LAN*' to also start-up the slave controller(s) automatically.**

☞ **Before continuing, please double-check whether a BNC connection for synchronization has been established between master (OUT1) and slave(s) (EXT.In).**

Now, you can proceed with calibrating the room as usual. Please refer to chapter 4.8.3 on page 51 where room calibration is explained.

6 Interaction devices

6.1 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 6.1: 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.

6.1.1 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 6.2: Flystick2 control elements

Top View	*Event*	*Description*
status LEDs	green pulse	button pressed or joystick position successfully transmitted
	yellow pulse	button pressed or joystick position could not be transmitted
	yellow flickering	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 6.1: Description of the Flystick2

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.

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.

Data output 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 250 for more information about the format of the output data.

6.1.2 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 6.3: 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 6.4: 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 balances the cells inside the battery pack (’top-off charge mode’, status LED: Green with intermittent yellow flash) to help 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 6.2 on page 75 for an overview of the status LEDs on the battery charger.

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 6.2: Status LEDs quick reference

6.1.3 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.

6.2 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 6.5: 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. All interactions are transmitted wirelessly via a 2.4 GHz ISM radio connection. Synchronization of the active Flystick3 (discontinued) is provided wirelessly with a modulated flash by one camera.

[1] discontinued in December 2011

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.**

6.2.1 Control elements

The numbering sequence of the buttons is as follows:

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

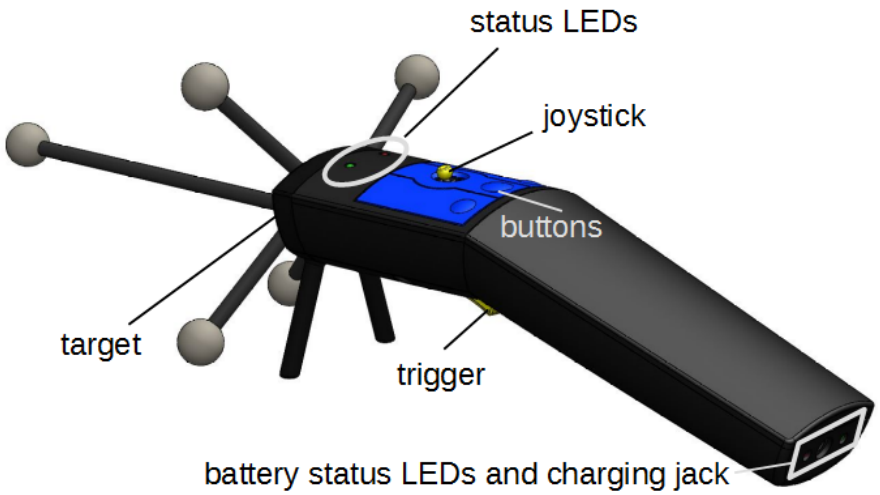


Figure 6.6: Flystick3 control elements

Top View	*Event*	*Description*
status LEDs	green pulse	button pressed or joystick position successfully transmitted
	yellow pulse	button pressed or joystick position could not be transmitted
	yellow (and green) flickering	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 6.3: Description of the Flystick3

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.

Data output 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 250 for more information about the format of the output data.

6.2.2 Battery pack

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

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

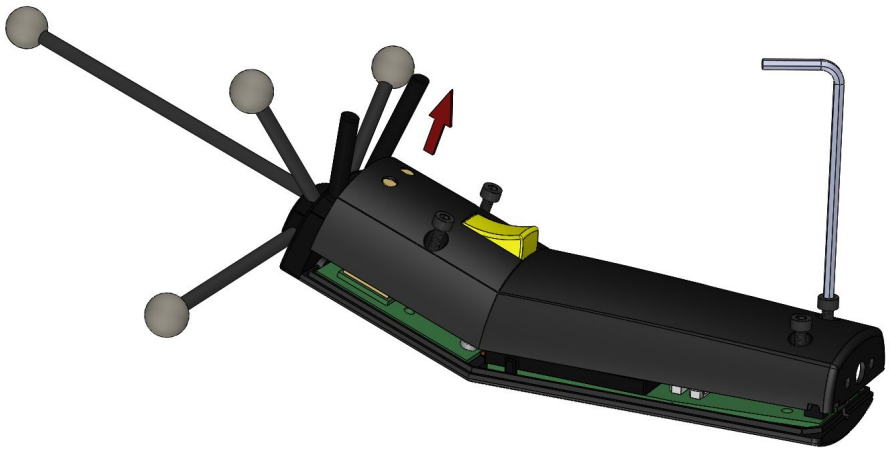


Figure 6.7: Open the battery compartment of Flystick3

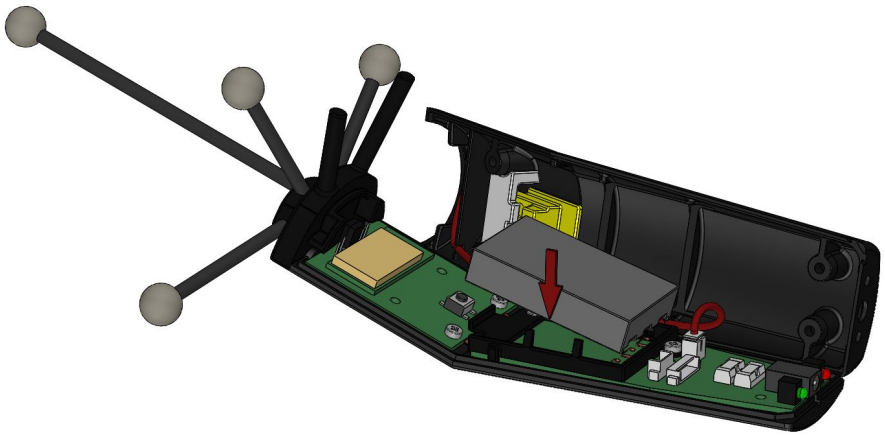


Figure 6.8: Insert new battery in Flystick3

Place the battery correctly within the cut-out.

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

Dispose of used batteries according to governmental regulations.

Apply the back cover again and tighten the screws carefully.

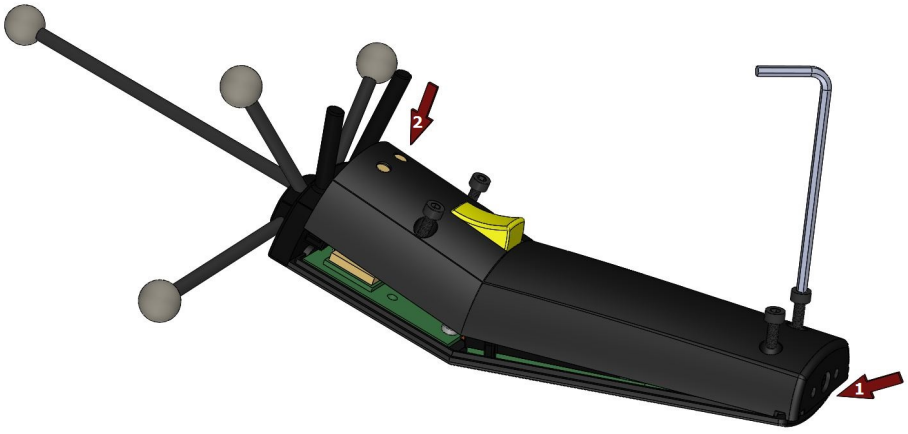


Figure 6.9: Close the battery compartment of Flystick3

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.

If the green LED is switched on permanently and the red LED is flashing at the same time an error occured during charging. The battery may be defective or it has been wrongly inserted.

6.2.3 Radio module

The Flystick3 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.

6.2.4 Wireless synchronization (active Flystick3 discontinued)

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. This coded signal can be generated by all ***ART*** tracking cameras, except for ***ARTTRACK1*** and older ***ARTTRACK2*** (up to SN 320) cameras. However, the Flystick3 may also be used with tracking systems where older ***ARTTRACK2*** ($<$ SN 320) or ***ARTTRACK1*** cameras are used (***DTrack2*** is required). For this purpose an additional external flash can be purchased from ***ART*** .

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:

- **Only one camera can emit the modulated flash, thus the selected one should have unobstructed view of the whole tracking area. Furthermore it has to be assigned to syncgroup #1 ! *ARTTRACK5* , *ARTTRACK5/C* , *TRACKPACK/E* , & *TRACKPACK* systems may be configured via software, while *ARTTRACK2* & *ARTTRACK3* have to be connected to 'OUT1' on the controller's Sync-card (refer to paragraph Sync group in chapter 8.5.1 on page 146).**
- **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 a camera (which has unobstructed view of the whole tracking area and which is in syncgroup # 1) from the dropdown list. Press *OK* to apply the changed settings. Please refer to chapter 8.5.1 on page 146.

If your system is configured with more than one syncgroup it is necessary to configure the Flystick3 as follows. Go to *Settings* → *Flystick* and increase the number of '*syncgroups*' according to the number of syncgroups used to set up the system.

6.3 Flystick Installation

6.3.1 Radio Transceiver

First, the USB Radio Transceiver has to be plugged in to any free USB port of the controller. In case this is done after the controller is switched on it is necessary to press *F2* in order to search for new hardware. The Radio Transceiver is then recognized by the system.

Please make sure that either the old radio transceiver (connected via the camera network) or the new USB radio transceiver is connected to the controller. Connecting both radio transceivers to one controller would lead to malfunction of the Flystick2 or Flystick3.

In case the controller is powered up, LED (2) (see figure 6.10 on page 81, circular frame) lights continuously while controller is booting. When *DTrack2* is started, LED (1) (see figure 6.10 on page 81, square frame) turns on and indicates that the radio transceiver was correctly initialized; LED (2) extinguishes.
During measurements, LED (1) is flashing whenever data is received from or transmitted

to the Flystick. In case of unsuccessful data transmission to the Flystick, LED (2) starts flashing.

Figure 6.10: USB Radio Transceiver3

The Radio Transceiver is configured automatically. In case you need to change settings manually please refer to chapter 8.5.4 on page 154.

6.3.2 Flystick Configuration

Next configure the number of Flysticks you are using: Select *Settings* → *Flystick* and configure the *number of Flysticks* (see figure 6.11 on page 81).

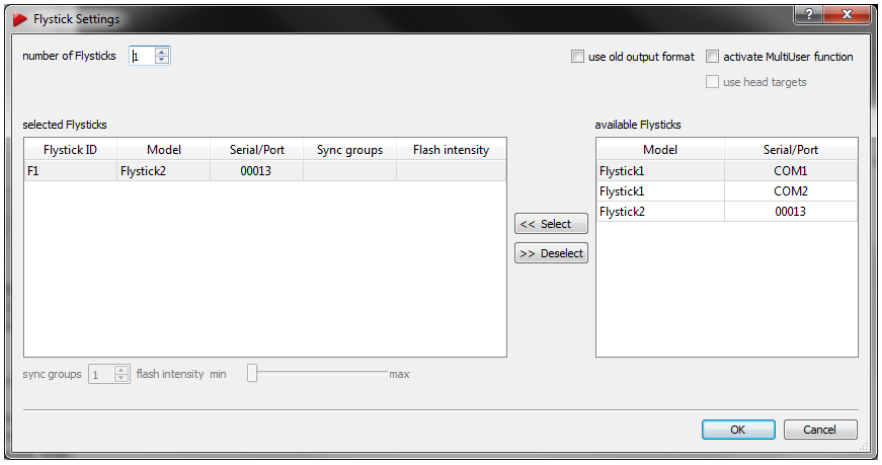


Figure 6.11: Flystick Settings

As soon as you change the *number of Flysticks* entries in the *selected Flysticks* field will pop up. 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 a '*Flystick ID*'.
Therefore,

- mark the respective Flystick ID, e.g. '*F1*', by selecting it from the '*available Flysticks*' list
- mark the desired available Flystick and
- press *Select* to finalize the assignment.

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

Repeat these steps if you want to use another Flystick.

There are two predefined entries for Flystick1 in the list *available Flysticks*, even if no Flystick1 is present in the volume. This is due to the fact that the Flystick1 connects via serial COMport which cannot be polled automatically. If you are using a Flystick1 please refer to the Flystick1 manual.

Inside the dialogue you can also configure the following settings for your Flystick:

Checkbox	**Description**
use old output format	Use the output format of the Flystick1 (see chapter B on page 250)
activate MultiUser function	Refer to page 82 in chapter 6.1 on page 71 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).
Option (active Flystick3 only)	**Description**
sync groups	Configure your active Flystick3 (discontinued) to send out IR flashes for one or more syncgroups (syncgroup #1, syncgroups #1 and #2, . . . ; default = syncgroup #1).
flash intensity	Change the flash intensity of the active target (discontinued) of the Flystick3 (default = 3) by moving the slider.

Table 6.4: Flystick settings - Description of the checkboxes and options

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. 20) 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 250 for more details on the output format.

6.3.2.1 Flystick Calibration

After assigning the Flystick to the ART radio transceiver, close the *Flystick Settings* dialogue and 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 chapter 8.6.5.2 on page 177 for more information concerning body calibration procedure.

6.3.2.2 Flystick Output settings

The last step is to 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 8.5.7 on page 160 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*. Please refer to chapter 8.3.3 on page 135 for details.

6.4 Fingertracking

Description The ***ART*** Fingertracking system is a device that measures the position of the hand and the finger bones. To achieve this, a 6DOF target is attached to the palm of the hand and thimbles with 1 or 2 markers are worn on the measured finger tips. All other information is derived from the kinematics of the hand, which are measured by a short calibration process.
To use Fingertracking, a Fingertracking license has to be installed on the controller. Please refer to chapter 8.4.1 on page 141 for details how to add license codes to your controller.
There are two different Fingertracking versions available, Standard Fingertracking and FINGERTRACKING2 Tactile (see figure 6.12 on page 84). All Fingertracking devices consist of:

- a hand target unit for fixing on the back of the hand with IR LEDs (active markers) for tracking (see figures 6.13 on page 85 and 6.16 on page 88).

- three or five finger thimbles (a fixture for the finger tip), each featuring IR LEDs connected via flexible wires (see figure 6.19 on page 90)
- wireless synchronization using a receiver for a coded IR flash (modulated flash)
- rechargable batteries and a battery charger

Additionally, the FINGERTRACKING2 Tactile has:

- one vibration motor for tactile feedback on each thimble
- radio module in the hand unit for addressing the vibration motors

(a) Standard Fingertracking device with three active finger markers

(b) Standard Fingertracking device with five active finger markers

(c) FINGERTRACKING2 device with three tactile active finger markers

Figure 6.12: All Fingertracking devices

Data output The output data consists of:

- position and orientation of the hand,
- number of the tracked fingers and a value to distinguish between left and right hand
- position and orientation of the outermost phalanxes; the radius of the finger tip to identify its position and orientation
- angles between the single phalanxes and their respective lengths

Please refer to chapter B.1.7 on page 256 for more information about the format of the output data.

Tactile control Additionally FINGERTRACKING2 Tactile offers a list of control commands to address the tactile feedback within your application. These consist of:

- the *Hand ID* and *Finger ID* to address each finger of each hand individually
- a value denoting the strength of the feedback

Please refer to chapter B.3.1 on page 268 for details.

6.4.1 Standard Fingertracking Hand Targets

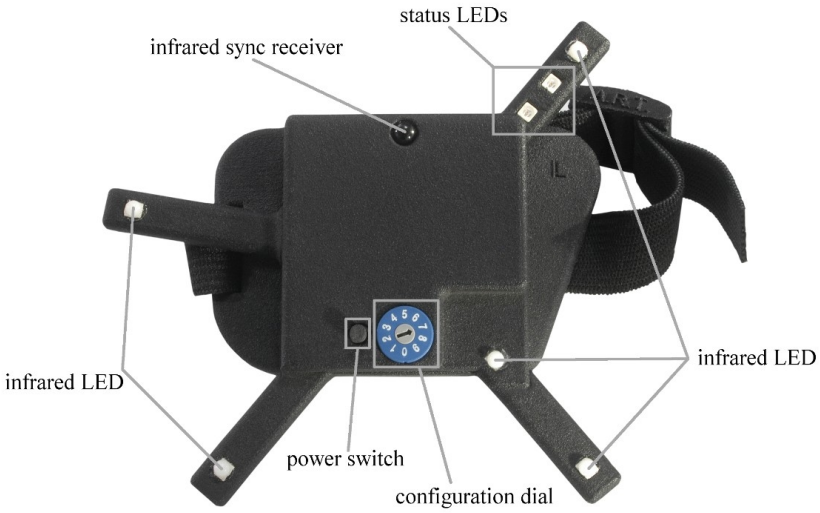


Figure 6.13: Standard Fingertracking hand target

Top View	*Event*	*Description*
status LEDs	green LED continuously	→ synchronization received and tracking
	red LED continuously	→ no synchronization received
	red and green LED flashing	→ battery low or discharged
infrared LEDs		IR LEDs for tracking
power button		activate or deactivate the Fingertracking hand target
configuration dial		select the LED brightness and the number of fingers
letters (L and R)		indicate whether the hand target is dedicated for the left or right hand
infrared sync receiver		receiver for the coded IR flash (i.e. synchronization signal)

Table 6.5: Description of the hand target (Standard Fingertracking)

On/off button Pressing the small black button next to the configuration dial activates or deactivates the target (please refer to figure 6.13 on page 85). After turning on the hand target unit, the status LEDs light up according to table 6.5 on page 85. When deactivating the hand target all IR LEDs are switched off and the microcontroller is put into sleep mode. Therefore a certain minimal power consumption is inevitable.

When the Standard Fingertracking is not used for a longer period of time (i.e. more than a week) the batteries should be removed from the hand target to prevent deep discharge which could destroy the battery.

Configuration dial The configuration dial is used to select the LED brightness and the number of fingers used in the setup (please refer to figure 6.13 on page 85).
A detailed description of the configuration dial may be found in table 6.6 on page 86.

ID	no. of sync finger	Flash time [μs]
0	3	25
1	3	50
2	3	75
3	3	100
4	5	25
5	5	50
6	5	75
7	5	100
8	-	-
9	-	-

Table 6.6: Description of the configuration dial (Standard Fingertracking)

Note For serial numbers < 100 the LED brightness and the number of flash groups is configured differently:

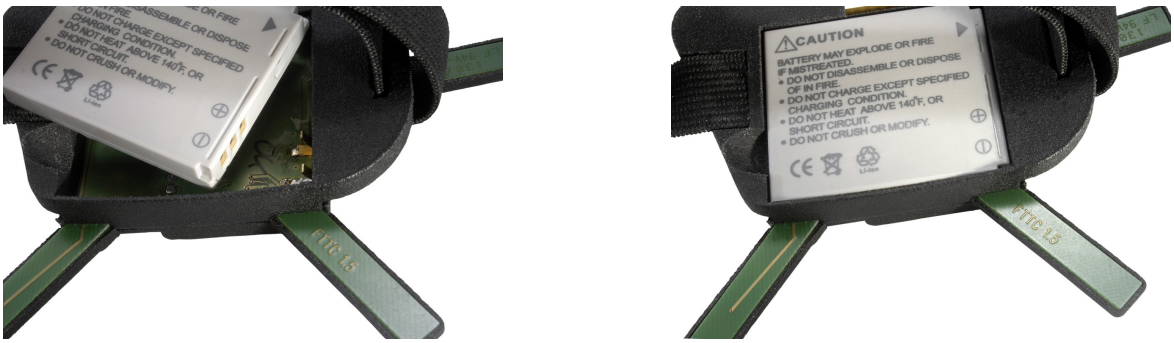
- positions 0 to 3: one syncgroup
- position 4 to 7: three syncgroups
- position 8 to 9: unused

Connecting the finger thimble set with the hand target Just plug in the connector of the finger thimble sets into the hand target as shown in figure 6.14 on page 87.
Then apply the finger thimbles to your thumb and fingers observing the order of the flexible wires shown in figure 6.14 on page 87.

(a) The finger thimble connector in detail (b) Order of flexible wires (5-finger AR thimble set)

Figure 6.14: Connecting the finger thimble set to the hand unit (Standard Fingertracking)

Inserting the battery The Fingertracking hardware uses standard CAN NB-4L batteries. Two batteries and a charger are provided with each Fingertracking set. Squeeze the battery in with the contact side first and then gently press the battery into the compartment until it snaps in (see figure 6.15 on page 87).



(a) Step1 (b) Step2

Figure 6.15: Inserting the battery (Standard Fingertracking)

6.4.2 FINGERTRACKING2 Tactile Hand Targets

On/Off switch Move the switch to the *On* position to turn on the hand target unit. In case of tactile thimbles the vibration motors are started sequentially as a test run. After turning on the hand target unit, the status LEDs light up according to table 6.7 on page 88. In *Off* position the hand target is switched off completely. There is no need to remove the batteries when not using the devices for a longer period of time.

L/H switch Move the switch to *H* position to increase the brightness of the IR LEDs if necessary, e.g. at far distances (> 3 m) from the cameras or instead extend the battery

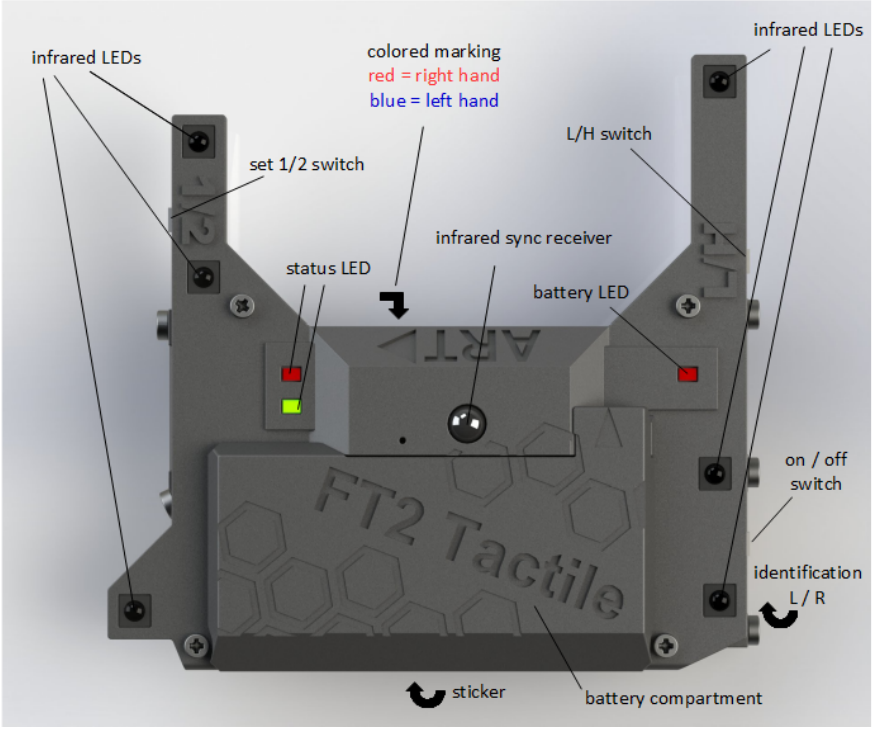


Figure 6.16: FINGERTRACKING2 Tactile hand target

Top View	*Event*	*Description*
green status LED	continuously flashing	→ synchronization received and tracking → assigned to ***ART*** Controller, no active tracking
red status LED	active flashing	→ indicates radio communication → not assigned to ***ART*** Controller
red battery LED	continously	→ battery low or discharged
infrared LEDs		IR LEDs for tracking
On/Off switch		activates / deactivates the hand target
L/H switch		select the IR LED brightness (low / high)
set 1/2 switch		select the target geometry (i.e. 2=second pair)
colored marking front-side		indicates the correct thimble set (red=right hand or blue=left hand)
letters (L and R) embossed bottom-side		indicates whether the hand target is dedicated for the red=right hand or blue=left hand
sticker bottom-side		showing the type and serial number of the tactile device
infrared sync receiver		receiver for the coded IR flash (i.e. synchronization signal)

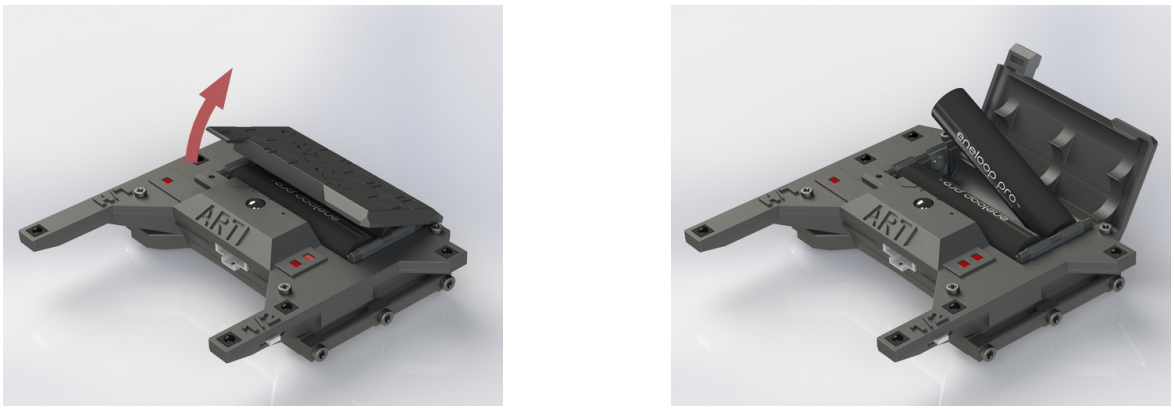
Table 6.7: Description of FINGERTRACKING2 Tactile handheld

lifetime by switching to *L* position.

Set 1/2 switch To use two pairs of FINGERTRACKING2 Tactile sets simultaneously, configure one to Set *1* and the other to Set *2*.

Select the Set *1* or *2* configuration of the FINGERTRACKING2 Tactile handtargets during first-time installation only. Do not change the setting during routine operation or tracking will fail.

Inserting the battery The FINGERTRACKING2 Tactile hardware uses standard micro-AAA batteries. A set of batteries and a charger are provided with each FINGERTRACKING2 Tactile set.



(a) Step1 (b) Step2

Figure 6.17: Inserting the battery (FINGERTRACKING2 Tactile)

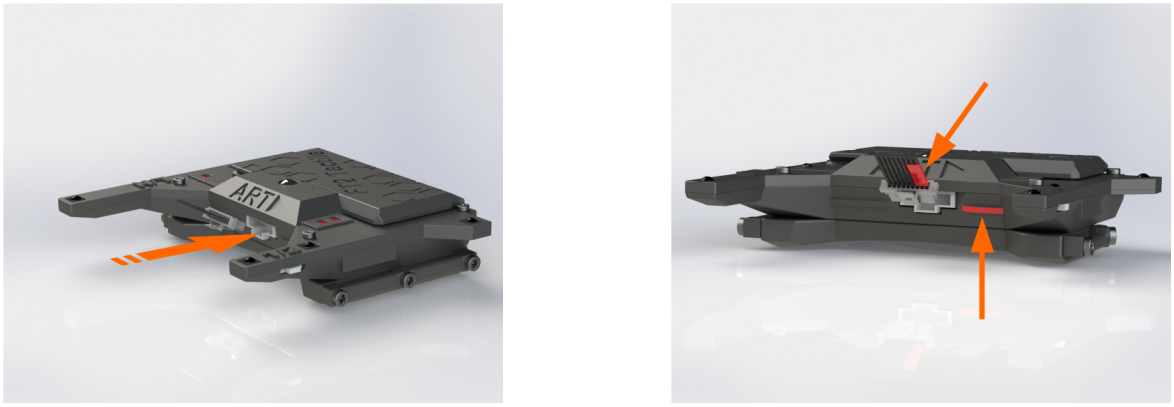
Open the battery compartment and insert the batteries (see figure 6.17 on page 89). Watch for correct polarity! Close the lid of the battery compartment afterwards.

Connecting the finger thimble set to the hand target unit Just plug in the connector of the finger thimble sets into the hand target as shown in figure 6.18 on page 90. Please connect the correct thimble set to the corresponding hand target by verifying the colored markings.
Then apply the finger thimbles to your thumb and fingers observing the order of the flexible wires.

Watch out for the colored marking of the thimble set! red=right hand, blue=left hand

6.4.2.1 Radio module

FINGERTRACKING2 Tactile 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 10m but can be reduced when passing material, e.g. projection screens.



(a) Plugging in the connector

(b) Colored marking of thimble set and handheld red=right hand, blue=left hand

Figure 6.18: Connecting the finger thimble connector with the hand target (FINGERTRACKING2 Tactile)

6.4.3 Finger thimble sets

Standard Fingertracking can be ordered as a 3-finger VR, a 3-finger AR or a 5-finger AR version, while FINGERTRACKING2 Tactile can be ordered as a 3-finger AR version only. The difference between the AR and VR versions is the position of the LED on the finger thimble: for the VR version the LED is placed on the tip of the thimble, whilst for the AR version it is placed on top of the thimble (see figure 6.19 on page 90).
Tactile thimbles additionally feature a vibrational motor to induce feedback.

AR thimble set for all fingers | VR thimble set for all fingers | AR/VR thimble set for the thumb | Tactile AR thimble set for all fingers | Tactile AR thimble set for the thumb

Figure 6.19: Comparison of the finger thimble sets (VR, AR) for Fingertracking and AR for FINGERTRACKING2 Tactile

The active markers for the finger tips are sequentially addressed to allow the tracking system to discriminate between the single fingers. Therefore, the update rate of the fingers is only a fraction of the tracking frequency for the hand target, i.e. one-third for 3 thimbles and one-fifth for 5 finger tracking, e.g. 12 Hz for a 60 Hz update rate with five fingers (Standard Fingertracking) or up to 100 Hz for a 300 Hz measurement with three fingers and tactile feedback (FINGERTRACKING2 Tactile).

Standard Fingertracking is delivered with three pairs of thimble sets with different sizes (see table 6.8 on page 91). FINGERTRACKING2 Tactile sets come with four sets of

thimbles.

Finger size	Scope of delivery
Extra-Small-sized fingers (Tactile only)	Diameters of 14mm (thumb) and 11-12mm (other fingers)
Small-sized fingers	Diameters of 16mm (thumb) and 13-14mm (other fingers)
Medium-sized fingers	Diameters of 18mm (thumb) and 15-16mm (other fingers)
Large-sized fingers	Diameters of 20mm (thumb) and 17-18mm (other fingers)

Table 6.8: Description of the finger thimbles

6.4.4 Wireless synchronization

The black sphere on top of the Fingertracking hand targets is a receiver for the coded IR flash (i.e. modulated infrared signal) which is used for synchronization (see figure 6.13 on page 85 or 6.16 on page 88). This coded signal can be generated by all *ART* tracking cameras, except for *ARTTRACK1* and older *ARTTRACK2* (up to SN 320) cameras. However, Fingertracking may also be used with tracking systems where older *ARTTRACK2* (< SN 320) or *ARTTRACK1* cameras are used. For this purpose an additional external flash can be purchased from *ART* .
To activate the modulated flash please refer to chapter 8.5.1 on page 146.

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:

- **Only one camera can emit the modulated flash, thus the selected one should have unobstructed view of the whole tracking area. Furthermore it has to be assigned to syncgroup #1 ! *ARTTRACK5* , *ARTTRACK5/C* , *TRACKPACK/E* , & *TRACKPACK* systems may be configured via software, while *ARTTRACK2* & *ARTTRACK3* have to be connected to 'OUT1' on the controller's Synccard (refer to paragraph Sync group in chapter 8.5.1 on page 146).**
- **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).**

6.4.5 Battery charger

A battery charger is supplied with all Fingertracking devices and must be used for charging the batteries.

Standard Fingertracking When you connect the battery charger to a power socket, the red LED ("Status") is switched on and the green LED ("Charge") starts flashing. As soon as you place the battery correctly in the charger, the "Charge" LED changes its colour to red and stops flashing. Once the battery is fully charged the "Charge" LED changes its colour to green again. Now, the battery may be used.

FINGERTRACKING2 Tactile Insert the batteries in the corresponding slots and plug the charger into a power socket. Charging will start automatically. When the batteries are fully charged all LEDs adjacent to the corresponding slot will light up. Please refer to the manual of the charger for further details.

6.4.6 Fingertracking Installation

The following steps describe a full calibration of one hand using non-customized ***ART*** Fingertracking hardware:

1. Select the number of hands you want to use with your tracking system (up to 4).
2. Assign body calibrations for all hand targets (using the target library). When using customized hand targets please refer to the corresponding chapter 6.4.6.4 on page 95 for further details.
3. Calibrate the complete hand geometry (i.e. the position and orientation of the finger tips in respect to the hand target).
4. (optionally) Install an ***ART*** radio transceiver when using FINGERTRACKING2 Tactile devices (refer to chapter 6.3.1 on page 80 for details).
5. (optionally) Assign tactile devices for all applicable hand targets.

Simply repeat all steps for the corresponding other hand.

6.4.6.1 Fingertracking Settings

First, open the dialogue *Settings* → *Fingertracking* and configure the *number of hands* you are using. Enter the *number of hands* '*0...4*' directly or use the numeric updown button.

Hand target calibrations without corresponding hand geometries are marked with a yellow tick on the corresponding *Hand ID* row under *selected hands*. A fully calibrated *Hand ID* is marked with a green tick.

For each *Hand ID* a row from '*H1...H4*' will show up correspondingly on the left side of the window. The '*Name*' and '*Geometry*' entries will be empty, while the column *Cal.* will show a grey *No Entry* sign.

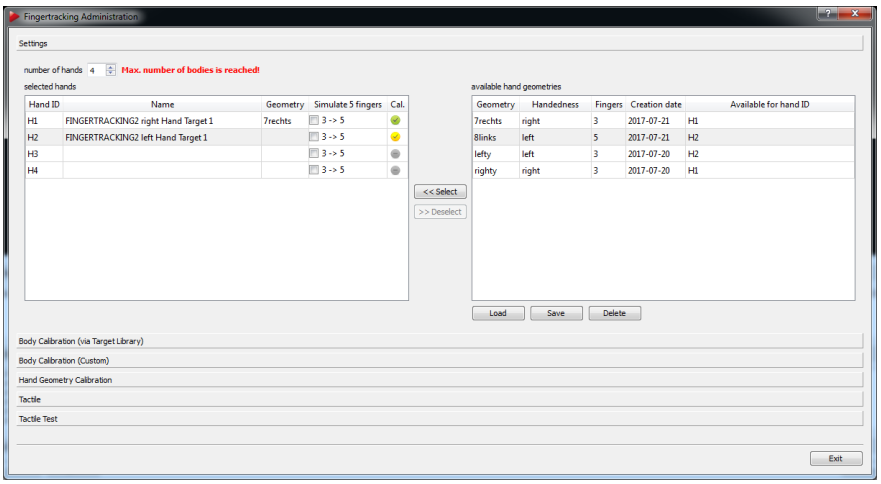


Figure 6.20: Fingertracking Administration - Settings

Next a body calibration for the hand target has to be assigned using the target library (refer to chapter 6.4.6.3 on page 94).

6.4.6.2 Fingertracking Available hand geometries

It is also possible to (re-)assign previously calibrated hand geometries (i.e. position and orientation of the finger tips) to existing hand target calibrations. This way one set of Fingertracking hand targets can be used by several different users and, most importantly, one needs to calibrate the hand geometry only once for each person during first installation.

A hand geometry (list shown on the right side of the window) can be assigned to a selected *Hand ID* the following way:

- mark the respective *Hand ID* from row '*H1...H4*' under *selected hands* by left-clicking
- mark the appropriate entry '*Available for hand ID*' → '*H1...H4*' under *available hand geometries* by left-clicking and
- press *Select*
- (optionally) confirm to overwrite the assignment by pressing *OK*. This confirmation will only show up when the assignment to a specific *Hand ID* is to be changed.

If the hand geometry is already in use (multiple assignment) a warning message will be shown instead. You can always delete the assignment by pressing the button *Deselect*. The geometry will be available again for assignment.

In order to identify the correct hand target under *available hand geometries* and assign it to the corresponding hand geometry please use meaningful names for the '*geometry*' and double-check the column '*Available for hand ID*'.

In case of multiple assignments (i.e. one hand geometry is to be assigned to more than one hand target calibration) a warning message will pop up. Delete the current assignment prior to re-assigning.

Import / Export of hand geometries You can also import previously saved hand geometries by pressing the button '*Load*'. A window will open to select the respective folder. Choose the appropriate file and press '*OK*'.
In order to export hand geometries just press '*Save*' and select the hand geometries you would like to export in the upcoming window. Press '*Save*' again, select the location of the respective folder and choose an appropriate file name.
You can also remove entries from *available hand geometries* by left-clicking and pressing '*Delete*'.

6.4.6.3 Fingertracking Body calibration via Target Library

Open the sub-dialogue *Fingertracking* → *Body Calibration via Target Library* to assign the corresponding body calibration of each hand target to a selected *Hand ID*. All hand target body calibrations stored in the target library are shown on the right side of the window.

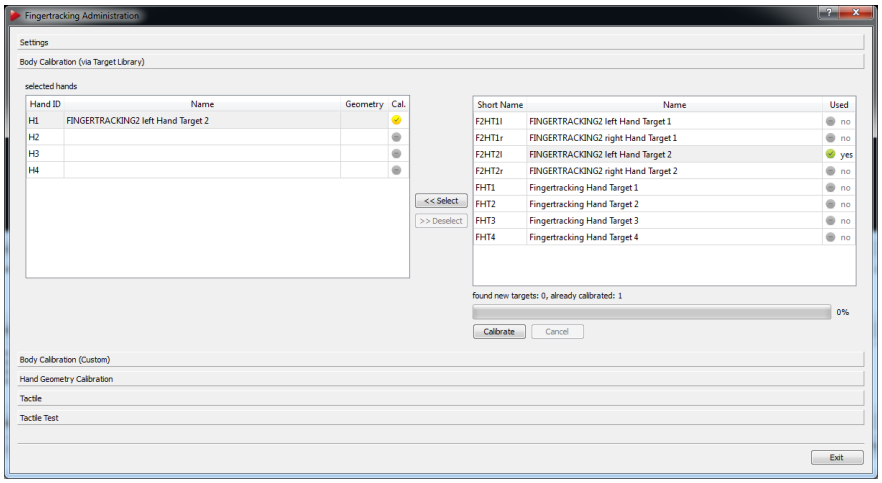


Figure 6.21: Fingertracking Administration - Body Calibration Target library

The integrated target library contains most hand target calibrations of *ART* Fingertracking hardware. Perform a custom body calibration only when the hand target cannot be identified automatically.

The body calibration can be assigned to a selected *Hand ID* the following way:

- turn on one Fingertracking device and place it inside the tracking volume
- run the target library identification by pressing *Calibrate*. The *Short Name* of the corresponding hand target will be marked green
- mark the respective *Hand ID* from row '*H1...H4*' under *selected hands* by left-clicking

- mark the appropriate entry in the target library (e.g. '*FINGERTRACKING2 Tactile left Hand Target 1*') by left-clicking and
- press *Select*

The '*Name*' and '*Geometry*' entries will be updated. The entry in the column *Cal.* will turn into a yellow tick. On the right side of the window the corresponding entry in column *Used* will turn into a green tick and marked '*yes*'. You can always delete the assignment by pressing the button *Deselect*. The body calibration will be available again for assignment to a different *Hand ID*.

The next step is to calibrate the handedness as well as the position and orientation of the finger tips (refer to chapter 6.4.6.5 on page 96).

Note: By default, the Fingertracking without tactile support is delivered with different hand target geometries when using two pair of sets, whereas FINGERTRACKING2 Tactile devices have to be set up properly, i.e. one pair needs to be configured to Set *1* while the other pair is running on Set *2*. Please refer to chapter 6.4.2 on page 87 how to switch the configuration.

Select the Set *1* or *2* configuration of the FINGERTRACKING2 Tactile handtargets during first-time installation only. Do not change the setting during routine operation or tracking will fail

6.4.6.4 Fingertracking Body calibration Custom

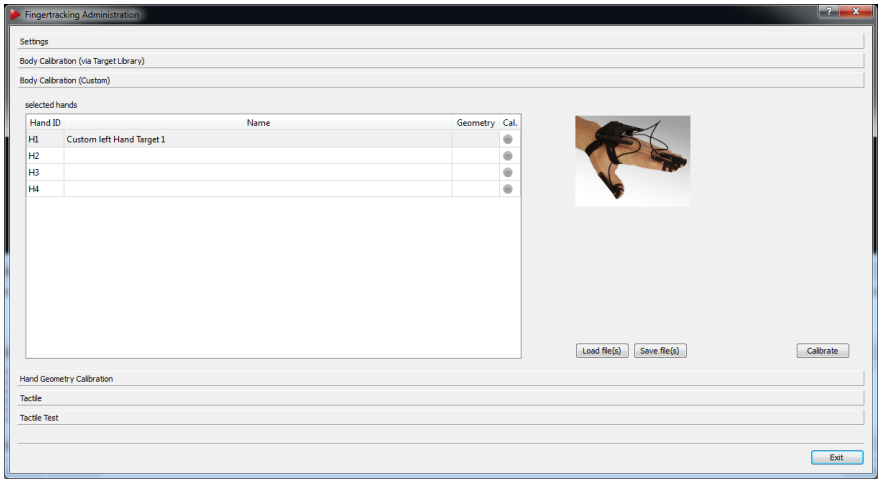


Figure 6.22: Fingertracking Administration - Body Calibration Custom

When using hand targets not found inside the target library (e.g. customized) a standard body calibration has to be carried out. The process of calibrating a 6DOF body is described in chapter 8.6.5.2 on page 177.

Mark the respective *Hand ID* from row '*H1...H4*' under *selected hands* by left-clicking and start the calibration by pressing the button *Calibrate*.

You can also load a calibration from a calibration file instead by pressing '*Load*' after marking the corresponding *Hand ID*. Please refer to chapter 8.6.5.6 on page 180 for details.

6.4.6.5 Fingertracking Hand geometry calibration

Open the sub-dialogue *Fingertracking* → *Hand Geometry calibration* to calibrate the handedness as well as the position and orientation of the finger tips. The respective *Hand ID* is selected automatically during the calibration process.

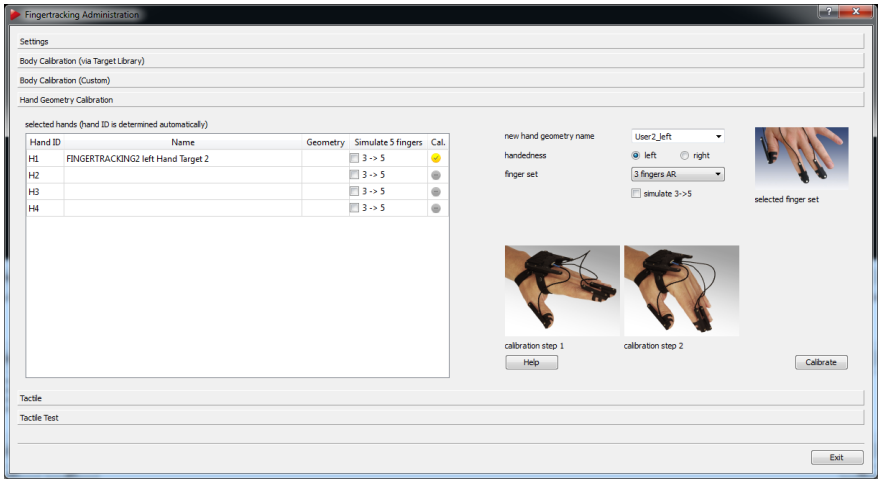


Figure 6.23: Fingertracking Administration - Hand Geometry Calibration

The hand geometry calibration is performed the following way:

- enter a meaningful name for the geometry (e.g. username-left) in the field *new hand geometry name*
- select the handedness by ticking the corresponding radio button for *left* or *right* hand
- select the appropriate thimble set from the dropdown-menu *fingerset*
- (optional) activate the 5 finger simulation (only available for 3-finger thimble sets) by ticking the checkbox *3 -> 5*
- press *Calibrate* to start the a two-step calibration process

In order to identify the correct hand target under *available hand geometries* and assign it to the corresponding hand geometry please use meaningful names for the '*geometry*' and double-check the column '*Available for hand ID*'.

Note: It is important that the hand is held inside the tracking volume and all markers are visible to at least two cameras when starting the calibration process. Click on the button *Help* to open a window where the calibration process is additionally explained and visualized.

Hand geometry calibration process After pressing *Calibrate* a countdown for the first step of the calibration process begins.

In the first phase (calibration step 1)

- all fingers have to be stretched out (see left picture in dialogue, refer to figure 6.23 on page 96)
- the thumb has to be spread away from the hand
- do not spread the other fingers, keep them together. Take care, that there is no space between them
- do not move any finger nor the thumb during the first calibration phase
- it's no problem to move the entire hand slightly

A progress bar shows the status of the calibration.

☞ **If calibration step 1 fails, please check if modulated flash is activated for one camera, and if the correct handedness and thimble set is selected**

After the first step has been completed a new countdown for step 2 is started.

During the second phase (calibration step 2)

- keep the fingers stretched out (see right picture in dialogue, refer to figure 6.23 on page 96)
- keep the thumb spread away from the hand
- keep the other fingers close together
- gently move all of your fingers up and down at the same time until calibration process is finished. The thumb is still spread away from the hand and should not be moved during this phase.
- do not bend or cross your fingers

Recommendation: Try to achieve an angle of approximately 60°between up and down position of the fingers.

☞ **If calibration step 2 fails, please take care not to bend your fingers, and not to move the thumb too much**

After data collection a calculation process is started which calculates the finger sizes from the movement of the finger tips. The length of the thumb is derived by the finger lengths. After successful calibration the '*Geometry*' entry under *selected hands* will be updated. The entry in the column *Cal.* will turn into a green tick.

If the calibration terminates with an error message, double-check the calibration procedure by clicking the button *Help*.

When using Standard Fingertracking without tactile support, the next step is to activate the data output. Please refer to chapter 6.4.6.8 on page 100. Otherwise you need to assign the tactile devices, see to chapter 6.4.6.6 on page 98 for details.

5 Finger Simulation If you are using a three finger thimble set but would like to get data for five fingers, tick the checkbox *simulate 3 -> 5*. ***DTrack2*** will simulate the data of the two missing fingers by putting them parallel to the middle finger. By default, the checkbox *simulate 3 -> 5* is unticked until you have carried out a hand geometry calibration.

Resetting finger tip sequence When the Fingertracking device has been removed from the hand and afterwards is put on again by the same user, the system needs to reset the correct order of the finger tips. To regain the correct sequence, the hand must be kept still with all fingers stretched out and the thumb spread to the side (see first phase of calibration process). When using two hands, both hands have to be separated by at least 50 cm during this procedure.
Although the Fingertracking devices will compensate short synchronization losses internally, this procedure should be also used in the rare case when the Fingertracking devices have lost synchronization (please refer to status LEDs on tables 6.5 on page 85 or 6.7 on page 88).

6.4.6.6 Fingertracking Tactile Assignment

Open the sub-dialogue *Fingertracking* → *Tactile Assignment* to assign a tactile device to the corresponding *Hand ID*. All *available tactile devices* will show up on the right side of the window. This function is only applicable to FINGERTRACKING2 Tactile devices.

Please install an *ART* radio transceiver when using FINGERTRACKING2 Tactile devices (refer to chapter 6.3.1 on page 80 for details).

Tactile devices are assigned the following way:

- activate the support for tactile devices by ticking the corresponding checkbox *tactile Fingertracking active*
- mark the respective *Hand ID* from row '*H1...H4*' under *selected hands* by left-clicking
- mark the appropriate entry under *available tactile devices* (e.g. '*FINGERTRACK-*

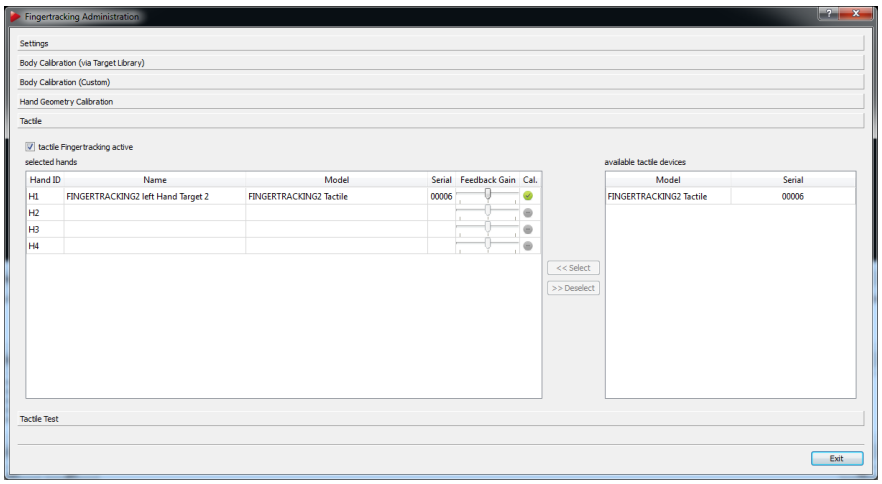


Figure 6.24: Fingertracking Administration - Tactile Device Assignment

ING2 Tactile' with '*serial number*' XY) by left-clicking and

- press *Select*

The '*Model*' and '*Serial Number*' entries will be updated accordingly.

The serial number of the tactile device can be found on the bottom of the hand target, e.g. 8L means tactile device #8 (see figure 6.16 on page 88 and table 6.7 on page 88 for details).

You can always delete the assignment by pressing the button *Deselect*. The tactile device will be available again for assignment to a different *Hand ID*.

Feedback Gain The feedback strength can be adjusted using a global gain setting, i.e. the feedback used inside the application is multiplied by this value. By default, this feedback gain is set to average. Please refer to B.3.1 on page 268 for more information about setting the feedback strength.
Activate the slider *Feedback Gain* by double-clicking, then move it to the right to increase the gain setting, move the slider to left to decrease it respectively.

You can also test the feedback strength (refer to the next chapter 6.4.6.7 on page 99).

6.4.6.7 Fingertracking Tactile Test

Open the sub-dialogue *Fingertracking* → *Tactile Test* to test the feedback on the thimbles. This function is only available after assignment of a FINGERTRACKING2 Tactile device to a corresponding *Hand ID*.

Mark the respective *Hand ID* from row '*H1...H4*' under *selected hands* by left-clicking. Then press the button *Test hand*. The tactile thimbles will be activated sequentially from thumb over index finger to middle finger. You can also test one finger after the other by

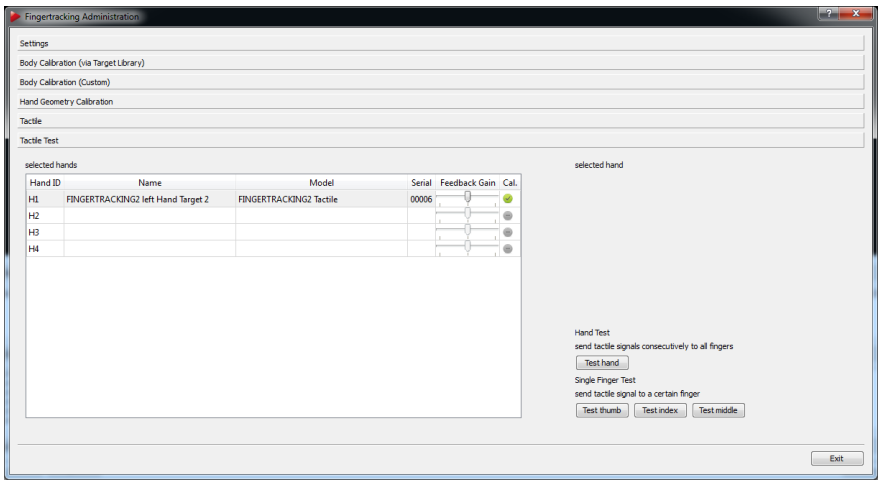


Figure 6.25: Fingertracking Administration - Tactile Device Test

pressing the corresponding buttons *Test thumb*, *Test index* or *Test middle*. The corresponding status LED will light up to indicate radio communication (see figure figure 6.16 on page 88 and table 6.7 on page 88).

6.4.6.8 Fingertracking Output settings

The last step is to define where the Fingertracking 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 '*gl*' and '*glcal*' you can define the Fingertracking data to be transmitted. Please refer to chapter 8.5.7 on page 160 for more details.

Press *Start* to start the measurement. In order to see the tracking data you have to enable the Fingertracking display by clicking *Display* → *Fingertracking*. Please refer to chapter 8.3.3 on page 135 for details.

6.4.7 Display tool Fingertracking Viewer

The Fingertracking Viewer is a tool for visualisation of the hand and finger positions. It is available free of charge for demonstration and testing purposes to be installed on the PC that receives ***DTrack2*** data.

After starting the viewer, proceed the following way:

- specify the ***ART*** Controller to connect to by defining the host name or IP address
- specify the UDP data port the viewer has to listen to
- press the *Go Online* button

- press *OK* to connect the viewer to ***DTrack2***
- choose the *Hand ID* you want to display

The light adjacent to the *Hand ID* setting indicates whether this hand is tracked or not (green=tracked, red=not tracked). Finally click on one of the buttons featuring a hand to see your tracked hand and fingers.

You can also start a small demo showing the handling of a virtual object by opening the *Demos* menu. There is a limited number of simple demos available, e.g. you can handle a virtual sphere or cube. To insert the virtual object into the tracking volume, place the tracked hand at a convenient position and press the *Grab object* button.

6.5 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 6.26: 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 purchased from ***ART*** . Please refer to chapter 8.4.1 on page 141 for details how to upgrade your system.

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 6.26 on page 101 (i.e. markers have to be 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.

Data output 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 250 for more information about the format of the output data.

6.5.1 Measurement Tool Configuration

First, you have to define how many Measurement Tools you want to use. Therefore, please go to *Settings* → *Measurement Tool* (see figure 6.27 on page 102).

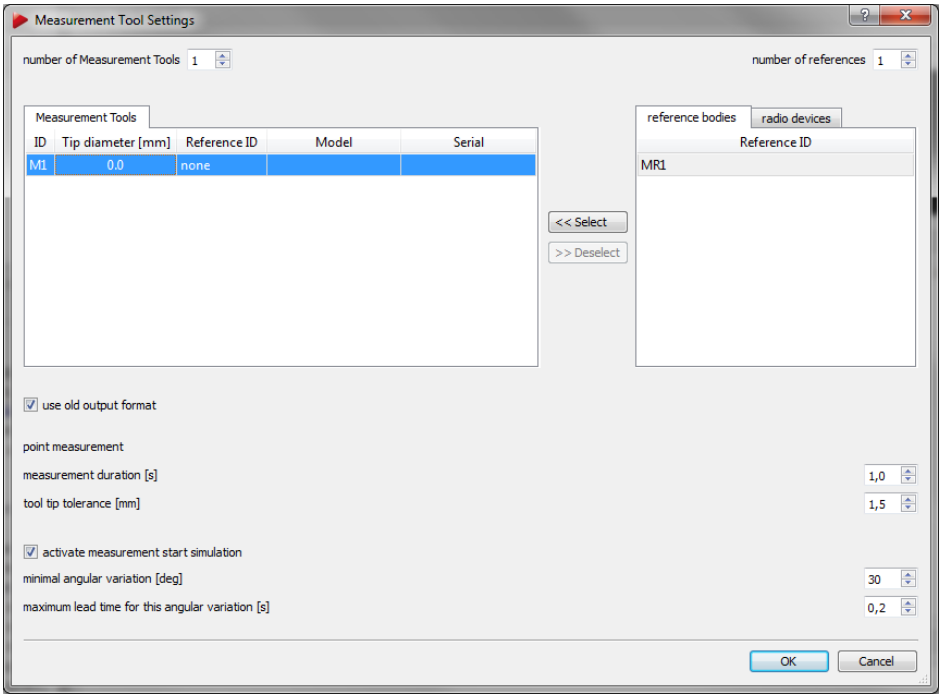


Figure 6.27: Measurement Tool Settings

In this dialogue you can define the '*number of Measurement Tools* ' as well as '*number of references*'. Additionally several other parameters can be changed 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
use old output format	configure legacy output format (refer to chapter B.2.9 on page 265
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 gesture detection 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 after gesture detection

Table 6.9: Measurement Tool settings

References 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 .

Measurement Duration It is possible to define the duration of a point measurement. A compromise has to be found between the amount of data collected and the convenience of holding the measurement tool. Enter the value in seconds in the field *measurement duration [s]*.

Tool Tip Tolerance The tracking system will take measurements up to a defined jitter in millimeter around the tool tip. Configure this tolerance to suit your application. Enter the value in millimeters in *tool tip tolerance [mm]*.

Start Simulation In certain applications and use cases it might be more convenient to start the measurement by a gesture rather than pressing a button on your PC. Tick the

checkbox *activate measurement start simulation* to enable the gesture detection. The gesture is simply tilting the the Measurement Tool along the tip axis similar to waving. You can configure the minimum angle of tilt that is necessary to detect the gesture. Enter the value in °[deg] in the field *minimal angular variation [deg]*. Additionally you can specify a waiting time until the measurement starts after detection of the gesture. Specify the time in seconds in the field *maximum lead time for this angular variation [s]*.

6.5.1.1 Measurement Tool 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.

Body Calibration First, please calibrate the Measurement Tool with a standard body calibration (see chapter 8.6.5.2 on page 177) by selecting *Calibration* → *Body*. In the upcoming 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 also 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 a successful body calibration, you have to calibrate the tip of the Measurement Tool by selecting *Calibration* → *Measurement Tool* (see figure 6.28 on page 104) .

Figure 6.28: Measurement Tool Tip Calibration

Place the Measurement Tool in front of the cameras with the tip fixed at exactly one position (e.g. on a hard surface). Press *Calibrate* to start the calibration process. Gently move

the Measurement Tool while tilting it around its tip in all axes (Note: Keep it positioned at exactly one point, i.e. do not lift it from the surface).
DTrack2 will calculate the position of the tip relative to the markers of the Measurement Tool , i.e. the origin of the body coordinate system is transformed into the Measurement Tool 's tip.

Note that the progress bar will stop 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.

6.5.1.2 Measurement Tool 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 8.5.7 on pag 160 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*. Please refer to chapter 8.3.3 on page 135 for details.

7 Hybrid tracking

With introduction of v2.14.0 ***DTrack2*** supports advanced sensor fusion of optical and inertial tracking data.
Compatible hybrid targets available from ***ART*** are communicating with the ***DTrack2*** system either via wireless 2.4 GHz ISM radio connection or via wired USB connection.

7.1 Hybrid motion capture suit

Wireless hybrid targets are distributed together with an antenna and two wireless transceivers ('Dongles') for communication with the inertial sensors as a part of our Hybrid Motion Capture suit. Please also refer to table 3.3 on page 28.

7.1.1 Connecting the wireless transceivers

First connect the USB plugs of the transceivers ('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*.

Be sure just to use active (USB 2.0) extension cables (like the supplied 'ATEN UE250') to connect the transceivers ('Dongles') to an *ART* Controller. Otherwise proper function of the transceivers cannot be guaranteed.

Now within ***DTrack2*** go to the menu *Settings* → *Inertial Sensor* and open the *Settings* sub-dialogue (see figure 7.1 on page 107) to check that all attached dongles have been found showing the following

Dongle properties:

- Device ID dongle
- Model (Dongle USB)
- Name (n/a)
- Firmware Version
- Currently used radio channel (default: 35 / 55); use the drop-down menu to change the radio channel
- Wake-up mode (n/a)
- Battery level (n/a)

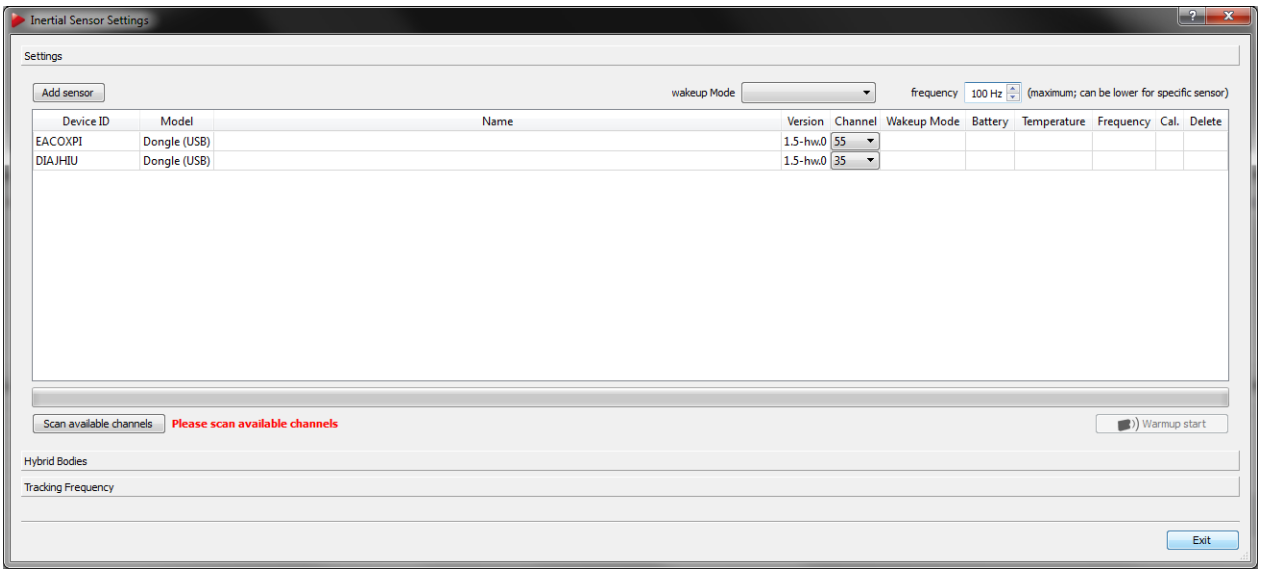


Figure 7.1: Inertial Sensor Settings - Connecting wireless transceivers

- Temperature (n/a)
- Frequency (n/a)
- Calibration Status (n/a)
- Delete function (n/a)

At this point only dongles should be listed, otherwise check that all previously added sensors show up together with their corresponding dongle. Please refer to figure 7.4 on page 110.
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 (see figure 7.2 on page 107). The currently used channel is marked in bold digits, while all channels that are not recommended are greyed out. Additionally ***DTrack2*** shows recommended channels (marked green).

	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	**35**	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81									

Figure 7.2: Dongle Configuration - Selection of a radio channel

Please select an appropriate channel for each dongle now. The selected dongle will change its channel accordingly and likewise all assigned sensors. Do not set both dongles to the same channel or on occupied frequencies from other devices in range.

☞ **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. A minimum distance of 10 channels is mandatory between dongles, and recommended from otherwise unavailable channels for optimum connectivity.**

7.1.2 Connecting the wireless inertial sensors

This needs to be done initially - in case the sensors are already connected please skip this step.
All *ART* pre-calibrated targets are delivered with their corresponding optical target geometries stored inside the inertial sensor. Thus when adding the recognized inertial sensors, all corresponding target geometries are automatically added to the tab '*standard bodies*' in the menu *Body Administration* (Shortcut:F8) and the sub-dialogue *Hybrid Bodies* of the menu *Inertial Sensor Settings* respectively.

☞ **Please ensure that all sensors have been charged or alternatively attach the sensors to the supplied charging hub prior to the following steps.**

Turning on/off wireless inertial sensors Turn on all sensors by pressing their corresponding buttons. The status LED will turn green.
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.**

7.1.2.1 Adding wireless inertial sensors

In the menu *Settings* → *Inertial Sensor*, press *Add sensor* to identify and connect all inertial sensors in range (see figure 7.1 on page 107).

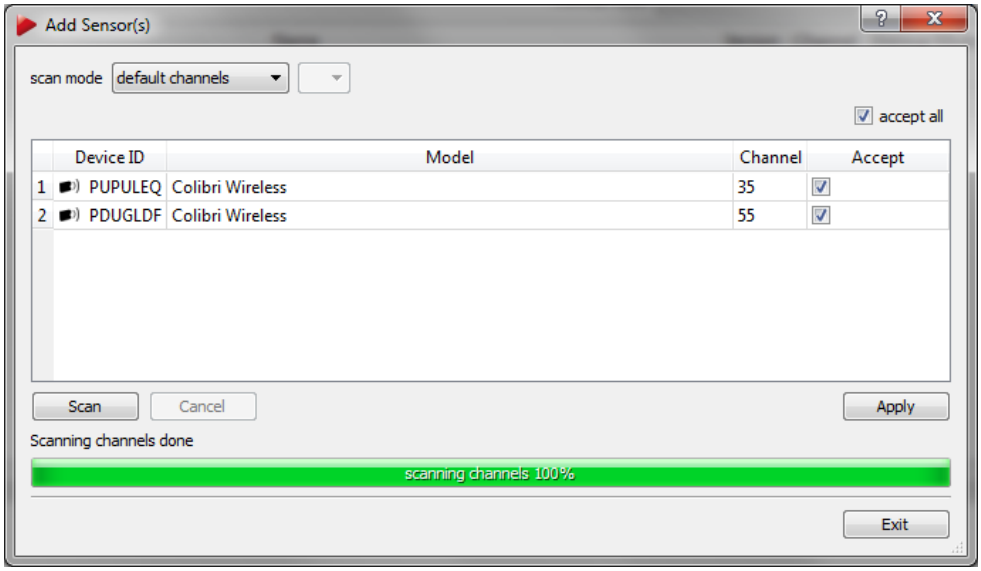


Figure 7.3: Adding wireless inertial sensors

In the upcoming dialogue (see figure 7.3 on page 109) you should find the *Scan mode* being '*USB*'. Please change the mode to '*default channels*' using the adjacent selection box. In this mode ***DTrack2*** will search for the sensors on default channels 35 and 55, even if the current channel of dongles / sensors has been set differently. In case the dongles / sensor channels have been set manually, please change the scan mode to '*single*' and select the corresponding channels in the adjacent selection box.
Press *Scan* and the system will identify all sensors in range running on the specified channels. Expect 15 inertial sensors for a complete ***ART*** Hybrid Motion Capture suit. 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.

If you cannot remember the current radio channel of your sensors, you can either choose '*all*' to scan all channels (from 1 to 80, note: this takes some time) or identify the sensors via wired connection. To this end connect all sensors to the *ART* Controller via a USB charging cable and select the scan mode '*USB*'. All attached sensors will be listed together with their corresponding channel.

Take care that all inertial sensors are assigned to a radio channel of one of the dongles; otherwise such a sensor cannot be used during measurement. Also take care that (roughly) the same number of sensors are assigned to each dongle.

After adding the sensors the dialogue *Inertial Sensor Settings* (see figure 7.4 on 110) now shows all available dongles and their assigned sensors with the following

sensor properties:

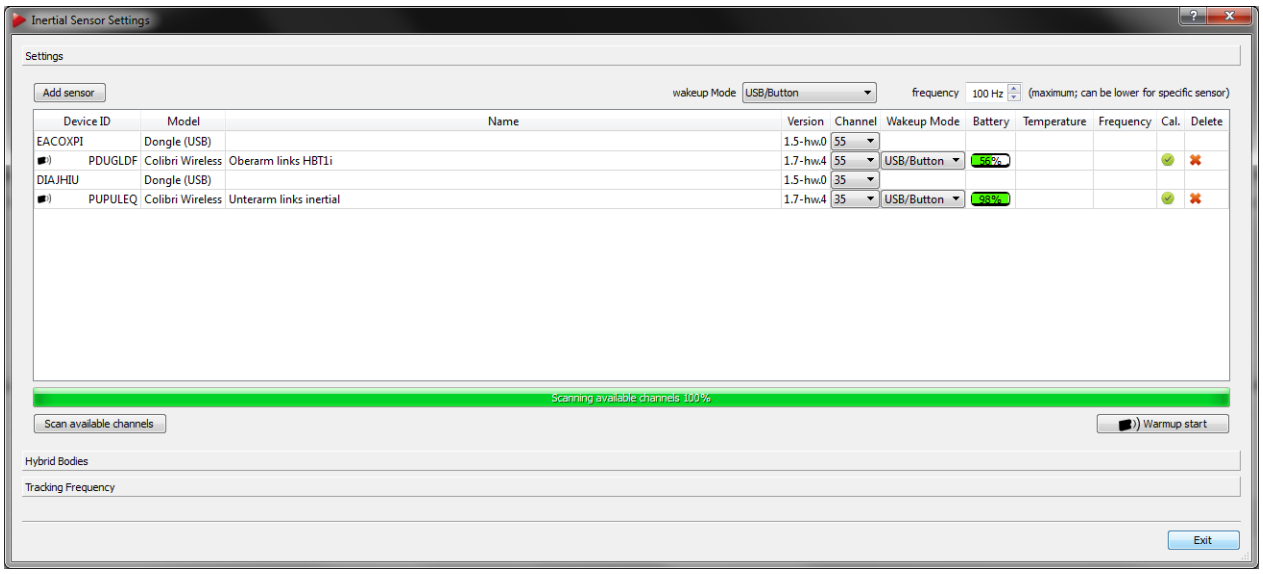


Figure 7.4: Inertial Sensor Settings - Wireless transceivers and sensors added

- Device ID sensor + wireless icon (e.g. PUPULEQ)
- Model (e.g. Colibri Wireless)
- Name (target name from Hybrid Motion Capture suit or user-defined)
- Firmware Version
- Currently used radio channel (default: 35 / 55); use the drop-down menu to change the radio channel of the corresponding dongle
- Wake-up mode (radio, tapping, USB/button)
- Battery level (%)
- Temperature (°C, only after measurement)
- Current tracking frequency (Hz, only after measurement)
- Calibration Status (*not calibrated*, *optical only*, *fully calibrated*)
- Delete function

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.

Tracking frequency Finally please check the maximum tracking frequency the inertial sensors are operating at (default for wireless sensors: 100 Hz). Use the spinbox in the upper right corner of the window to select a different value, if necessary.

Selecting the pulse generating source Please refer to chapter 7.2.5 on page 119 for further details.

It is NOT recommended to select a wireless inertial sensor as pulse generator due to the nature of the connection (i.e. high latencies and timing jitter). Therefore change the default settings in the menu *Settings* → *Tracking* only when necessary.

7.1.3 Calibration of custom wireless hybrid targets

Custom wireless hybrid targets will show up as '*not calibrated*' in the column *Calibration* under the tab '*standard bodies*' in the menu *Body Administration* (Shortcut:F8) or in the sub-dialogue *Hybrid Bodies* of the menu *Inertial Sensor Settings*. Therefore a multi-step calibration procedure for each body has to be performed analogue to wired hybrid targets. Please refer to chapter 7.2 on page 111.

***ART* delivers a pre-calibrated hybrid motion capture suit, i.e. both the optical target geometry as well as the hybrid body calibration are stored directly on the sensor. Unless the hybrid targets are disassembled or become damaged, it is sufficient to identify and add all sensors using the menu *Settings* → *Inertial Sensor* → *Add Sensors*. There is no need to (re-)assign the inertial sensors on pre-calibrated targets or to calibrate the targets manually.**

Reassignment or disassociation of inertial sensors and pre-calibrated optical targets will render the corresponding bodies useless. Therefore enter the sub-dialogue *Inertial Sensor Settings* → *Hybrid Bodies* only when necessary.

7.2 Wired hybrid targets

Within ***DTrack2*** go to the menu *Settings* → *Inertial Sensor* → Hybrid Bodies (see figure 7.8 on 114) and activate the desired amount of bodies. Next assign suitable names by double-clicking the corresponding field *Name* from row '*1...n*' under *selected body*. Now a multi-step calibration procedure for each body has to be performed:

1. A standard optical body calibration needs to be carried out. Alternatively load a body calibration from a file. Start by pressing the button *Calibration*. Please refer to 8.6.5.2 on 177 for more details.

2. An inertial sensor has to be added and then assigned to an optical target. Please refer to chapters 7.2.1 on page 112 and 7.2.2 on page 114 respectively for further information.

3. A hybrid body calibration has to be performed to align the inertial sensor with its corresponding optical target by pressing the button *Hybrid Body Calibration*. During this hand-eye calibration process the relative orientation of the two coordinate systems is determined. Please refer to chapter 7.2.3 on page 115.

4. An inertial sensor calibration needs to be applied to compensate drift from the inertial sensor. Start by pressing the button *Inertial Sensor Calibration*. Please refer to chapter 7.2.4 on page 117.

Repeat all steps for each hybrid target and finally set the pulse generating source that drives the tracking frequency according to your application's requirements. Please refer to chapter 7.2.5 on page 119.

Wired hybrid targets for use with e.g. HMDs are not delivered pre-calibrated, simply due to the fact that mechanical changes during assembly on top of the customer's gear would render any pre-calibration useless.

7.2.1 Connecting the wired inertial sensor

This needs to be done initially - in case the sensor is already available please skip this step.
Within ***DTrack2*** go to the menu *Settings* → *Inertial Sensor* and open the *Settings* sub-dialogue (see figure 7.5 on page 112).

Never attempt to connect *3-Space* wired sensors / hybrid targets to a personal computer or try to access the sensor using software provided by the original manufacturer *Yost Labs*. This may result in irreversible damage of the sensor.

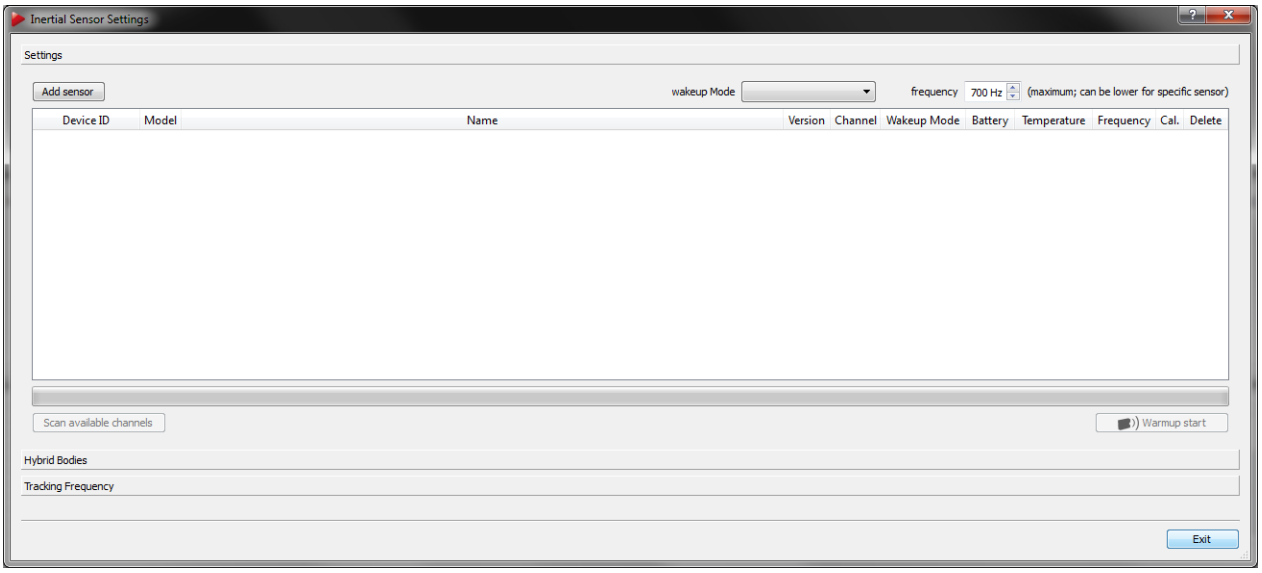


Figure 7.5: Inertial Sensor Settings - No wired inertial sensor connected

7.2.1.1 Adding wired inertial sensor

Please ensure that the sensor has been connected to the ***ART*** Controller. Then press the button *Add sensor*.

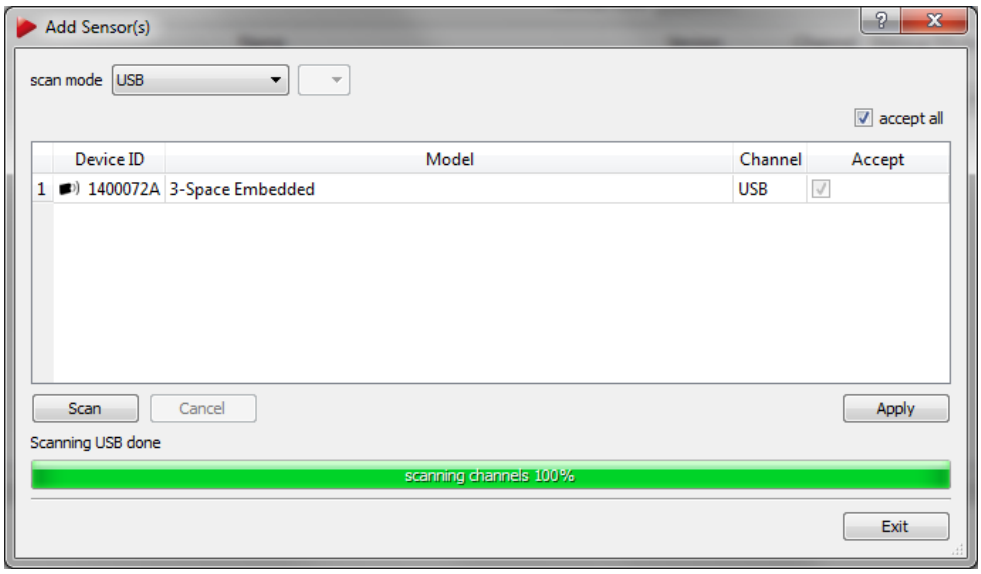


Figure 7.6: Adding wired inertial sensor

In the upcoming dialogue (see figure 7.6 on page 113) you should find the *Scan mode* being '*USB*'.
Press *Scan* and the system will identify all attached sensors. Tick the checkbox of the 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.
The dialogue *Inertial Sensor Settings* (see figure 7.7 on page 113) now shows all available sensors with the following properties:

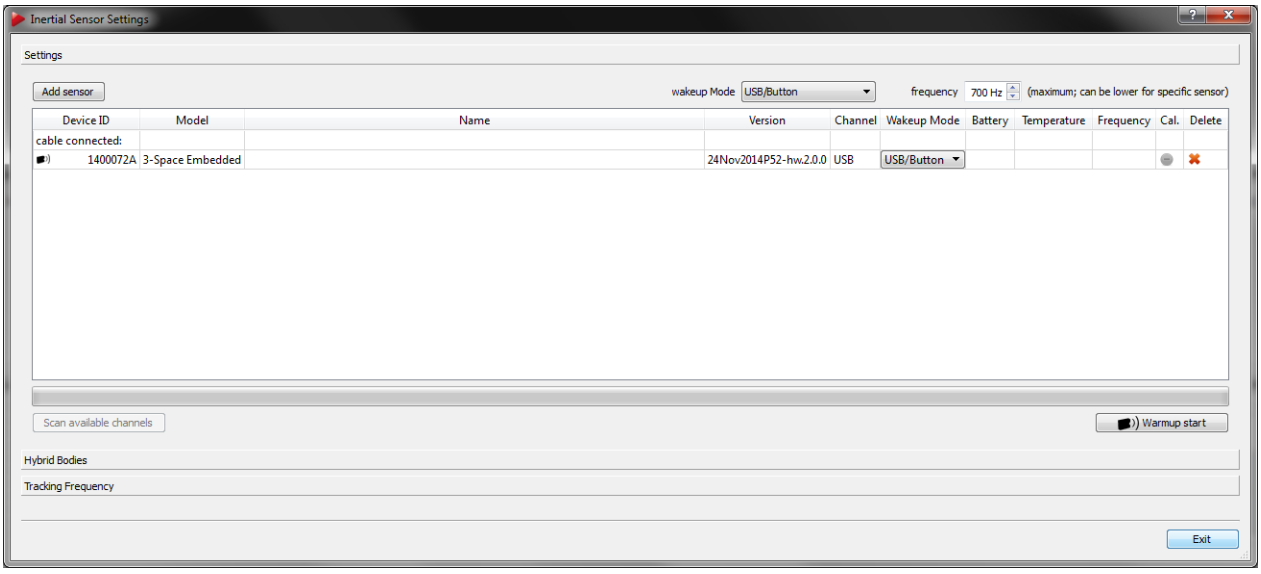


Figure 7.7: Inertial Sensor Settings - Wired inertial sensor added

- Device ID
- Model (e.g. 3-Space wired)

- Name (empty unless user-defined)
- Firmware Version
- Currently used channel (USB)
- Wake-up mode (n/a)
- Battery level (n/a)
- Temperature (°C, only after measurement)
- Current tracking frequency (Hz, only after measurement)
- Calibration Status (*not calibrated*, *optical only*, *fully calibrated*)
- Delete function

Tracking frequency Finally please check the tracking frequency the sensors are operating at (default for wired sensors: 700 Hz). Use the spinbox in the upper right corner of the window to select a different value, if necessary.

7.2.2 Assigning the wired inertial sensor

After adding the inertial sensor it needs to be assigned to an optical target, which has been calibrated beforehand. Change to the sub-dialogue *Hybrid bodies* inside the dialogue *Inertial Sensor Settings* (see figure 7.8 on 114).

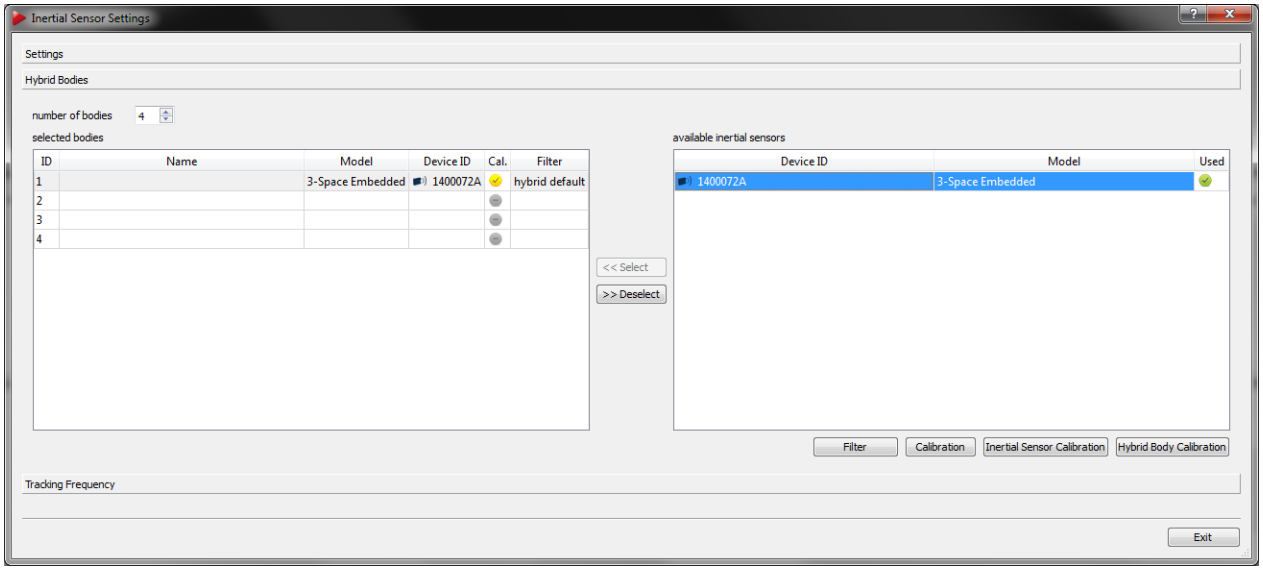


Figure 7.8: Inertial Sensor Settings - Hybrid Bodies sub-dialogue

In order to assign an inertial sensor to a optical target follow these steps:

- mark the respective *Body ID* under *selected bodies* by left-clicking

- mark the appropriate entry '*Device ID*' under *available inertial sensors* by left-clicking and
- press *Select*.

You can always delete the assignment by pressing the button *Deselect*. The inertial sensor will be available again for assignment.

If the inertial sensor is already in use a green tick is shown in the column *Used* on the right side of the window.

For each uncalibrated body the '*Name*' entry will be empty, while the column *Cal.* will show a *No Entry* sign. Body IDs without corresponding hybrid body calibration are marked with a yellow tick on the corresponding *Body ID* row in the column *Cal.*. A fully calibrated *Body ID* is marked with a green tick.

After assignment the corresponding body is shown on the left side of the window with the following properties (see figure 7.8 on 114):

- Body ID
- Name (empty unless user-defined)
- Model (e.g. 3-Space wired)
- Device ID (of the assigned inertial sensor)
- Calibration Status (*not calibrated*, *optical only*, *fully calibrated*)
- Filter Status (please refer to chapter 8.5.6.1 on page 158

Additionally all attached inertial sensors are listed on the right side together with:

- Device ID
- Model (e.g. 3-Space wired)
- Assignment Status (*not used*, *Used*)

In order to identify the inertial sensor and to assign it to the corresponding *Body ID* please double-check the serial number on top of the sensor and compare it to the entry in column *Device ID*.

7.2.3 Hybrid Body Calibration

After assigning an inertial sensor, select the respective *Body ID* under *selected bodies* and press the button *Hybrid Body Calibration* (see figure 7.8 on 114).
In the appearing window (see figure 7.9 on page 116) verify the target by its corresponding '*name*' and '*bodyID*' from the adjacent drop-down menu. Also double-check the '*Device ID*' of the inertial sensor for correspondence with the selected optical target. Then press *Calibrate*. During the following calibration process the target has to be tilted with moderate

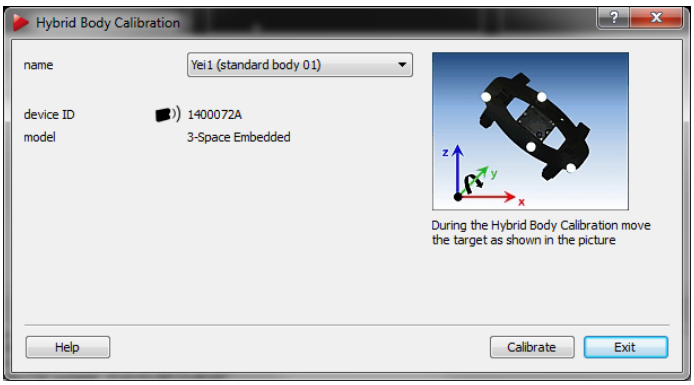


Figure 7.9: Hybrid Body Calibration

speed around all axes of the inertial sensor (please refer to the animation in the dialogue see figure 7.9 on page 116). After the countdown disappears the upcoming dialogue will show the status of the calibration via a progress bar (see figure 7.10 on page 116.)

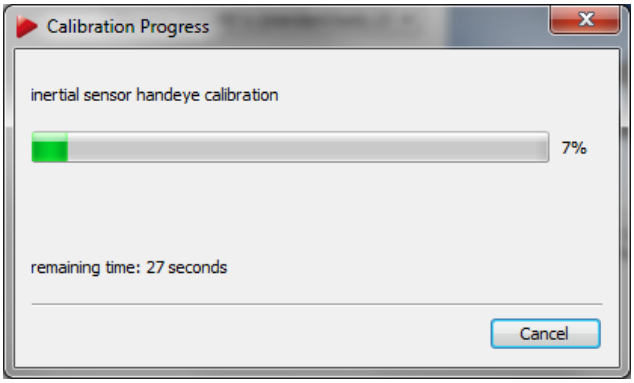


Figure 7.10: Hybrid Body Calibration - Progress Bar

In the upcoming result window (see figure 7.11 on page 116) the residual of the calibration and the sensor delay of the inertial tracking data is displayed.

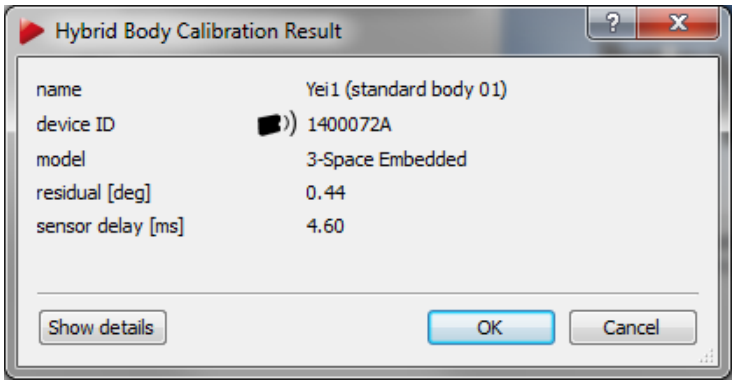


Figure 7.11: Hybrid Body Calibration Result

The residual specifies how well the rotational data from the inertial sensor matches the optical tracking data. Thus it is a measure of the accuracy of the hybrid body calibration. Values up to 1° are ideal, while anything less than 3° is still acceptable.

The sensor delay specifies the latency of the inertial data compared to real-time. This is sensor specific and dependent on the type of connection (wired / wireless). Values up to 5 ms are ideal for HMD applications.

You can accept the calibration by pressing *OK* to return to the *Hybrid Body Calibration*. Press *Exit* to return to the *Hybrid Bodies* sub-dialogue. Now, the sensor should show a green tick in the column *Calibration* under *selected bodies* on the left side of the window.

Show details You can display the result of the hybrid body calibration as a rotation matrix by pressing the button *Show details*.

7.2.4 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, all sensors have to be warmed-up beforehand. Please refer to chapter 7.2.4.1 on page 118 for more details.
To start the inertial sensor calibration, select *Inertial Sensor Calibration* from the sub-dialogue *Hybrid bodies* inside the dialogue *Inertial Sensor Settings* (see figure 7.8 on 114). The upcoming window shows a list of all available hybrid targets, i.e. bodies with successful optical calibration and assigned inertial sensor (see figure 7.12 on page 117).

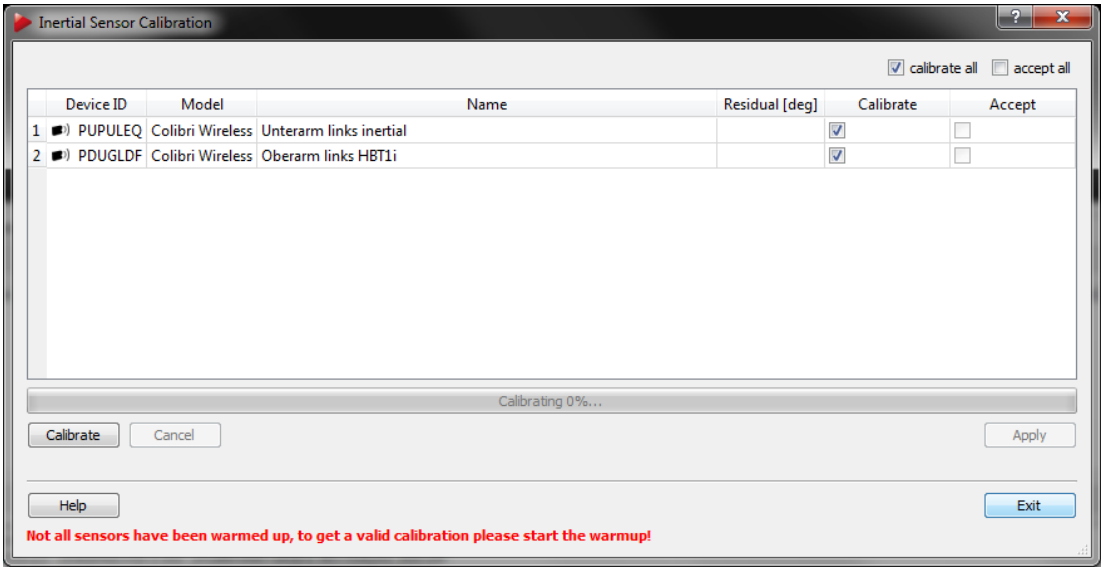


Figure 7.12: Inertial Sensor Calibration

Put the respective sensor inside the tracking volume on a level surface (pre-condition: a successful Hybrid Body Calibration for each inertial sensor). Tick the checkboxes in the column *Calibrate* of all sensors to be calibrated and press *Calibrate*. Do not move or

touch it during the following calibration !
In the upcoming result window (see figure 7.13 on page 118 the residual of the drift correction is displayed.

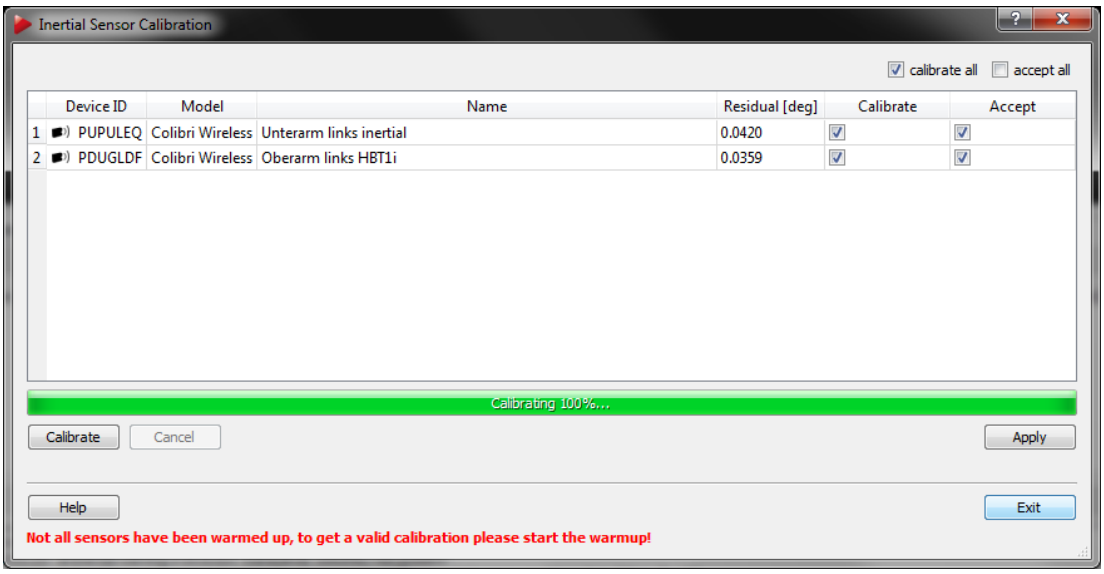


Figure 7.13: Inertial Sensor Calibration - Result Window

The residual specifies the drift correction for the inertial sensor. Values below 0.1 ° are ideal, while still being acceptable up to 0.2 ° . Higher values indicate possible movement during the calibration.

When the calibration is done, you can apply the drift correction either to a single sensor by ticking the appropriate checkbox in the column *Accept* or by ticking '*accept all*' for all sensors in range. Press *Apply* and exit the dialogue. A list of all successfully calibrated sensors appears (see figure 7.14 on page 119. Press *Exit* to return to the *Inertial Sensor Calibration* window. Return to the *Inertial Sensor Settings* → *Hybrid Bodies* subdialogue by pressing *Exit* once again.

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

7.2.4.1 Warm-up of inertial sensors

To start up the procedure simply press the button *Warmup start* in the dialogue *Inertial Sensor Settings* (see figure 7.7 on page 113) or in the toolbar of ***DTrack2*** frontend (refer to chapter 8.3.2 on page 134) 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 and do not cool down until the calibration takes place.

Please ensure that all sensors have been charged prior to any calibration process.

Please perform inertial sensor calibrations with warmed-up sensors at constant ambient temperature prior and during the calibration for optimum tracking performance.

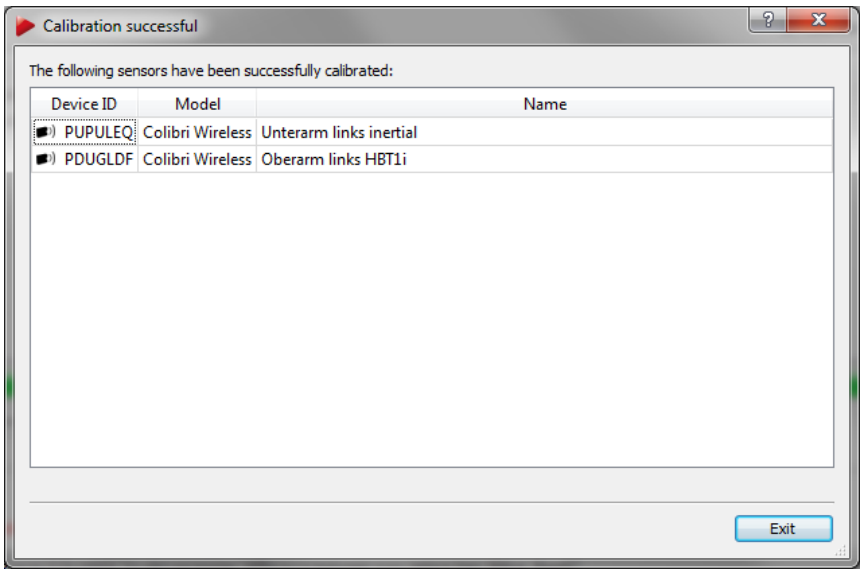


Figure 7.14: Inertial Sensor Calibration - Result Window Successful

7.2.5 Selecting the pulse generating source

There are several independent pulse generating sources available in a hybrid tracking setup (i.e. combined optical & inertial tracking). Therefore it is necessary to select the appropriate one that drives the tracking frequency.

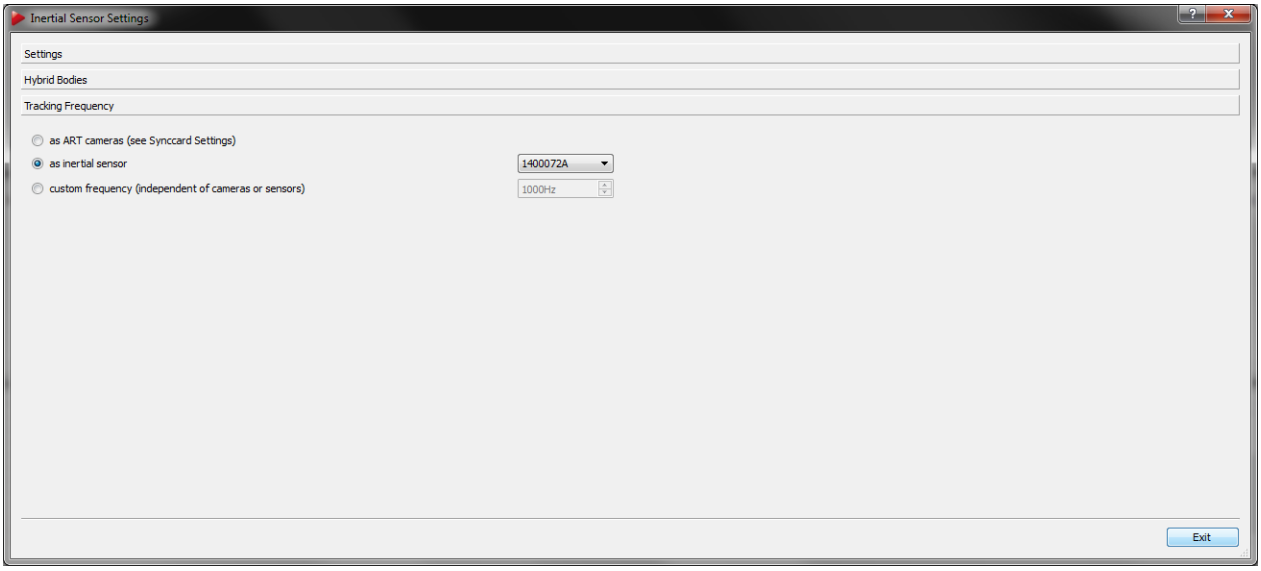


Figure 7.15: Hybrid Tracking Settings - Inertial Sensors available (license necessary)

You can switch between the following sources by ticking the corresponding radio button in the subdialogue *Inertial Sensor Setting Tracking frequency*:

- '*as ART cameras*': The ***ART*** controller's synccard is used. The tracking frequency is set according to the *Synccard Settings* menu. Please refer to the corresponding chapters 8.5.2 on page 151.

- '*as inertial sensor*': An inertial sensor is used (only available, if attached). If using multiple inertial sensors use the adjacent drop-down menu to select the appropriate one. The tracking frequency is set according to the *Inertial Sensor Settings* menu. Please refer to the corresponding chapter 7.2.1.1 on page 112.

- '*custom frequency*': An internal source is used providing a custom frequency (only available with inertial license). Use the adjacent spinbox in a range from 10 to 1000 Hz.

Selecting a custom frequency higher than the tracking frequency provided by the inertial sensors (e.g. 700 Hz for *3-Space* wired inertial sensors) could lead to minor tracking quality.

Keep in mind that '*send data divisor*' in menu *Output Settings* is also affecting the resulting data output frequency. Please refer to chapter 8.5.7 on page 160 for further information.

It is NOT recommended to select a wireless inertial sensor as pulse generator due to the nature of the connection (i.e. high latencies and timing jitter). Therefore enter the menu *Settings* → *Tracking* only if necessary.

8 *DTrack2* frontend software

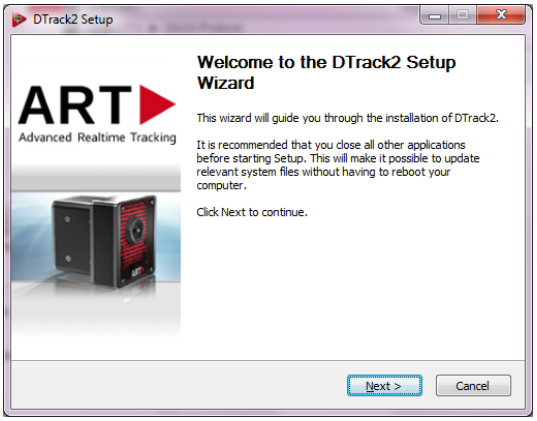
The software ***DTrack2*** is intended to access any ***ART*** controller via ethernet and runs on a remote PC (Windows or Linux). ***DTrack2*** itself is delivered via USB pen-drive. The latest version can be downloaded from our Download Center at http://www.ar-tracking.com/support/

8.1 Getting started

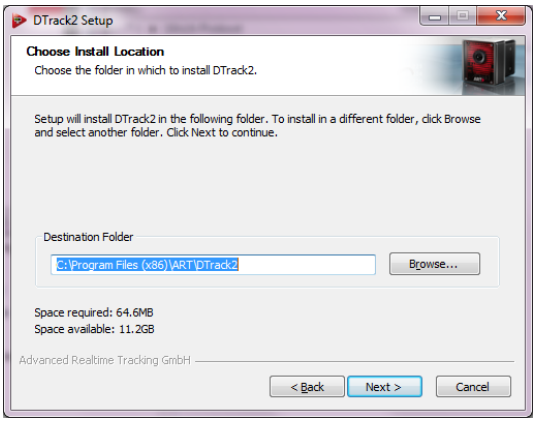
Please refer to chapter A.6 on page 245 for more information on supported operating systems.

8.1.1 Installation guide (Windows)

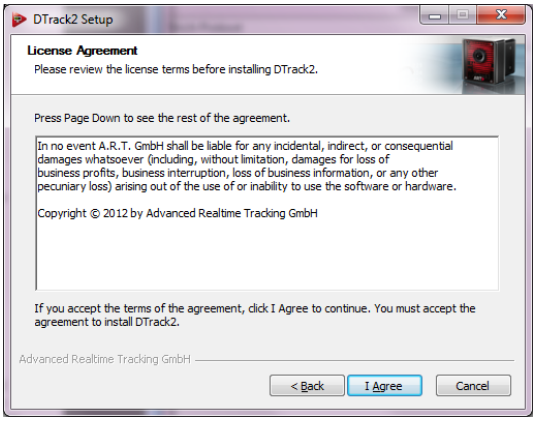
Run the installation executable "*DTrack2_v2.x.x_win32_install.exe*" and the installation wizard of ***DTrack2*** starts.



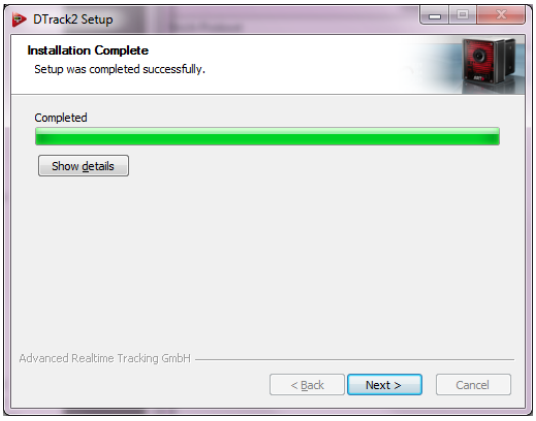
Click *Next* to continue and to start the installation process for ***ART DTrack2*** software. Administrator rights are not necessary.



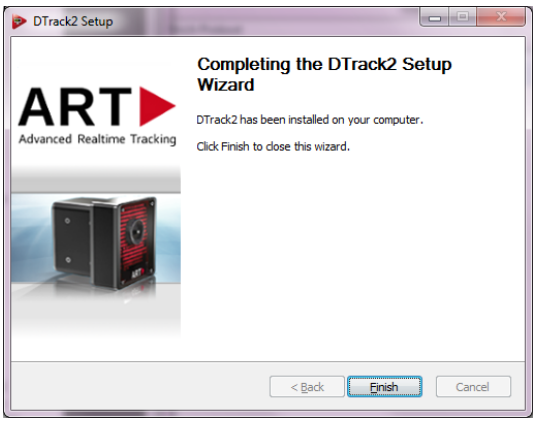
Now, please choose the destination folder in which you want to install ***DTrack2*** .



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*** .

8.1.2 Installation guide (Linux)

The software (32-bit and 64-bit package available) is packed in an archive. (*DTrack2_v2.x.x_linux32.tar.gz*) 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_linux32.tar.gz` 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`.

8.1.3 Software update

The latest *DTrack2* software is always available from our Download Center at http://www.ar-tracking.com/support/. For the installation of the frontend dupdate, please proceed as mentioned before in chapters 8.1.1 and 8.1.2.
After installing *DTrack2* on the host PC the controller can be updated after establishing a connection with the new frontend. Please refer to chapter 8.8.1 on page 188.

8.1.4 Start *DTrack2* frontend software

When you start up *DTrack2* on the remote PC you will see the following splash screen (see figure 8.1 on page 123).

Figure 8.1: Welcome screen of *DTrack2*

Using the mouse or shortkeys (2 = down, 4 = left, 6 = right, 8 = up) you can move around the splash screen window, e.g. to a secondary screen. The position of the window is then saved and will be used at the next start-up.

8.1.5 *DTrack2* command line parameters

The following parameters (refer to table 8.1 on page 124 may be added to the command line (i.e. *DTrack2* icon → properties → shortcut → target) when starting the *DTrack2* frontend.

Command line parameter	Description
-directstart	Connect with the last used controller (can be combined with -measure)
-help	Shows a window with these command line parameters and additional examples
-host <name or IP>	Connect with given controller (by name or IP number) (can be combined with -measure)
-measure	After connecting, start measurement
-wakeup	Wake up the last connected controller (can be combined with -directstart and -measure)
-wakeup <MAC>	Wake up controller with given MAC address (can be combined with -host and -measure)

Table 8.1: Command line parameters

8.2 Connecting to the controller

When you start up ***DTrack2*** for the first time, you will need to specify the default controller. Please jump to chapter 8.2.1 on page 124.
After the first run of ***DTrack2*** your controller is still known by the frontend and it will automatically search for it. The welcome screen will show the host-name, the last known IP-address and the status of your controller (i.e. 'testing IP-address OK' and 'resolving host-name OK', see figure 8.1 on page 123). If you would like to connect to the controller shown at this point, just press *Connect*. The main window will open (refer to 8.3 on page 132). In case you would like to choose a different controller, press *Other Controller*.
To wake up your controller from standby-mode (Wake on LAN), please refer to 8.2.3 on page 126.
In any other case (i.e. 'testing IP-address unsuccessful' and 'resolving host-name unsuccessful' and Wake on LAN unsuccessful), please refer to chapter 9 on page 192.

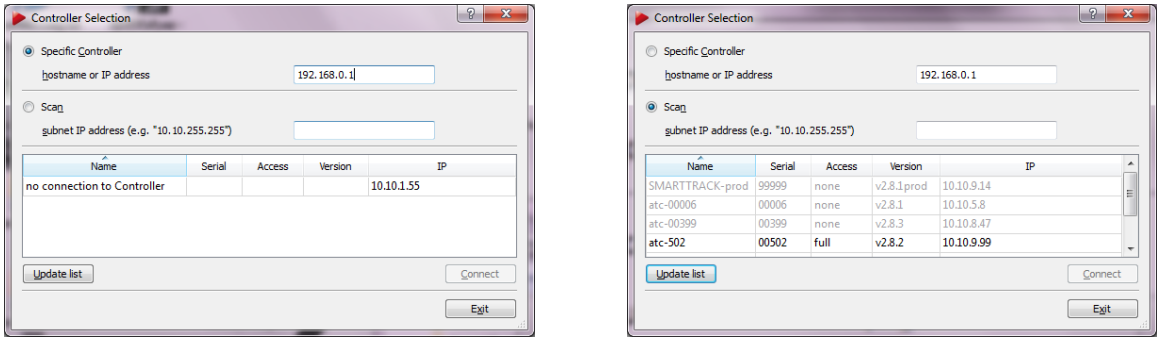
8.2.1 Other Controller (1st run after installation)

Whenever you would like to select a different controller than the default or last known (done automatically after installation and first run of ***DTrack2***) the splash screen is skipped and a separate window will be opened (see figure 8.2 a on page 125). The radio button will be ticked at position *Specific Controller*. Depending on your type of connection (see 5.4 on page 59) you can now either scan your LAN (DHCP-service necessary) for available controllers or specify the IP-address or host-name of your controller directly.

Specific controller In case of LANs without a DHCP server or via direct connection to your remote PC (see 5.4 on page 59) you may specify the IP-address of your controller by entering it in line *hostname or IP address*. To connect press *Connect*. In order to find out the IP address of your controller please refer to chapter 8.2.4 on page 127.

Scan LAN To scan your LAN simply select *Scan* followed by pressing *Update list*. You will see a list of all controllers in your network. Controllers set in grey are used by other remote PCs in your network (→ IP address listed at the bottom of the welcome screen), whereas available controllers for connection are set in black. If not, please refer to chapter 9 on page 192. You can easily identify your controller by comparing the serial number (e.g. 301422021 listed in column *Serial*) with the corresponding one on its label (back of the ***ART*** controller, refer to 5.2 on page 55). You can also sort the list by host-name *Name* or IP-addresses *IP*. Select the appropriate entry of your controller and press *Connect*.

If the Controller is not connected via an ethernet cable or no DHCP server is running, it will use its fall-back IP address (IP 192.168.0.1, subnet mask 255.255.255.0)



(a) specific controller (b) scan the network

Figure 8.2: Controller Selection

8.2.2 Setting a static IP address inside *DTrack2*

If necessary you can set your controller to a static IP address using the following steps:

- start up ***DTrack2*** and connect to your controller by pressing *Connect*
- select the menu *Settings* → *Controller* (see figure 8.20 on page 163)
- untick the checkbox *DHCP client*
- enter *IP address* and *subnet mask*
- optionally, enter *gateway* and *nameserver*
- reboot the controller for the changes to take effect

Please note that these settings are not part of your personal configuration. Changes in this menu will affect all users of your controller! Your controller may become unreachable with wrong IP settings! Refer to chapter 8.2.4 on page 127).

In case you need to specify a static IP address without using the frontend (e.g. installation on network without DHCP service available) please refer to chapter 8.2.4 on page 127 instead.

8.2.3 Wake On LAN

The controller is capable of Wake On LAN (WOL) when powered down in standby mode by the user (***DTrack2*** → *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. It will search for the controller but the '*Connect*' button will change its name into '*Wake On LAN*' after a few seconds (see figure 8.3 on page 126).

Figure 8.3: Welcome screen of ***DTrack2*** with Wake On LAN option

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

Press the '*Wake On LAN*' button and ***DTrack2*** will try to wake up the controller - this may take up to two minutes as the controller has to boot up (see figure 8.4 on page 126).

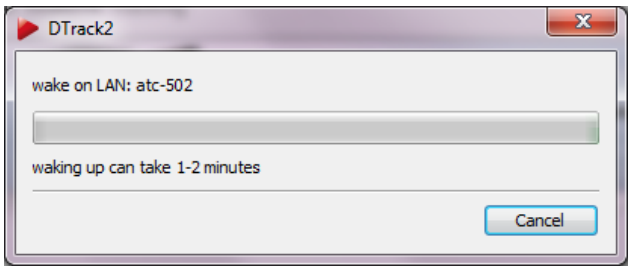


Figure 8.4: Wake On LAN progress bar

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

Option 2 - WOL via separate tool You will need the hostname of the controller as well as its MAC address. To get this information, either refer to 8.2.4 on page 127 or enter ***DTrack2*** and go to *Settings* → *Controller*. Copy the '*hostname*' and 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 controller restarts:

for Linux openSUSE:

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

for Ubuntu:

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

8.2.4 Configuring your controller without the *DTrack2* frontend

It is possible to retrieve ('information file') and to configure ('setup file') the current settings of the controller without the ***DTrack2*** frontend software. You only need a standard USB pen drive (FAT32 formatted).

Please note that these settings are not part of your personal configuration. Changes will affect all users of your controller! Your controller may become unreachable with wrong IP settings!

- Plug the USB pen drive in any available USB port of the controller. Controller can be powered up or off
- If necessary start up the controller
- Wait some time for the controller to write two files onto the USB pen drive (approx. 20-30 seconds, signalled by two (2) consecutive beeps)
- Unplug the USB pen drive
- Now view the information file 8.2.4.1 on page 128 or edit the setup file 8.2.4.2 on page 128 with any editor
- When changing the setup file please plug the USB pen drive in the controller again afterwards
- Wait some time for the controller to read the setup file (approx. 20-30 seconds, signalled by three (3) consecutive beeps)

- Unplug the USB pen drive
- Reboot the controller for the changes to take effect

Now, your controller is configured according to your requirements.

8.2.4.1 The information file

This file contains the current settings of the controller. Following, a description of the file format (e.g. ART_Controller_301422021_info.txt):

```
ART Controller Information:

Name              : atc-301422021
Serial Number     : 301422021

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

Gateway (LAN)     : 10.10.111.111

Domain Name       : xyz.site
Domain Name Server: 10.10.0.1
```

8.2.4.2 The setup file

This file is used to:

- configure the controller to be a DHCP client,
- set a static IP address and
- to carry out a factory reset.

You can find your current license codes in the file 'ART_Controller_XXXX_licenses.txt' (will be written to USB pen drive during factory reset)

Carrying out a factory reset will result in the loss of all your settings including your license codes! Backup your configurations or export your systems configuration log file beforehand (please refer to 8.4.2.1 and 8.4.2.2 on page 143).

Following, a description of the file (e.g. ART_Controller_00117_setup.txt) format:

```
# ART 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"

# ethernet and routing settings: fix IP address, subnet mask and corresponding gateway
#  - only use if destination for tracking data or DTrack2 frontend is in a different network than ATC
#  - note: gateway must be an IP number in same network/netmask as ATC!
#  - uncomment the following line to set a fix IP address, subnet mask and gateway IP address
#SETNET="ip 192.168.0.1 255.255.255.0 192.168.0.253"

# name settings: host name
#  - uncomment the following line to set the host name
#SETHOSTNAME="atc"

# name settings: domain name
#  - uncomment the following line to set the domain name
#SETDOMAINNAME="art.site"

# name settings: domain name server
#  - uncomment one of the following lines to set (or clear) a domain name server
#SETNAMESERVER="192.168.0.254"  # set DNS (IP or hostname)
#SETNAMESERVER="-"              # clear DNS


# factory reset of all other settings:
#  - CAUTION: use with care, all your settings will be lost!
#  - uncomment the following line to reset all other Controller settings
#  - additionally your ethernet settings will be set to DHCP if no fix IP is set above
#  - CAUTION: also all license settings will be reset!
#    - export 'system informations' (DTrack2->Configuration) to save your license codes;
#      or see 'ART_Controller_X_licenses.txt' (will be written to USB stick during factory reset)
#    - re-enter all license codes after factory reset under DTrack2->Licenses
#RESETSETTINGS="yes"
```

Example:
If you would like to set a static IP you have to remove the '#' sign and enter the desired IP address (here e.g.: 123.123.0.1)

before:

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

after:

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

8.2.5 Remote command strings

The following commands may be used in combination with DTrackSDK to control the tracking system remotely (e.g. with your media control) and without the ***DTrack2*** frontend.

Command string	Description
dtrack2 tracking start	Start tracking
dtrack2 tracking stop	Stop tracking
dtrack2 system shutdown	Shut down controller (WOL active)
dtrack2 system reboot	Reboot controller
dtrack2 get config active_config	Get currently active config ID, e.g. 'config20160808102933552'
dtrack2 set config active_config <ID>	Select an existing configuration. Warning: Must use <ID>, not name of configuration, except for default configuration (see next entry). Find under *Edit* button, e.g. 'config20160808102933552'
dtrack2 set config active_config standard	Set back to default configuration
dtrack2 get status active	Check whether tracking is currently measuring: **none** (stopped), **mea** (measuring), **cal** (running a calibration), **wait** (waiting for external sync input) or **err** (error in starting measurement)
dtrack2 get system access *supported on 2nd connection*	Check whether control connection can be established: **full** if accessible, **none** if not. **none** usually means another front-end is connected
dtrack2 get system accessed_by *supported on 2nd connection*	Ask who is currently connected with full access, e.g. to find front-end blocking shutdown from Crestron/AMX

Table 8.2: Remote command strings

To send a command, a TCP connection to port 50105 of the server has to be opened and the commands (see table 8.2 on page 130) can be sent. The controller replies with either "dtrack2 ok" or with an error message for commands and set requests, or with result strings in case of a get request.

Please ensure that the commands are sent exactly in the given way, with exactly one blank (`0x20`) between the elements and no trailing blanks, CR or LF characters, but including a trailing `NUL` (`0x00`) character.

Multiple remote connections *DTrack2* allows multiple clients to connect to the controller, but only the first connection is allowed to send commands except for those listed for secondary connections above. Therefore, scripts can test whether another client is connected to the controller. To do this, the command `dtrack2 get system access` checks the availability. It must return **full**; if it returns **none**, another process is already connected to the command port. In this case, the request `dtrack2 get system accessed_by` can be used to find the host of the connection.

It is recommended to use DTrackSDK (available under C++ and Java) to implement command support into own software and to use the *DTrack2* CLI software to send commands from scripts. Both DTrackSDK and *DTrack2* CLI are available for Windows and Linux, and can be downloaded after registering on the support part of the *ART* web page at `http://www.ar-tracking.com/support/`

When using the ***DTrack2*** CLI tool, please make sure to send commands and parameters as one argument by using quotes:

```
DTrack2CLI myATC -set "config active_config" "config20170724121806418"

DTrack2CLI myATC -get "config active_config"
config20170724121806418

DTrack2CLI atc-301604025 -cmd "dtrack2 set config active_config config20160808102933552"

DTrack2CLI atc-301604025 -get "config active_config"
config20160808102933552
```

To switch back to the default configuration use the following command:

```
DTrack2CLI atc-301604025 -set "config active_config standard"

DTrack2CLI atc-301604025 -get "config active_config"
standard
```

Linux For Linux shell scripts, additionally the 'nc' command can be used, e.g:

```
\$ echo -n "dtrack2 system shutdown" | nc 10.10.9.44 50105
dtrack2 ok
```

8.3 Main GUI

The graphical user interface of ***DTrack2*** can be divided into the following parts (see figure 8.5 on page 132):

- the menu bar with access to all settings (please refer to chapter 8.3.1 on page 132)
- the toolbar with graphical elements regarding the status of the tracking system (please refer to chapter 8.3.2 on page 134)
- the docking displays with graphical information (see chapter 8.3.3.1 on page 135) and measurement results (please refer to chapter 8.3.3 on page 135).

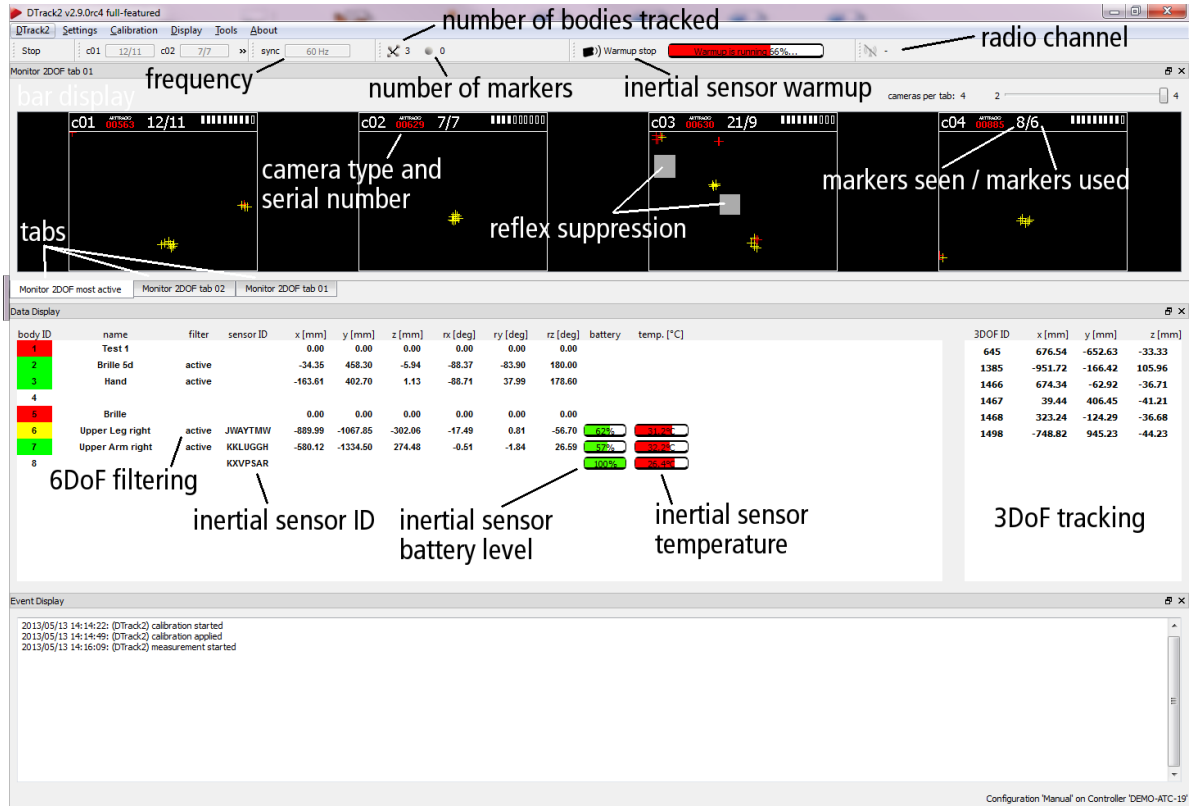


Figure 8.5: Graphical user interface of ***DTrack2***

8.3.1 Menu bar overview

DTrack2	*Shortcut*	page 141
Licenses		License overview → Adding licenses (e.g. higher amount of cameras, Fingertracking, Measurement Tool or Cascaded Systems)
Configurations		Select, create new and save different configurations, lock the current configuration, backup all settings or export system information

Start/Stop	M	Start/Stop measurement
Search hardware	F2	Search for newly added hardware
Controller standby		Force the controller to go into standby mode
Controller reboot		Reboot the controller
Quit	Q	Quit ***DTrack2***

Settings	*Shortcut*	page 146
Cameras	F7	Camera settings (e.g. flash intensities, syncgroup assignment)
Synccard		Synccard settings (e.g. tracking frequency, external synchronisation)
Inertial Sensor		Settings for inertial sensors
ART Radio Info		Settings for ***ART*** radio transceivers and devices within your setup
Tracking		Activate 3DOF calculation, automatic start of measurement
Body Administration	F8	General settings for all targets and interaction devices
Output	F9	Set output channels and configure the data to be transmitted
Fingertracking		Configure your Fingertracking (incl. tactile feedback) device
Flystick		Configure your Flystick
Measurement Tool		Configure your Measurement Tool
Controller		Configure the IP and NTP settings of your controller
Cascaded System		Configure a Cascaded System with available controllers

Calibration	*Shortcut*	page 165
Start static reflex scan for all enabled cameras		Starts the static reflex scan
Inertial Sensor Calibration		Re-calibrate the drift correction of the inertial sensor
Room	F5	Room calibration
Room adjustment	Shift + F5	Adjust / transform the room coordinate system
Body	F6	Body calibration
Body adjustment	Shift + F6	Adjust / transform the body coordinate system
Hybrid Body		Determine the relative rotation between optical and inertial sensor (i.e. run hand-eye calibration)
Fingertracking		Start calibration process for Fingertracking (i.e. hand geometry)
Measurement Tool		Start tip calibration process for the Measurement Tool

Display	*Shortcut*	page 187
Monitor 2DOF		Graphical display of markers recognized by the cameras
Data	F10	Display measurement results (6DOF and / or 3DOF)
Fingertracking		Display Fingertracking measurement data
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 188
Controller Update		Start the assistant for the controller update
Measurement Tool demo		Provides simple measurement acquisition for use with the Measurement Tool

About	*Shortcut*	page 189
DTrack2		Software version of frontend & backend
About Qt		Qt toolkit version
What's new?		Overview of the new features
What's this?	Shift + F1	Help

Table 8.3: *DTrack2* menu structure overview

8.3.2 Toolbar

By default, the toolbar (see figure 8.5 on page 132 consists of the following elements (from left to right):

Toolbar element	Description
Start/Stop button	Starts and stops the measurement
Camera Status	Shows the number of markers seen / tracked for each camera (2DOF)
Sync Status	Displays the current tracking frequency
Tracking Status	Shows the number of tracked targets (6DOF) / single markers (3DOF)
ART Radio Status	Displays the currently selected channel of the ART radio transceiver (greyed out, if not installed)
ART InertialSensor Status	Displays the currently selected channel of the inertial dongles (wireless only) and the status of the sensor's warm up process (greyed out, if not installed)

To change or activate elements right-click anywhere on the toolbar. Drag & drop the elements for re-arrangement by left-clicking.

The *Sync status* field is changing its colour from grey to yellow, then orange and finally red in case the effective frequency is decreasing due to processing overload (see figure 8.6 on page 135):

- grey: max. 5 frames per minute lost (i.e. 3600 frames per minute are transmitted, not shown)
- yellow: 5 - 10 frames per minute lost

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

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

(c) red: > 15 frames per minute lost

Figure 8.6: Visualization of the synchronization frequency decrease

- orange: 10 - 15 frames per minute lost
- red: > 15 frames per minute lost

8.3.3 Docking Displays

By default the first three of the following docking displays are activated (see figure 8.5 on page 132).

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

To change or activate the docking displays right-click anywhere on the toolbar or use the menu *Display* (refer to chapter 8.7 on page 187. Drag & drop the display windows for re-arrangement by left-clicking.

8.3.3.1 Monitor 2DOF display

The *Monitor 2DOF display* essentially is a 2-dimensional graphical display of all markers / flashes or other IR sources that can be seen inside the FoV of the cameras. It is particularly useful for the adjustment (especially orientation) of the cameras (refer to chapter 4.8.1 on page 48).
The *Monitor 2DOF display* shows a black window for each camera (equivalent to the field of view) with a schematic display of positions, size and shape of all recognized markers.

Cameras per tab In case several ***ARTTRACK*** cameras are being used in one system, it may prove helpful to adjust the number of cameras shown in the *Monitor 2DOF display*

in order to achieve a clear arrangement. Move the slider '*cameras per tab*' to the left to decrease the amount of cameras. Tabs containing the remaining cameras will be added below the *Monitor 2DOF display*.
The special tab '*most active cameras*' contains only those cameras which see the markers / targets most of the time.

Example: Consider a four camera system with cameras c01 through c04 where you have set the number of '*cameras per tab*' to two. Now if you move a target in front of cameras c02 and c03 most of the time, these two cameras will then be shown in the '*most active cameras*' tab.

Adding/removing cameras It is possible to add or remove cameras without restarting the ***ART*** Controller. Please refer to chapter 8.4.4 on page 145 how to dynamically analyse your system for changes in configuration.

When cameras are added to an already calibrated tracking system these cameras will not contribute for calculation and measurement until you perform a room recalibration (see chapter 8.6.3.3 on page 170). Therefore as as reminder the *Monitor 2DOF display* of the corresponding cameras will show the message '(re-)calibration required!' in red color.

On the contrary the ***ART*** Controller will detect all cameras that have been removed from an already calibrated tracking system (e.g., due to a disconnected cable) and mark them as missing until a room (re-)calibration has been performed. The *Monitor 2DOF display* of the corresponding cameras will be disabled (crossed out) and in case of larger systems their corresponding displays will be moved to a new camera tab.

☞ ***DTrack2* is able to operate when cameras have been added or removed; for best performance it is highly recommended to perform a recalibration**

Marker display Each marker is either displayed as a circle or as a cross. This indicates the projected size of the marker on the camera sensor and depends strongly on the distance to the camera. A simple color code represents the quality (i.e. circularity) of the markers.

green markers	...	very good tracking quality
yellow markers	...	good tracking quality
red markers	...	bad circularity, unreasonable size of marker and / or low intensity; may result in poor tracking quality
circles	...	big marker (e.g. close to camera)
cross	...	small marker

Recommendation Increase the flash intensity until all markers are yellow or green. Additionally the intensity of the brightest pixel in the field of view is shown using a simulated LED bar display (refer to figure 8.5 on page 132). Note: Except for ***ARTTRACK1*** cameras where the bar display is integrated into the camera on the front side.
As a rule of thumb: for measurement applications with high accuracy requirements the markers should be displayed in green with intensities of min. 4 bars; for VR applications yellow markers with intensities down to 2 bars are sufficient.

Additional *Monitor 2DOF display* settings In the *Monitor 2DOF display* additional functions are assigned to mouse interactions.

- left mouse button
  Drag & drop to move the camera monitors' position within the *Monitor 2DOF view*.

- middle mouse button
  Click to hide all camera monitors but the one you selected. Click again and all camera monitors will be displayed.

- right mouse button
  Click on a camera monitor to open a menu for the respective camera settings; see table 8.4 on page 138 and figure 8.7 on page 137 for more details.

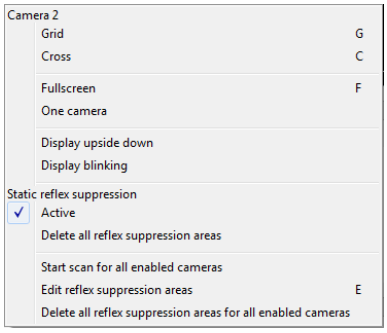


Figure 8.7: Monitor 2DOF view menu (e.g. camera 2)

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		Switch display orientation by 180°. '*UD*' is displayed in the camera display.
Display blinking		***ARTTRACK5*** only : Activates / deactivates blinking of 2-digit LED matrix and status LEDs on the camera for easy identification.
Static Reflex Suppression Active		Enable static reflex suppression functionality for this camera. '*SR*' is displayed in the camera display.
Delete all reflex supression areas		Deletes the defined reflection areas for the selected camera only.
Start scan for all enabled cameras		Initiates a scan for static reflections. Enabled only if *Active* is ticked.
Edit reflex suppression areas	E	Enter the reflex suppression area edit mode in order to manually suppress unwanted reflections.
Delete all reflex supression areas for all enabled cameras		Deletes the defined reflection areas for all enabled cameras at once.

Table 8.4: Features of the *Monitor 2DOF view*

8.3.3.2 Data Display

On the left hand side, the *Data Display* shows the respective 6DOF measurement results (i.e. the position and orientation relative to the room coordinate system) of all calibrated bodies. The rotation angles are rotations around the X, Y and Z axis. The mathematical definition can be found in chapter B on page 250. The bodies are sorted by increasing *body ID*. A simple colour code indicates the tracking status of the body:

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

Filtering of 6DOF measurement results Next to the *body ID* the filtering status (i.e. active or empty) is shown. The *Filter Settings* menu opens by right-clicking on the column *filter* for the corresponding target. For more information about filtering options please refer to chapter 8.5.6.1 on page 158.

Additional information for inertial sensors In the *Data display* additional information is provided for inertial sensors:

- sensor ID
- battery level
- temperature in °C

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.

3DOF measurement results On the right hand side, the *Data display* shows the 3DOF measurement results. All recognized markers that have not been assigned to a calibrated 6DOF body (i.e. uncalibrated targets) and single markers are shown here.
Note: The *calculation of 3DOF markers* has to be activated in *Settings* → *Tracking* by ticking the checkbox. By default, the calculation is deactivated.

8.3.3.3 Fingertracking

The *Fingertracking* display shows the measurement results of the hands - i.e. of each finger (thumb, index, middle, ...) - that are available in the measurement volume. A simple colour code indicates the status of the *Fingertracking*:

green	...	Fingertracking device is being tracked; tracking data is displayed
yellow	...	Hand-target is being tracked (i.e. fingers are calibrated, but outside cameras FoV); last known tracking data is displayed
red	...	Fingertracking device is not being tracked (e.g. only back of the hand is calibrated); last known tracking data is displayed
white	...	Fingertracking device is not calibrated; columns are left blank

The coordinate system of the measurement data may be switched by using the radio buttons *hand* and *room*. You can distinguish between the hands either by the hand ID or by the name of the hand geometry.

8.3.3.4 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 indicates the status of the *Flystick*:

green	...	Flystick is being tracked; tracking data is displayed
red	...	Flystick is not being tracked (e.g. Flystick has not been assigned to ART radio transceiver); instead of tracking data dashes are displayed
blue	...	button is being pressed
white	...	Flystick is not calibrated; columns are left blank

8.3.3.5 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 the status of the Measurement Tool and the reference body, respectively:

green	...	tool is being tracked; tracking data is displayed
red	...	tool is not being tracked (e.g. tip calibration is missing); instead of tracking data dashes are displayed
blue	...	measurement is being performed
white	...	tool is not calibrated; columns are left blank

A Measurement Tool with an assigned reference body can only be tracked when the reference body is tracked as well.

8.3.3.6 Event display

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.

8.4 Menu DTrack2

DTrack2	*Shortcut*
Licenses	
Configurations	
Start/Stop	M
Search hardware	F2
Controller standby	
Controller reboot	
Quit	Q

Table 8.5: Menu *DTrack2*

8.4.1 License management

The capability of the tracking system is defined by licenses which can be managed here. Up to ***DTrack2*** v2.10 different license models were available for ***ARTTRACK*** and ***TRACKPACK*** systems:

- ***ARTTRACK*** systems → extended and full-featured licenses
- ***TRACKPACK*** systems → basic, extended and full-featured licenses

Starting with ***DTrack2*** version v2.10 a new license model has been established:

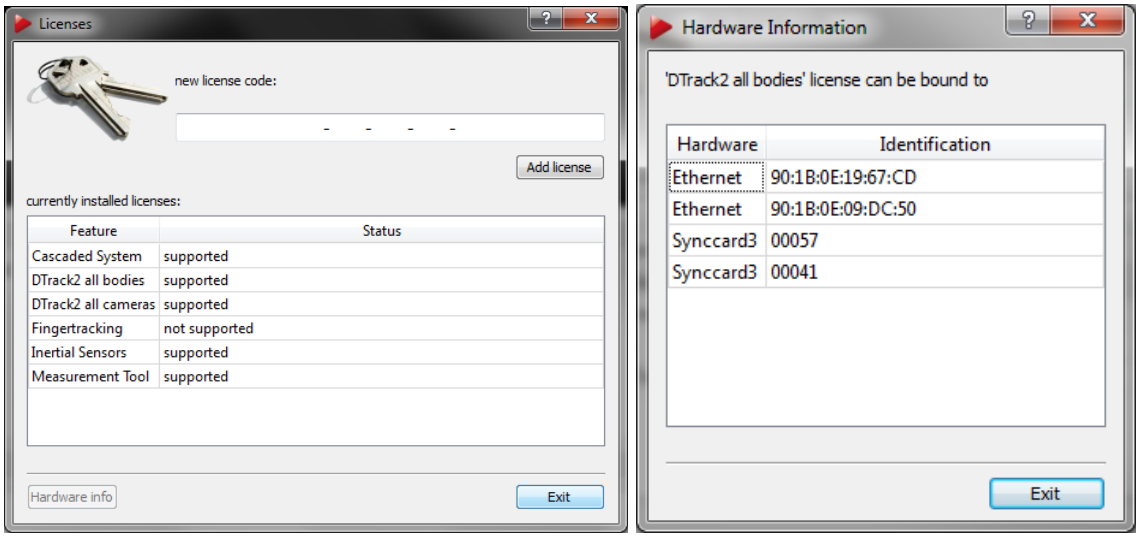
Feature	Values	Possible license status
Cascaded Systems		supported / not supported
Fingertracking		supported / not supported
Inertial Sensors		supported / not supported
Measurement Tool		supported / not supported
DTrack2 max. C cameras [1]	*C* = 2, 4, 8, 16	supported
DTrack2 all cameras		supported
DTrack2 max. B bodies	*B* = 4, 10, 30	supported
DTrack2 all bodies		supported

Table 8.6: Licenses overview

The maximum number of bodies that may be used in the *ARTTRACK* or *TRACKPACK* system includes all calibrated interaction devices (Fingertracking, Flystick, Measurement Tool)!

You can upgrade to any functionality by simply entering a license code. Ask your ***ART*** representative for pricing (see figure 8.8 on page 142).

Example If you want to add the Measurement Tool , go ahead as follows:



(a) Licenses overview (b) Hardware information

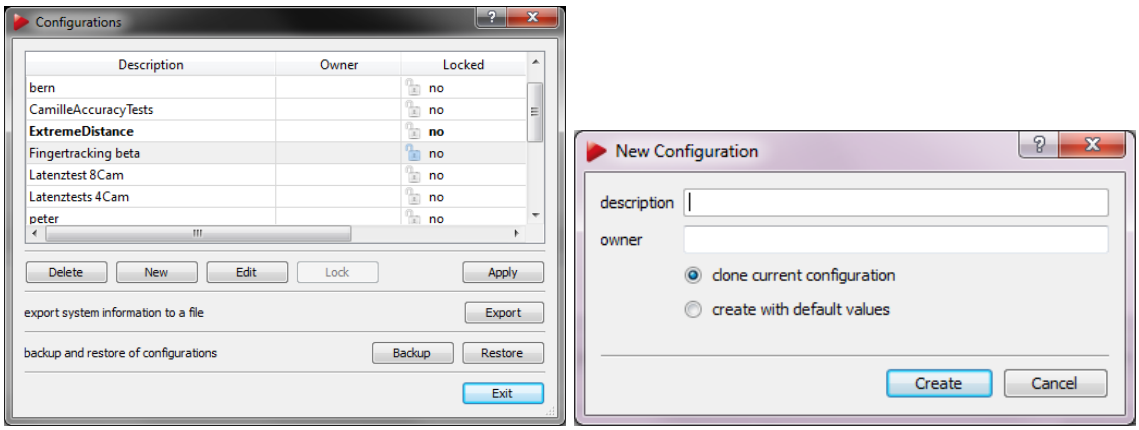
Figure 8.8: Managing the licenses

- Select the feature *Measurement Tool* .
- Click on *Hardware Info*.
- Contact ***ART*** and communicate your version of ***DTrack2*** together with the serial number of the synccard or the MAC address of the Ethernet port (=*Identification*) in order to receive a valid license code.
- Exit the window *Hardware Info* and enter a valid license code in the field *new license code*.
- Click on *Add license*.

The process is the same for other modules.

8.4.2 Configuration management

It is possible to create personalised configurations, e.g. with different targets or flash settings. You can assign a user name and, if necessary, lock the settings by password-protection. Press *New* to create a new personal configuration (see also figure 8.9 a on page 143).
Assign a meaningful description ($\rightarrow$ '*description*') and enter your user name ($\rightarrow$ '*owner*') (see figure 8.9 b on page 143). Unless the configuration is password protected, it may be changed later on with *Edit*.
Your personal configuration is created using the settings / values of the currently active configuration ($\rightarrow$ '*clone current configuration*') or by applying default values ($\rightarrow$ '*create with default values*'), respectively:



(a) Select a configuration (b) Create a new configuration

Figure 8.9: Managing the configurations

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

Just press *Create* and the configuration is saved on the controller.
It is possible to protect the settings of any configuration with a password by pressing the button *Lock*. You will be asked to enter a new password to lock your configuration.

Locking the configuration does not provide access-control! Only changes in settings / calibrations are disabled.

In case you forget the password please call *ART* for assistance

Any existing configuration may be activated by selecting the corresponding entry and clicking *Apply*. Quit this dialogue by pressing *Exit* - the configuration is loaded.
Only existing configurations without password-protection can be deleted. Select the entry to be deleted and click *Delete*.

8.4.2.1 Backup of Configurations

It is possible to export and re-import single configurations or to backup all settings at once. '*Load*' imports previously saved configurations. The imported configuration will be activated automatically. It is possible to import multiple configurations at the same time.
'*Save*' will open a window for selecting the configuration(s) to export. Either (de-)select individual configurations by left-clicking or *select all*. Tick the checkbox *all settings and coniguration (backup)* to save a complete backup of your system's settings. Press '*Save*' to select a destination directory on a remote PC. Please also refer to chapter 9.1 on page 192 for further information.

☞ **When exporting single or multiple configurations please assign meaningful filenames (e.g. exporting date 'Standard 07122012'). Configurations using the standard filename (e.g. "Standard") will be overwritten !**

8.4.2.2 Export System Information

The export function is intended for saving an information file (i.e. number and types of camera, validity of room calibration, number and types of targets, current settings, event display logs, etc.) in case you need to contact tech support at ***ART*** . *Export* opens a new window (see figure 8.10 on page 144 where a list of all event logs from the past 30 days is shown. Select the appropriate *File* by left-clicking or by moving the slider below the table to the left or right respectively. You can also enter the number of *last days* manually. Pressing *Export* saves the selected event logs together with a system information file in (ASCII-)TXT format on any remote PC in your local network.

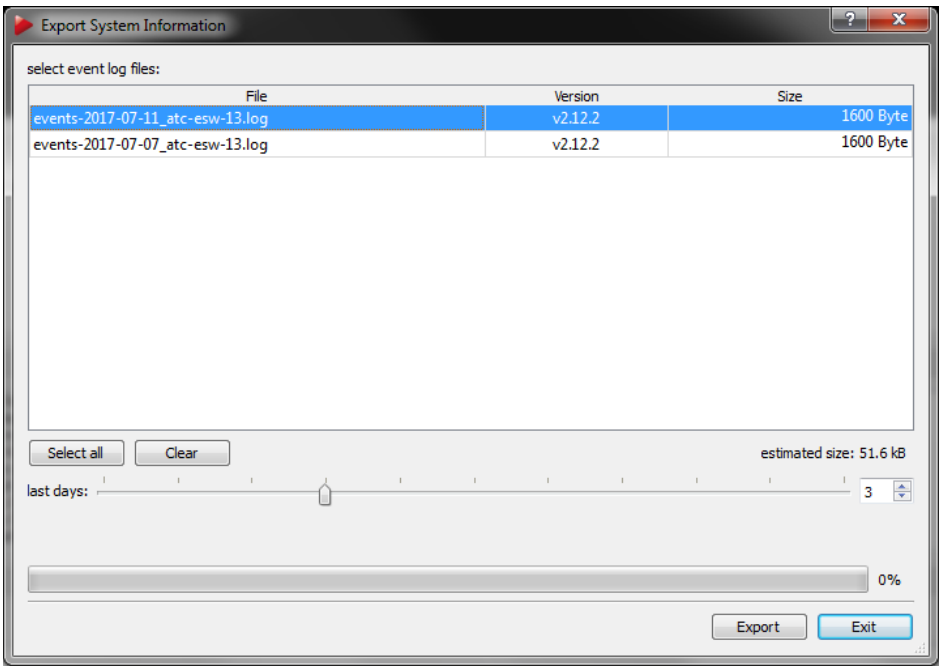


Figure 8.10: Export System Information

8.4.3 Start/Stop

Start/Stop measurement by pressing the button *Start / Stop* or by using the keyboard shortcut 'M'.

8.4.4 Search for new hardware

Without the need of restarting the controller you can dynamically analyse your system for changes in configuration (e.g. added or removed cameras, ***ART*** radio transceiver). Therefore proceed as follows:

- connect a new camera to the controller
- wait until the camera has finished booting
- within ***DTrack2*** press '*F2*' to perform a search for new hardware
- check if the camera has been recognized successfully (e.g. by opening camera settings '*F7*')
- start the measurement, the message '(re-)calibration required!' should appear in red color inside the *Monitor 2DOF display* of the corresponding camera (see chapter 8.3.3.1 on page 135 for details)
- perform a room re-calibration 8.6.3.3 on page 170, added cameras are automatically marked as '*moved*' in the room re-calibration dialogue.

***DTrack2* is able to operate when cameras have been added or removed; for best performance it is highly recommended to perform a recalibration**

8.4.5 Controller standby

Force the controller to go into standby mode with this command. You can restart the controller manually or by using Wake On LAN. Please refer to chapter 8.2.3 on page 126 for more details.

8.4.6 Controller reboot

Reboot the controller with this command.

8.4.7 Quit

Quit ***DTrack2*** frontend software. In case the system is still in measurement mode, a confirmation window will show up. You may leave the active measurement running, the frontend software will quit anyway.

8.5 Menu Settings

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

Table 8.7: Menu *Settings*

8.5.1 Cameras Settings

This dialogue (see figure 8.11 on page 146) shows a list of all cameras currently connected to the system as well as all cameras that have been removed since the last valid room calibration. It allows changes of all camera specific settings (e.g. flash intensity, camera orientation, syncgroup assignment, etc.). Here you can also toggle *modulated flash* in order to synchronize an active target.

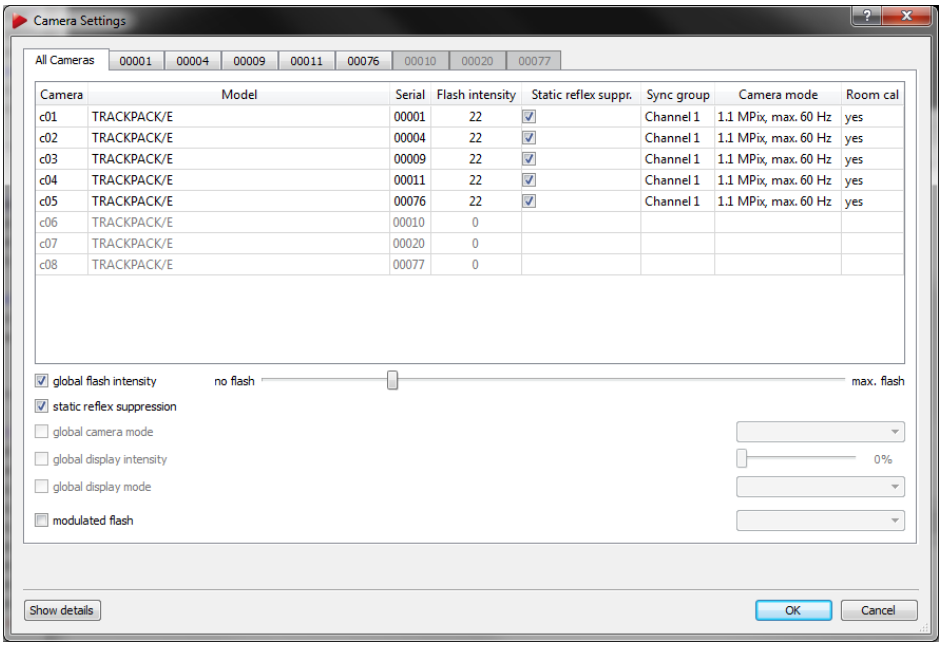


Figure 8.11: Camera Settings - All Cameras Tab

8.5.1.1 All Cameras tab

By default the window opens up showing the tab *All Cameras*. Here you can change camera specific settings (e.g. flash intensity, camera orientation, syncgroup assignment) either for all cameras at once (globally) or for each camera separately by left-clicking and selecting the appropriate entry. When cameras are removed from an already calibrated tracking system (e.g., due to a disconnected cable) without performing a room recalibration the ***ART*** Controller will detect and mark them as missing. The corresponding entries are greyed out to show that the cameras have been disabled. The only data shown is model and serial number.

The following settings can be accessed (from left to right):

Column	Description
Camera	Shows the assigned camera ID (see 2-digit LED matrix display on ***ARTTRACK5***)
Model	Shows the type of camera
Serial	Shows ***ART*** internal serial number of each camera
Flash intensity	Change the currently selected flash intensity (set individually)
Static reflex suppr.	(De-)activates the static reflex suppression for this camera (set individually)
Sync group	Select the syncgroup ('*Channel 1*' - '*Channel 3*' for ***ARTTRACK5*** , ***ARTTRACK5/C*** & ***TRACKPACK/E*** , set individually)
Camera mode	Select the camera mode (available modes depend on model, set individually)
Room cal	Shows the status of room calibration (i.e. '*no*' for newly added but not yet calibrated cameras)

Flash settings The flash intensity may be changed within an interval from

- 0 .. 6 for ***ARTTRACK1*** ,
- 0 .. 8 for ***ARTTRACK2*** / ***ARTTRACK3*** ,
- 0 .. 100 for ***ARTTRACK5*** , ***ARTTRACK5/C*** and ***TRACKPACK/E***
- 0 .. 7 for ***TRACKPACK*** .

These settings strongly depend on the working area and range. If you are working in a small area, where you are close to the cameras, lower flash intensities may be sufficient. Otherwise, if your typical working distance is further away from the cameras (but still within tracking range of the cameras), higher flash intensities may be necessary. Adjust the flash intensity that tracking quality of all cameras is suitable using the *Monitor 2DOF display*. Please refer to chapter 8.3.3.1 on page 135 for instructions.

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.

When using *ARTTRACK2/C* cameras, it is not possible to adjust the flash intensity of the respective external flashes with the *DTrack2* frontend software!
Please contact *ART* in case you need to adjust the flash intensity of the external flashes.

Static reflex suppr. Tick the corresponding checkbox to activate the support of static reflex suppression. Please refer to chapter 8.6.1 on page 165 for further information.

Sync group In case of mutual blinding of cameras (see chapter 4.8.2.1 on page 49) one can assign different syncgroups for opposing or adjacent cameras. You may change the assignment either on the *All Cameras* tab or on the tab of the respective camera. Possible values are '*Channel 1*', '*Channel 2*' or '*Channel 3*'. These channels correspond to the three syncgroup outputs (#1: 0 μs - #3: 960 μs on the ***ART*** Controller) for ***ARTTRACK*** systems (see also chapter 5.1 on page 55). To change the predefined time delays please refer to 8.5.2 on page 151.

Camera mode Depending on the model and on your application one can change the camera mode (i.e. the FoV) in order to achieve:

- higher max. frame-rates
- lower latencies (i.e. time delays for measurement data). Please refer to chapter A.7 on page 246 for more details.

To switch the camera mode, select the appropriate entry to open a drop-down menu (e.g. *1.1 Mpix, max. 60 Hz*). The max. frame-rate is defined by the camera with the largest field of view selected respectively the max. frame-rate of that individual camera. Thus, in mixed systems the max. possible frame-rate is always limited to 60 Hz (for legacy systems with ***ARTTRACK2*** or ***ARTTRACK3*** & ***ARTTRACK5*** or ***TRACKPACK/E***) or 120 Hz (for systems with ***TRACKPACK/E*** & ***ARTTRACK5***) respectively.

Be aware, that higher frame-rates come at the cost of the cameras' reduced field of view.

Room cal This indicator shows whether the corresponding camera was used (i.e. present and running) during the last valid room calibration. Hence, *yes* shows that the camera will be used for measurements and will contribute to the tracking. On the contrary *no* indicates that additional cameras have been added to an existing configuration without performing

a room recalibration. Thus, a recalibration is necessary for the corresponding camera to contribute to the tracking. Please refer to chapter 5.1.3 on page 58 on how to add new cameras dynamically.

***DTrack2* is able to operate when cameras have been added or removed; for best performance it is highly recommended to perform a recalibration**

Global settings Tick the checkboxes to adjust the corresponding setting for all cameras at once.

Global flash intensity Move the adjacent slider to level the flash intensities of all cameras and adjust them globally.

Global camera mode Set the FoV of all cameras globally by using the dropdown-menu (e.g. *1.1 Mpix, max. 60 Hz*) to the right.

Global display intensity (ARTTRACK5 only) Move the slider to adjust the brightness of the status LEDs and the 2-digit LED matrix display. The brightness can be dimmed from 0...100%, if necessary (e.g. in light-sensitive environments).

Global display mode (ARTTRACK5 only) Select *default* to activate the status LEDs and the 2-digit LED matrix display to show the currently assigned camera ID only. Alternatively select *number of markers / camera ID* to display the number of detected markers in the camera's FoV instead (only during measurements). The 2-digit LED matrix display can also be deactivated by selecting *only status LEDs*.

Modulated flash *ART* tracking systems can be used with active markers, i.e. markers consisting of infrared LEDs instead of retro reflective material (see chapter 3.2 on page 21). Tick the checkbox *modulated flash* to activate the adjacent drop-down menu. Select one of the cameras to emit the synchronization signal (i.e. coded IR flash) that triggers active targets.

Due to the modulation the effective flash intensity is reduced when it is used in combination with low flash intensities. The influence is neglectible at higher flash intensity settings. Simply increase the flash intensity, if necessary.

The range of the modulated flash is significantly higher than the tracking distance of the camera.

Only one camera can emit the modulated flash, thus the selected one should have unobstructed view of the whole tracking area. Furthermore it has to be assigned to syncgroup #1 ! *ARTTRACK5* , *ARTTRACK5/C* , *TRACKPACK/E* , & *TRACKPACK* systems may be configured via software, while *ARTTRACK2* & *ARTTRACK3* have to be connected to 'OUT1' on the controller's Synccard.

Show Details Here it is possible to change the settings regarding low-level marker detection (see figure 8.12 on page 150):

Option	Description
global marker mode	configure the marker detection
global maximum number of markers	maximum number of markers that a camera is allowed to see
global maximum size of markers	maximum display size of a marker on the sensor
global minimum size of markers	minimum display size of a marker on the sensor

8.5.1.2 Individual tabs

Each camera can also be accessed by its corresponding tab within this dialogue (see figure 8.12 on page 150).

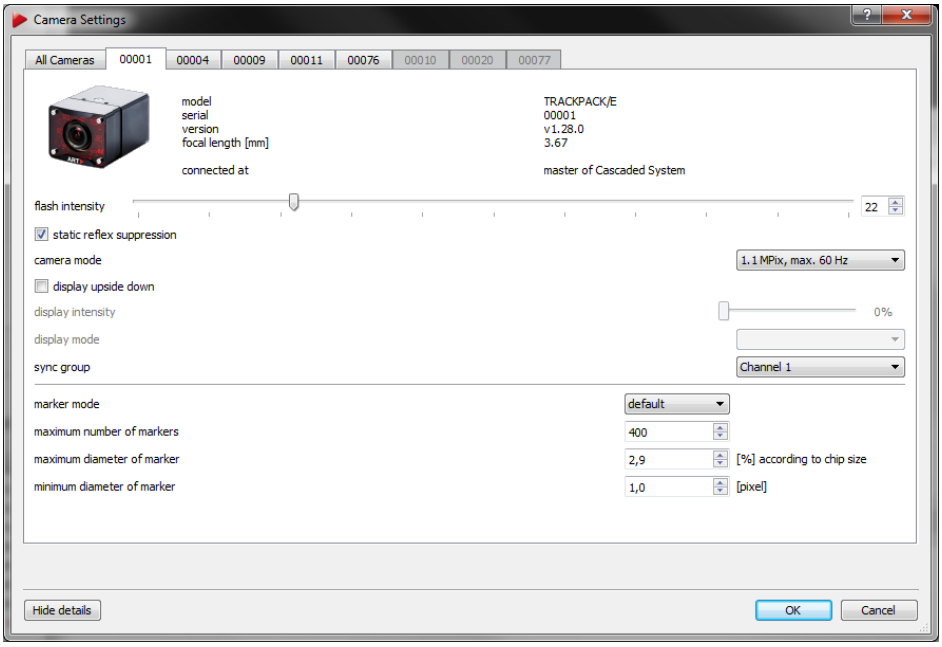


Figure 8.12: Camera Settings - Individual Tab

In the upper left corner of the tab you will find a depiction of the corresponding camera. To the right the following information is listed:

Info	Description
Model	Shows the type of camera
Serial	Shows ***ART*** internal serial number of the camera
Version	Shows ***ART*** internal firmware version of the camera
Focal length	Shows the focal length of the camera lens
Connected at	Shows the controller the camera is connected to (*Cascaded Systems* only)

Below you can change the following options (please refer to the former paragraphs for details):

Option	Description
Flash intensity	Change the currently selected flash intensity
Static reflex suppr.	(De-)activates the static reflex suppression for this camera
Camera mode	Select the camera mode (available modes depend on model)
Diplay upside down	Switch display orientation by 180°. '*UD*' is displayed in the *Monitor 2DOF display*.
*Display intensity (**ART-TRACK5** only)*	Adjust the brightness of the status LEDs and the 2-digit LED matrix display
*Display mode (**ART-TRACK5** only)*	(De-)activates the 2-digit LED matrix display
Sync group	Select the syncgroup ('*Channel 1*' - '*Channel 3*' for ***ART-TRACK5*** , ***ARTTRACK5/C*** & ***TRACKPACK/E*** , set individually)

Display upside down The checkbox *display upside down* switches the orientation of the corresponding display in *Monitor 2DOF display* by 180 °. This setting proves to be useful when mounting the camera upside down. Note: This setting is for display purposes only. It does not influence the tracking system or the room calibration.

8.5.2 Synccard Settings

This dialogue shows the model and the serial number of the synccard. Furthermore, it offers a dropdown list to select the mode of synchronization.

8.5.2.1 Synccard Modes

The available modes for synchronization are shown in table 8.8 on page 152.

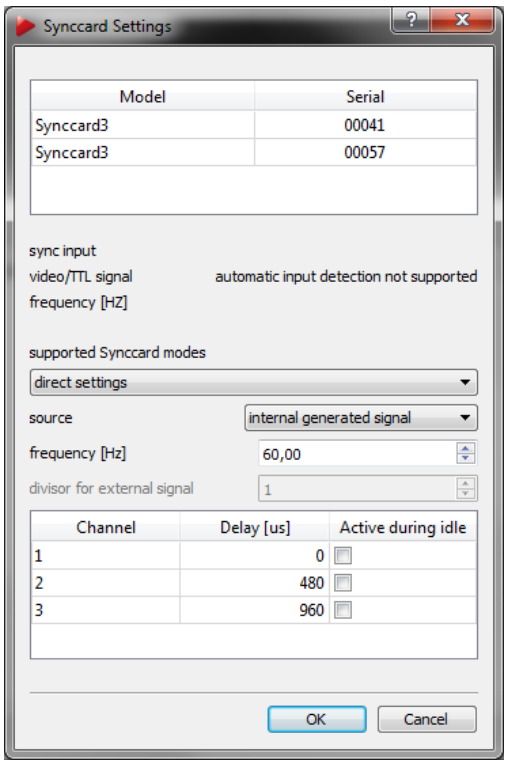


Figure 8.13: Synccard Settings

Supported synccard mode	**field of application**
internal generated signal (values dependent on camera model)	run the controller without external synchronization
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]	active-stereo projection with a TTL sync signal, triggers on rising edge
external TTL signal both edges [3] *external TTL signal both edges, for validated shutter glasses* [1] [3]	see above, triggers on rising AND falling edge
direct settings	advanced custom settings

[1] predefined settings that should be used with the shutter glasses described in table 8.9 on page 153
[2] use this mode if the frequency of the external synchronization signal is 2x higher than the max. frame-rate of the camera
[3] available only for Synccard3

Table 8.8: Overview of the supported synccard modes

8.5.2.2 Direct Settings

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

Brand	Type
RealD	CrystalEyes 1, 2, 3, 5
NuVision	APG6000, 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

Table 8.9: Overview of validated shutter glasses

Option	Description
source	configure the type of synchronization to be used
frequency [Hz]	enter the tracking frequency manually (max. frequency dependent on camera model and selected camera mode)
divisor for external signal	reduce the tracking frequency by a factor 1 - 10 (only for external synchronization)
Delay [us]	configure the delay between the syncgroups

Source The available options '*internal*', '*video*', '*ttl*' and '*ttlboth*' are equivalent to the aforementioned supported synccard modes (see table 8.8 on page 152). Additionally the option '*ttlinv*' is available, which inverts the external synchronization signal (i.e. switches TTL high / low states to trigger on falling edge instead of rising).

Frequency [Hz] The tracking frequency can be set between 10 Hz and the max. frame-rate of the cameras in steps of 1 Hz. The max. frame-rate depends on the camera model and the selected camera mode. Please refer to chapter 8.5.1 on page 146 for more information.

Divisor for external signal If the frequency of the external synchronisation source is higher than the max. frame rate of the cameras, a divisor can be set to reduce the frequency accordingly. The max. frame-rate depends on the camera model and the selected camera mode. Please refer to chapter 8.5.1 on page 146 for more information.

Delay [us] When assigning cameras to different syncgroups (e.g. due to mutual blinding 4.8.2.1 on page 49), the time delay for each syncgroup channel is preset for compatibility with active markers by ***ART*** .
These channels correspond to the three syncgroup outputs (#1: 0 μs, #2 480 μs , #3: 960 μs on the ***ART*** Controller). If necessary these values can be changed individually.
Note: The max. delay is limited dependent on the camera model. Additionally a difference of min. 300 μs between consecutive channels has to be maintained.
Example: *Channel 1*: 1200 μs, *Channel 2*: 1500 μs, *Channel 3*: 1800 μs

8.5.3 Inertial Sensor Settings

This dialogue is the center for configuration and calibration of inertial sensors (license for *DTrack2* necessary !). Please refer to chapter 7 on page 106 for more information how to install inertial sensors. When using inertial sensors you can additionally select the pulse generating source for the tracking frequency here. Please refer to chapter 7.2.5 on page 119 for more information.

8.5.4 ART Radio Info

Here you can configure the settings of the *ART* radio transceiver. Additionally you will get information about all attached interaction devices (e.g. Flystick).

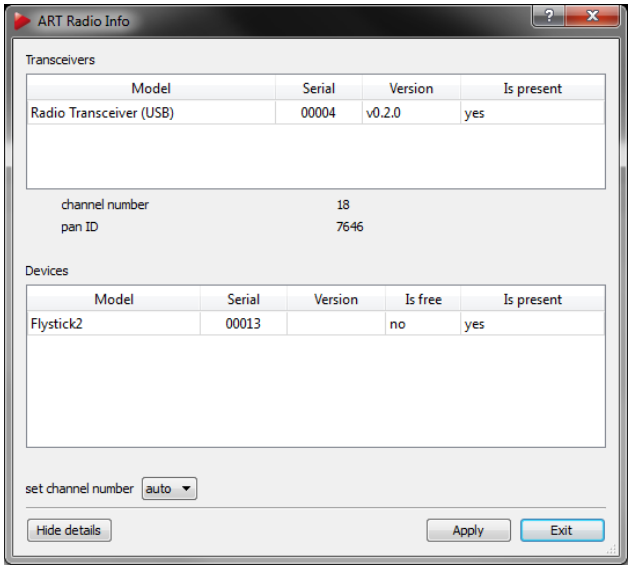


Figure 8.14: ART Radio Info Settings

The following information is offered:

Info	Description
Model	Shows the model of the transceiver or the device respectively
Serial	Shows the serial number of the transceiver or device respectively
Version	Shows the firmware version of the transceiver
Is present	('*yes*'): The transceiver is connected, the device is in range
Is free (only for Devices)	('*yes*'): The device is available for communication and has not been assigned yet, '*no*'): The device is already assigned to a transceiver

Show details By clicking the button *Show details* the drop-down menu for selecting the radio channel of the radio transceiver is shown.

Set channel number By default the radio transceiver is automatically selecting a radio channel during booting, the drop-down menu is set to (’*auto*’). You may also select a specific channel manually. The selected setting is saved persistently.

8.5.5 Tracking Settings

In this dialogue you can enable / disable the calculation of 3DOF markers as well as the automatic start of measurement after booting. Here you can also define the central axis for all 5DOF targets globally.

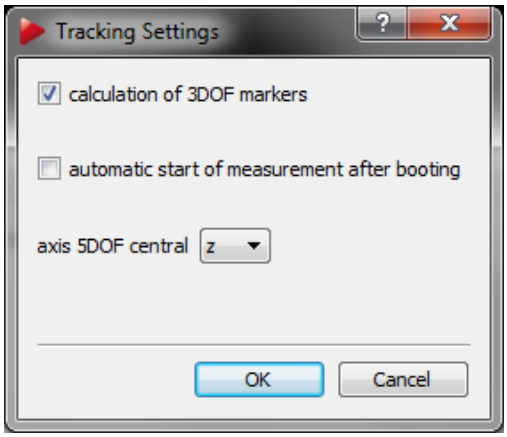


Figure 8.15: Tracking Settings

3DOF single markers The calculation of single markers is disabled by default. By enabling ’*calculation of 3DOF markers*’ the tracking data appears on the right hand side of the data display (refer to chapter 8.3.3 on page 135).

Automatic start of measurement By activating the feature ’*automatic start of measurement after booting*’ the tracking system starts measuring as soon as the controller has booted up. This is useful to run systems without the ***DTrack2*** frontend.

Axis 5DOF central Select the axis using the drop-down menu ’*axis 5DOF central*’. Please refer to chapter 8.6.5.5 on page 179 for details.

8.5.6 Body administration

This dialogue (see figure 8.16 on page 156) allows for managing all targets (e.g. Standard, Flystick, Measurement Tool , etc.) in the system. The number and types of bodies to be tracked may be configured in here. You can also assign names, delete or reset target calibrations, activate filtering of 6DOF tracking data or change the order in which

the targets appear in the data display (refer to chapter 8.3.3 on page 135.

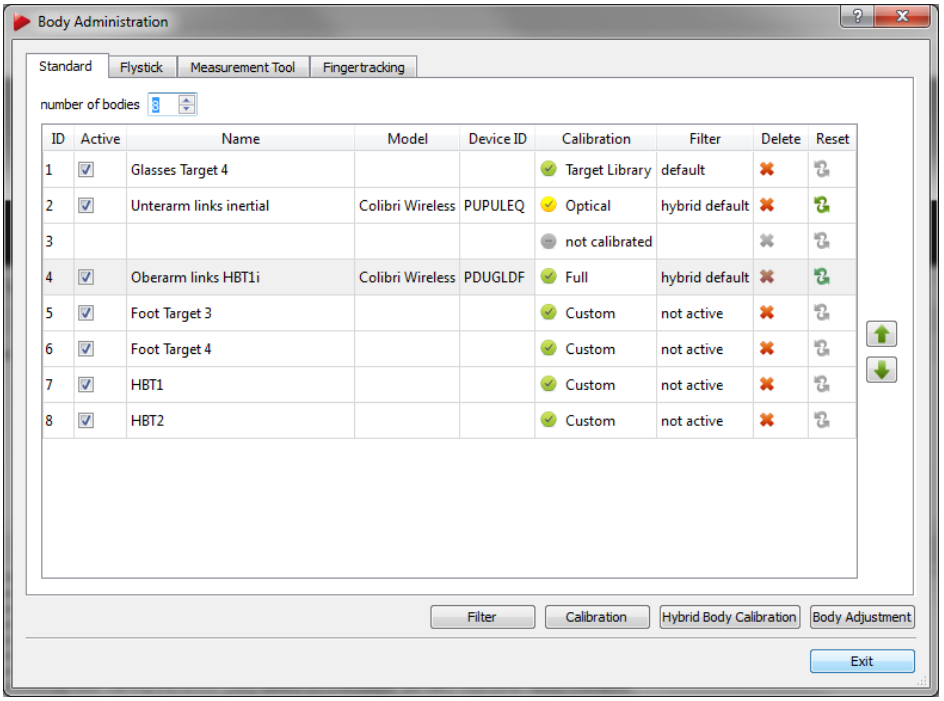


Figure 8.16: Body Administration (from *DTrack2* v2.9.0)

Using the different tabs on the top you can configure standard bodies or interaction devices. Please use the tabs *Flystick*, *Measurement Tool* and *Fingertracking*.
In the bottom right of the dialogue (see figure 8.16 on page 156) you will find four buttons for direct access to other functionalities:

Button	Description
Filter	Deactivate the filtering of tracking data for each target, filtering is activated by default. A detailed description of the filtering options can be found in chapter 8.5.6.1 on page 158.
Calibration	Switch to the Body Calibration dialogue and perform the optical calibration for the selected target. A detailed description for body calibration can be found in chapter 8.6.5.2 on page 177.
Hybrid Body Calibration	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 7.2.3 on page 115.
Body Adjustment	Go to the Body Adjustment dialogue and perform the necessary adjustment for the selected target. A detailed description for body adjustment can be found in chapter 8.6.6 on page 183.

Table 8.10: Body Administration - Detailed description of the Controls

The following table (8.11 on page 157) shows a detailed description of the functions in the dialogue:

Info / Action	Description
number of bodies	Increase / Decrease the number of accessible slots (i.e. body IDs) for calibration of targets.
ID	The targets are sorted in ascending order (i.e. increasing body ID).
Active	Activate or deactivate a target by ticking. Data of deactivated targets will not be transmitted in the data stream. The target sequence will not be affected.
Name	Change the name of a target by clicking. The target sequence will not be affected.
Model	Additional info about the model of an optionally assigned inertial sensor.
Device ID	The device ID of an optionally assigned inertial sensor.
Calibration	Provides information about the target calibration status.
Filter	Deactivate the filtering of tracking data for each target, filtering is activated by default. A detailed description of the filtering options can be found in chapter 8.5.6.1 on page 158.
Delete	Delete the calibration data of a target - effective immediately after confirming the query. The target sequence will not be affected.
Reset	Reset the calibration to predefined '*Target Library*' values, in case the geometry has been re-calibrated by the user manually after inital calibration via the '*Target Library*' function.
Change order	With the arrows on the right-hand side of the window you may rearrange the order of the targets. The data output will change accordingly.

Table 8.11: Body Administration - Detailed description

The maximum number of bodies depends on your license and includes ALL calibrated interaction devices (e.g. 4 body license: 1 standard body + 1 set of Fingertracking (left + right) + 1 Flystick). Hybrid targets are listed as standard bodies, with additional info about the model of the inertial sensor and its device ID.

The column *Calibration* (see figure 8.16 on page 156) provides information about the target calibration status:

- '*not calibrated*' means that a customized target has not been calibrated yet.
- '*Target Library*' means that the predefined calibration file from the system is being used.
- '*Target Library, re-calibrated*' means that the predefined calibration file has been used, but the geometry has been re-calibrated manually.
- '*Custom*' means that a manual body calibration has been performed.
- '*Optical*' means that an inertial sensor has been disassociated from a fully calibrated hybrid body .
- '*Full*' means that a hybrid body calibration has been performed or that predefined calibration data stored inside the hybrid inertial sensors is being used.

8.5.6.1 Filtering options for 6DOF tracking data

DTrack2 incorporates advanced filtering options for enhanced 6DOF tracking performance. One can choose between recommended presets or customize filtering options in order to optimize tracking behaviour individually for each target. For example in applications where reference targets are used to calculate the position of a seating buck it is possible to apply a strong filter for these targets which results in practically noise-free tracking data.
On the contrary tracking (e.g. of HMD units) oftentimes calls for a compensation of system intrinsic latencies. Here ***DTrack2*** is able to deliver tracking data that incorporates probabilistic prediction up to tens of milliseconds ahead in time.

Either by using the menu *Body Administration* or directly through the main GUI docking window *Data Display* one can set the filtering options for each target. Please refer to table 8.10 on page 156 and 8.3.3.2 on page 138 to open the menu *Filter Settings*.

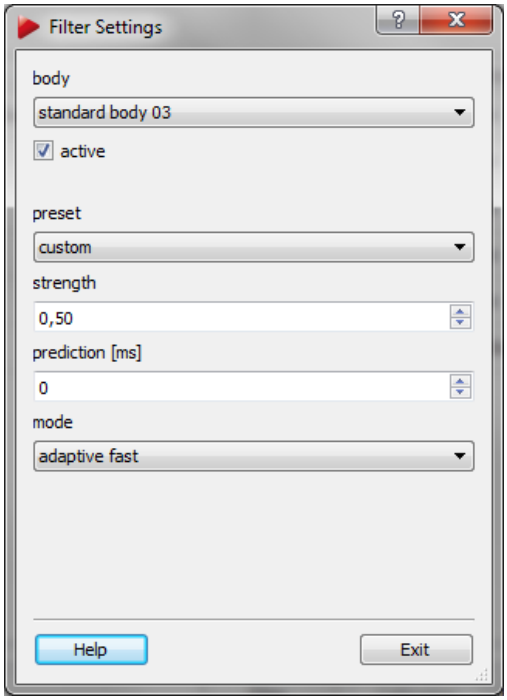


Figure 8.17: Filter Settings

Filter Settings Filtering of 6DOF tracking data is activated by default. Untick the checkbox '*active*' to deactivate filtering for the respective target or choose from several recommended presets shown in the following table:

Presets optical tracking	Description
custom	Customizable preset. A detailed description of the parameters can be found in table 8.13 on page 160.
default	Standard filtering without prediction or smoothing.
Flystick	Recommended setting for use with a Flystick (responsive filtering, designed for fast to slow motions).
HMD-1	Recommended setting for tracking of a HMD without hybrid tracking (down-tuned filtering with prediction, designed for fast motions).
medium prediction	Filter with prediction of tracking data (less responsive filtering, designed for slow to medium motion).
reference target	Filter with smoothing for tracking of stable reference positions (strong non-responsive filter, designed for occasionally moving objects).
smoothing (delayed)	Filter with strong smoothing and high averaging (responsive filtering with high latencies, designed for recording of tracking data).
Presets hybrid tracking	**Description**
hybrid custom	Customizable preset. A detailed description can be found in table 8.13 on page 160.
hybrid default	Standard filtering for hybrid targets without prediction or smoothing (designed for e.g. Hybrid Motion Capture).
hybrid HMD medium prediction	Filter for hybrid targets with prediction of tracking data. (designed for e.g. HMDs)

Table 8.12: Filtering of 6DOF tracking data - Detailed description of the presets

It is also possible to customize the tracking behaviour to the requirements of the application using the following tunable settings:

Settings	Description	Usage
Strength	Sets the strength of the filter. Low values lead to faster reaction but higher jitter. High values result in smoother output but slower reaction. Note: Not available for hybrid tracking.	A higher strength may be ideal for tracking seating bucks
Prediction	Predicts output for the specified time into the future (ms) in order to compensate tracking and rendering latency. Note: 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 and offline analysis.
Mode optical tracking	Specifies the elementary behavior of the filter. Several options are available:	for optical tracking only
'*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.
Mode hybrid tracking		–	for hybrid tracking only
	'*Hybrid target*'	Optimized for non-HMD hybrid targets incorporating an inertial sensor unit.	Hybrid Motion Capture
	'*Hybrid HMD*'	Optimized for HMD hybrid targets incorporating an inertial sensor unit	HMDs and similar projective units (e.g. AR glasses).

Table 8.13: Customizable preset 6DOF filtering - Detailed description of the parameters

8.5.7 Output Settings

In this dialogue one can determine the settings for data output via ethernet (see figure 8.18 on page 161). Tick the checkbox *active* on the corresponding tab to enable data output for each channel.
Please refer to chapter B on page 250 for the format of the data output.
In total up to 5 UDP data output channels can be configured. You can send data to any computer within your local network. Just enter the IP address of the receiving client in the box *send to* and choose a UDP port number in *UDP Port*.
Tick the checkbox *this computer* instead to send the data to the remote PC from where you started the ***DTrack2*** frontend. You can also send the data to a group of addresses in the range of 224.0.1.0 to 239.255.255.255 by ticking the checkbox *multicast*.

In order to reduce the amount of data from the data stream you can define a '*send data divisor*' from 1 to 10. The divisor works the following way:

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

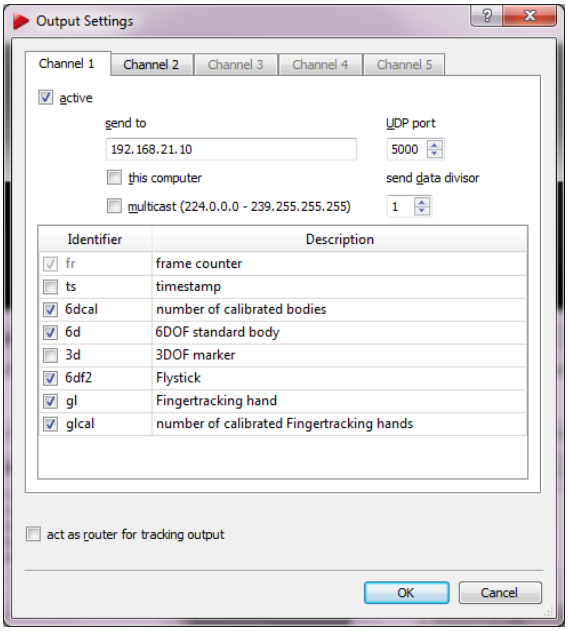


Figure 8.18: Output settings

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)
gl	Fingertracking hand
glcal	number of calibrated Fingertracking hands
6di	6D inertial body
6df	Flystick (old) only available if activated in Flystick settings (→ checkbox '*use old output format*')

Table 8.14: Output identifiers

Double-check the currently used pulse generating source in the *Tracking* menu. Please refer to chapter 8.5.5 on page 155 for further information.

When using the '*timestamp*' please note the remarks on accuracy in chapter B.2.2 on page 259.

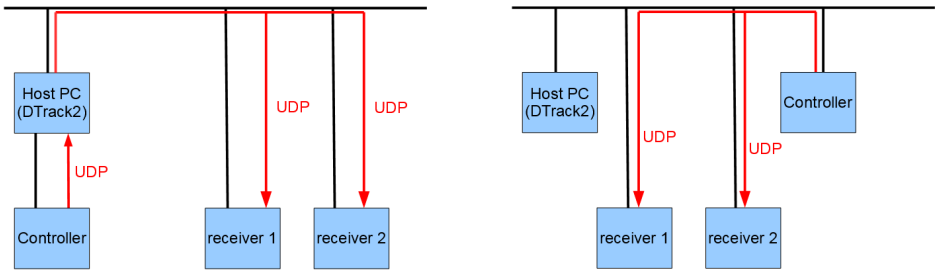
Act as router for tracking output The UDP output data may also be routed by *DTrack2* by ticking the checkbox *act as router for tracking output*. This functionality is especially important when it is not allowed to connect the controller to your local network due to IP security reasons.
The mandatory requirement for this function is that the PC running the *DTrack2* frontend is equipped with two ethernet LAN ports. One is needed for connecting the controller and one to your local network (see figure 8.19 on page 162). The data from the controller is then routed to the local network through the *DTrack2* frontend.

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

Do not use this function if the application PC and the controller are in the same network!

8.5.8 Fingertracking

This dialogue is the center for installation and calibration of Fingertracking hardware with optional tactile feedback. Please refer to chapter 6.4.6 on page 92 to learn how to install



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

Figure 8.19: Depiction 'act as router' functionality

Fingertracking.

8.5.9 Flystick Settings

Inside this dialogue you can manage the *number of Flysticks* (max. 20) as well as the corresponding settings to be used.
For installation of Flystick2 please refer to chapter 6.1 on page 71. For Flystick3 see chapter 6.2 on page 75.

8.5.10 Measurement Tool Settings

Within this dialogue you can define the *number of Measurement Tools* and the *number of references* (max. 4 each).
Please refer to chapter 6.5 on page 101 to learn how to install the Measurement Tool .

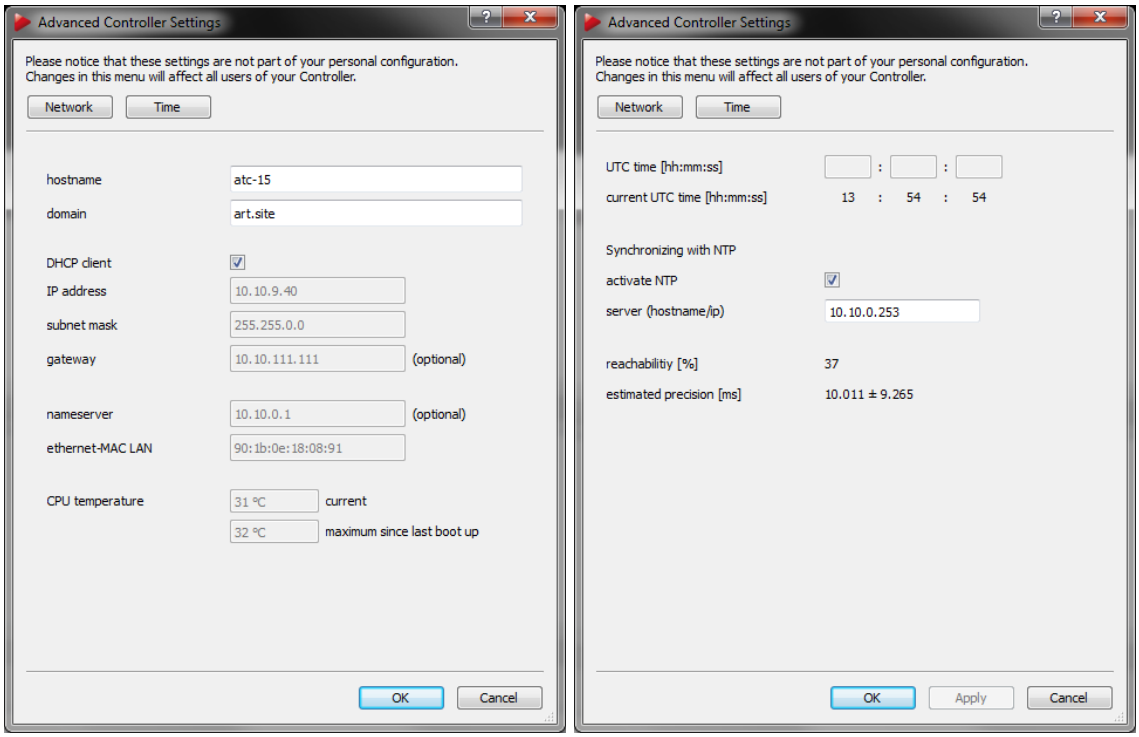
8.5.11 Advanced Controller Settings

The menu *Advanced Controller Settings* is divided into two tabs - *Network* and *Time*.

8.5.11.1 Network Configuration

On the *Network* tab you may change the network specific settings and watch the CPU temperatures inside the controller.

Network According to your network guidelines it may be necessary to specify e.g. *host-name* (not recommended!) and the *domain*.
When the checkbox *DHCP* client is ticked the controller may be connected to a LAN with DHCP support. The controller then works as a DHCP client. The *IP address*, *subnet mask*, *gateway* and *nameserver* assigned to the controller by the DHCP server is shown for your information.



(a) Network Configuration (b) NTP Configuration

Figure 8.20: Advanced Controller Settings

If the network cable is unplugged or the DHCP support is unavailable while booting the controller uses its default IP address (i.e. 192.168.0.1).

By unticking the checkbox *DHCP* you may also specify a static *IP address*, *subnet mask*, *gateway* and *nameserver*. The MAC address of the controller is printed in the line *ethernet-MAC LAN* for your information. Please refer to chapter 8.2.2 on page 125 for details how to set a static IP address.

CPU temperature On the bottom of this dialogue you can read the CPU temperature inside the controller. The upper value shows the *current* temperature in °C, while the lower value indicates the temperature *maximum since last boot up*, i.e. the highest temperature reached since the controller was started. When reaching elevated or critical levels, the values are highlighted in orange or red color.

8.5.11.2 NTP Configuration

On the *Time* tab you can set the ***ART*** controller's internal clock as well as synchronize it with a master clock (i.e. a reference time source) using NTP (=Network Time Protocol). NTP is a protocol designed to synchronize the clocks of computers over a network or even the internet (not recommended).
The *UTC time* (UTC = Coordinated Universal Time) can be set either manually using the

entry fields [hh:mm:ss] or automatically by the master clock which itself has to be synchronized to UTC time beforehand. To activate the synchronization, tick the checkbox *activate NTP* and enter hostname or IP address of your server. When NTP is activated the ***ART*** controller is trying to connect to the NTP server repeatedly in order to update its clock. As a measure of quality for the connection to the NTP server check its '*reachability*'. The values can range from 0% to 100 %, with higher values showing good connection. Furthermore the quality of the synchronization of the master clock and the ***ART*** controller's internal clock is indicated by the '*estimitated precision*' in the unit milliseconds (=ms).

Complete synchronization with NTP servers usually takes some time. In case of large differences between master clock and local time client the clock may be updated immediately but complete synchronization will still take some additional time.

Synchronization with NTP servers does not affect active measurements.

In general it is recommended to synchronize with a local master clock rather than directly to a remote time server on the internet. This reduces network latency and jitter, conserves bandwidth and limits the load on public time servers.

8.5.12 Cascaded System Settings

Here all settings regarding cascaded systems are configured. Please refer to chapter 5.4 on page 66 for more information.

8.6 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
Fingertracking	
Measurement Tool	

Table 8.15: Menu *Calibration*

8.6.1 Static reflex suppression

This starts the function of automatic reflex suppression. The feature can be enabled or disabled either globally for all cameras or individually for each camera in the camera settings (please refer to chapter 8.5.1 on page 146).

Be aware that reflex suppression leads to decreased FoV / effective measurement volume by blocking the area in which the reflection originated.

There are two possibilities to carry out a reflex suppression:

1. automatic static reflex scan
   A scan function will detect and suppress reflections automatically. Open *Settings* → *Camera Settings* and mark the checkboxes for each camera you would like to activate the reflex suppression feature. Please refer to chapter 8.5.1 on page 146 for details. Afterwards, select *Calibration* → *Start Static Reflex Scan for all enabled cameras* to start the scan.

2. manual static reflex suppression
   Define areas to be suppressed manually (may be combined on top of an automatic scan). In the *Monitor 2DOF display*, right-click on the respective camera window and enable the Static reflex suppression by selecting the option '*Active*'. Next start the edit mode by selecting '*Edit reflex suppression areas*'. Alternatively you may use the shortcut ('*E*') shown in figure 8.21 on page 166).

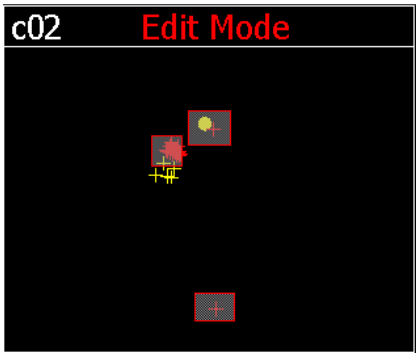
   

   Be sure to remove all targets from the measurement volume before starting the scan.

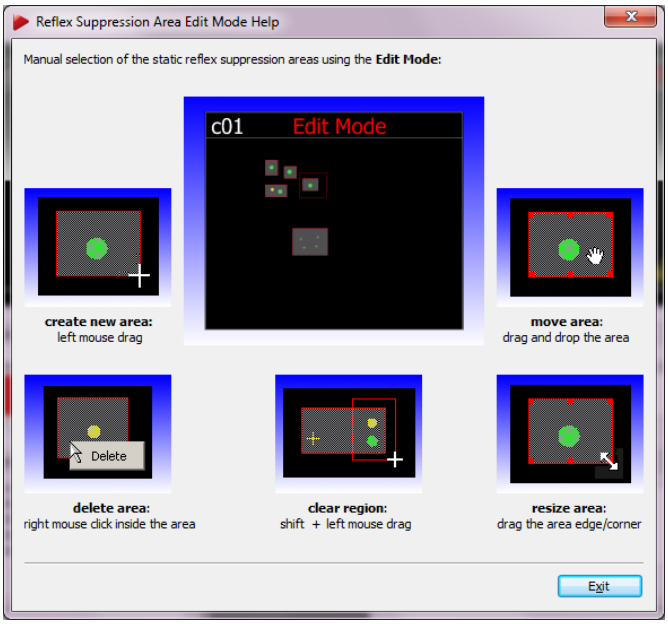
   Within the edit mode (see figure 8.21(b) on page 166) you may:

   - create new areas,
   - delete areas,

- clear regions,
- resize areas and
- move areas.



(a) Reflex suppression edit mode



(b) Reflex suppression edit mode help

Figure 8.21: Reflex suppression

Reflex suppression areas are enabled as soon as you leave the edit mode (right click on the respective camera window, then de-select '*Edit reflex suppression areas*') and accept the changes. The single areas defined are stored in the controller 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*'. To permanently delete the reflex suppression areas for one camera, right-click on the respective camera and select '*Delete all reflex suppression areas*' and accept the changes. You can also delete the reflex suppression areas for all cameras at once by selecting '*Delete all reflex suppression areas for all enabled cameras*'.

8.6.2 Inertial Sensor Calibration

This function carries out a drift correction for attached inertial sensors. Please refer to chapter 7.2.4 on page 117 for more information.

8.6.3 Room calibration

Use the room calibration dialogue (see figure 8.22 on page 167) to set parameters of your room calibration hardware and start the calibration process. After opening the dialogue,

the *Monitor 2DOF display* is automatically started in the background. Doublecheck to verify that all markers of the angle are seen by the cameras.

It is recommended to perform a room (re-) calibration on a regular basis (e.g. after a certain operating time of the tracking system) and especially if the camera setup was subject to extreme vibrations or changing environmental conditions e.g. due to high or low temperatures).

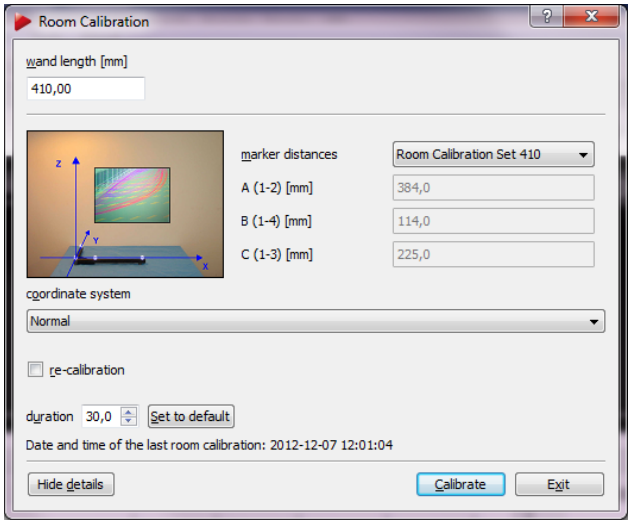


Figure 8.22: Room calibration settings (e.g. RCS 410)

The *Show details* option offers information about the date of the latest room calibration.

Room Calibration Sets Next select from a series of predefined calibrations sets (i.e. a pair of angle and wand representing the common ***ART*** Room Calibration Sets, see table 8.16 on page 167) using the dropdown-menu *marker distances* or use the *expert* mode.

Calibration Set	**wand length [mm]**	**marker dia. [mm]**	**height [mm] (see Fig. 8.23)**	*TRACK PACK*	*ART TRACK 2 & 3*	*ART TRACK5*	*TRACK PACK/E*
RCS TP	410.0	20	58	×			
RCS 410	410.0	20	43		×	×	×
RCS 710	710.0	20	43		×	×	×
RCS 720	720.0	30	48		×	×	×

Table 8.16: Overview of the ***ART*** Room Calibration Sets (RCS)

In any case please verify the wand length or enter it manually in the corresponding field *wand length*. The wand length is printed on a label on the wand. Start the calibration by pressing *Calibrate*. The room calibration is started with five seconds delay.

Expert settings Marker distances of the calibration angle can also be set manually using the setting *marker distances* → *expert*. The numbering of the markers is as seen in figure 8.23 on page 168.

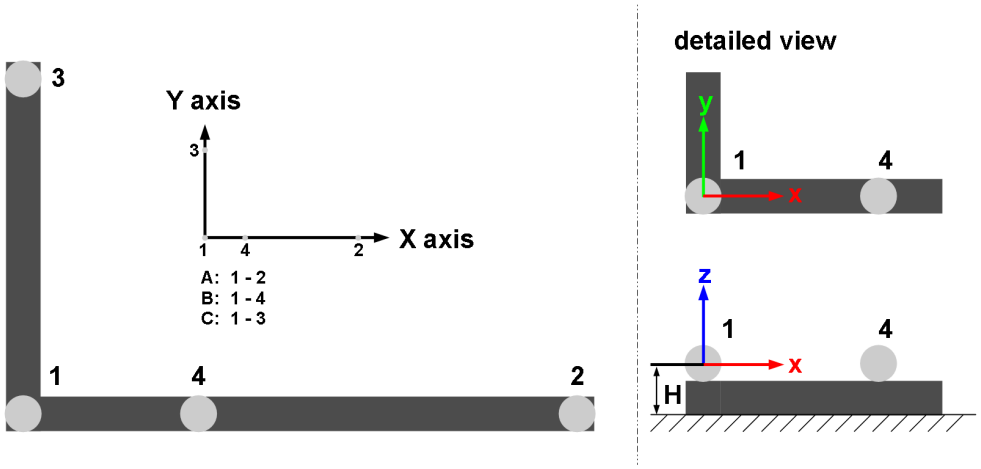


Figure 8.23: Marker distances (including numbering) on the angle and definition of room coordinate system

The longer arm of the angle defines the X axis (refer to figure 8.23); the shorter one the Y axis. The center of marker #1 defines the origin of the room coordinate system (at a height of 43mm).

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.

Coordinate System With the drop-down menu inside the dialogue you may define how the coordinate system of the room is created relative to the calibration angle (refer to table 8.17 on page 169).
Define the *coordinate system* as '*normal*' or '*powerwall*'.

Duration You may also adjust the '*duration*' of the room calibration (→ *Show details*) in a range of 10s - 120s. 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.

8.6.3.1 Room Calibration Progress

When the room calibration starts a window showing the progress of the room calibration appears (see figure 8.24(a) on page 169). The progress is shown for each camera which

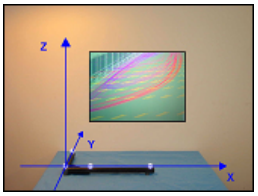
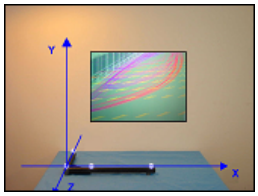
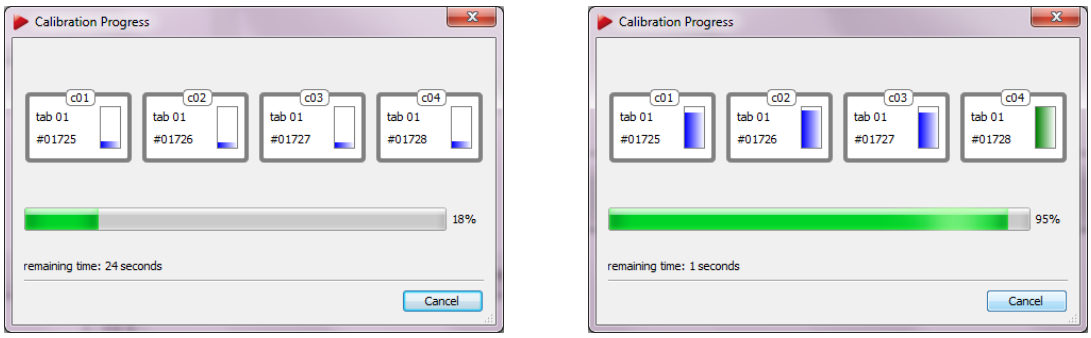
Normal	Powerwall
	
In the *Normal* setting the angle defines the X/Y plane (X at the long, Y at the short beam) and Z upward.	With the *Powerwall* setting the X/Y plane is in the screen and the Z axis pointing out of the screen. This is the standard screen coordinate system of many VR systems (e.g. OpenGL,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

Table 8.17: Defining the coordinate system for the room calibration

is especially helpful for big systems.



(a) (b)

Figure 8.24: Room calibration progress

As soon as the display for a camera changes its colour to green (see 8.24(b) on 169) enough data for calculation of the camera position has been collected for this camera. ***ARTTRACK5*** only: This progress is also displayed individually on each the 2-digit LED matrix display of each camera. After collection of sufficient data the LED matrix changes back to its defined setting. Please refer to chapter 8.5.1 on page 146 for detailed information.

☞ **The point cloud should fill at least two thirds of the measurement volume. Moving the wand in restricted volume will results in reduced accuracy of calibration or failure.**

8.6.3.2 Room Calibration Results

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. The value '*Used Frames*' represents the percentage of valid (i.e., used for room calibration) data for each camera.

Try to achieve a low '*mean wand residual*' up to 1 mm for VR installations while having high values for '*Used Frames*'. The number of '*Used Frames*' should be greater than 70% for each camera. Values under 50% indicate poor room calibration quality. The parameters '*Residual*' for each camera and the '*wand range*' depend on the system geometry and give additional information about the quality of calibration. Please call ***ART*** for further information.

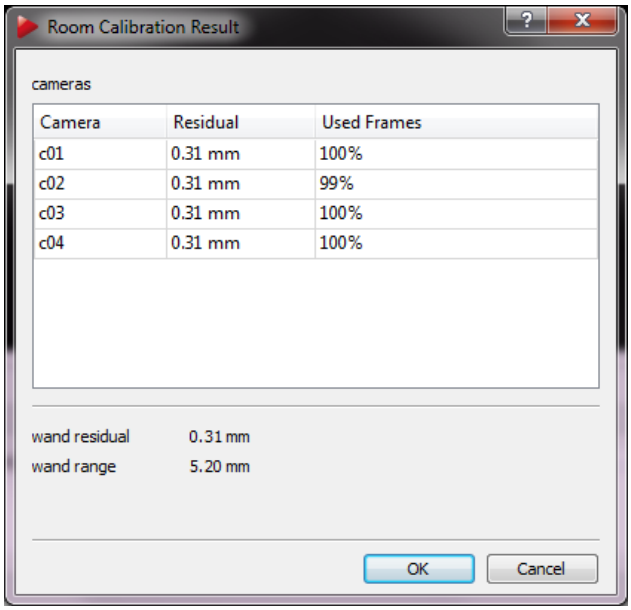


Figure 8.25: Room calibration result

The room calibration is confirmed (i.e., the data are stored) by pressing the button *OK*.

☞ **Please note that percentages of more than 70% may not be reached in large and complicated measurement volumes.**

8.6.3.3 Room re-calibration

All camera setups may change after a certain operation time; if e.g. movement of single cameras due to mechanical instabilities cannot be ruled out or thermal drifts occur it is necessary to perform room calibrations periodically. ***DTrack2*** provides a simplified room calibration to revise an existing room calibration without need of an calibration angle, called room *re-calibration*.
This means no calibration angle has to be present in the measurement volume; only the wand has to be moved 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.

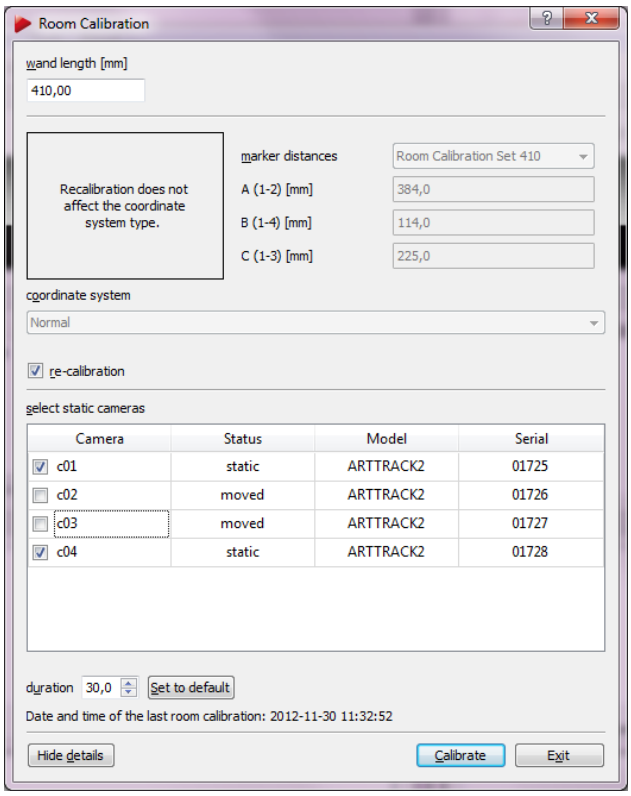


Figure 8.26: Room re-calibration dialogue

To re-calibrate your room tick the checkbox *re-calibration* in the bottom left corner of the room calibration dialogue (see figure 8.26 on page 171). Most settings are greyed out and thus are not allowed to be changed in comparison to the last valid standard room calibration. Settings regarding the wand may be modified, however. If camera positions have changed in the meantime you would have to mark them in the room calibration dialogue as '*moved*' by unticking the corresponding checkboxes. Re-calibration is possible as long as camera movements are not too large. It will fail, e.g. if the mounting of cameras was changed completely.

8.6.4 Room adjustment

During a room calibration the reflective marker (marker #1) in the angle's vertex (see figure 8.23 on page 168) defines the origin of the coordinate system. Oftentimes it might be more suitable to set the origin in respect to a well-known point in space. Use this functionality to alter the room coordinate system after calibration.

Possible scenarios for the application of the *Room adjustment* functionality are:

- adjust the origin to the center of a screen,
- align the coordinate system colinear / parallel to a screen (even very small angular deviations might lead to substantial misalignment over the full width of the projection

0.1° on 5m length equals 8.7 mm deviation)

- shift and / or rotate the camera coordinate system to match a reference coordinate system, e.g. from CAD models
- maintaining a specific coordinate system / orientation when using mobile installations of cameras, i.e. frequently changing the camera setup locations (suitable reference points provided)

In all these cases the coordinate system must be altered after calibration.

Coarse The *Coarse* tab offers a simple way to manipulate the orientation of the room coordinate system with just one click (see figure 8.27 on page 172. You can define the orientation of two axes using the drop-down menus - the third one will be oriented automatically according to the right-hand rule.

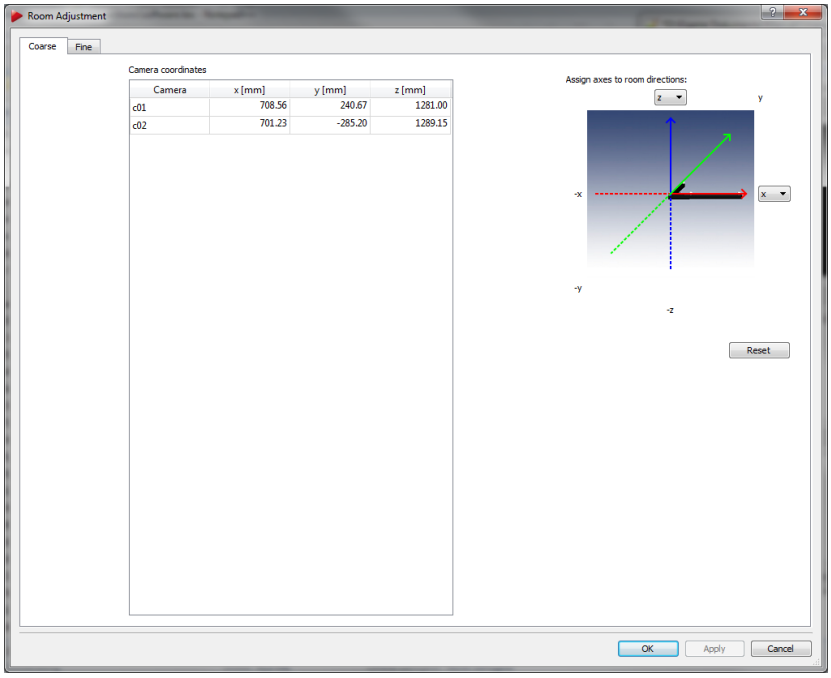


Figure 8.27: Room adjustment dialogue (coarse)

☞ **If you press *Enter* or click *OK*, all changes so far will be confirmed (changes are sent to the controller) and the dialogue closes. Pressing *Apply* accepts the current changes, but the dialogue is left open. Discard all changes by pressing *Cancel*. Press *Reset* to switch back to the unmodified state.**

Fine More detailed options to adjust the room coordinate system are given in the *Fine* tab (see figure 8.28 on page 173). By default a cartesian coordinate system is displayed on the left side of the window. The room coordinate system is shown as a triplet of arrows

with a defined color-coding (x-axis: red, y-axis: green, z-axis: blue), while the xy-plane is shown as a yellow grid. The current and the transformed room coordinate systems are marked with ('O') and ('T') respectively.

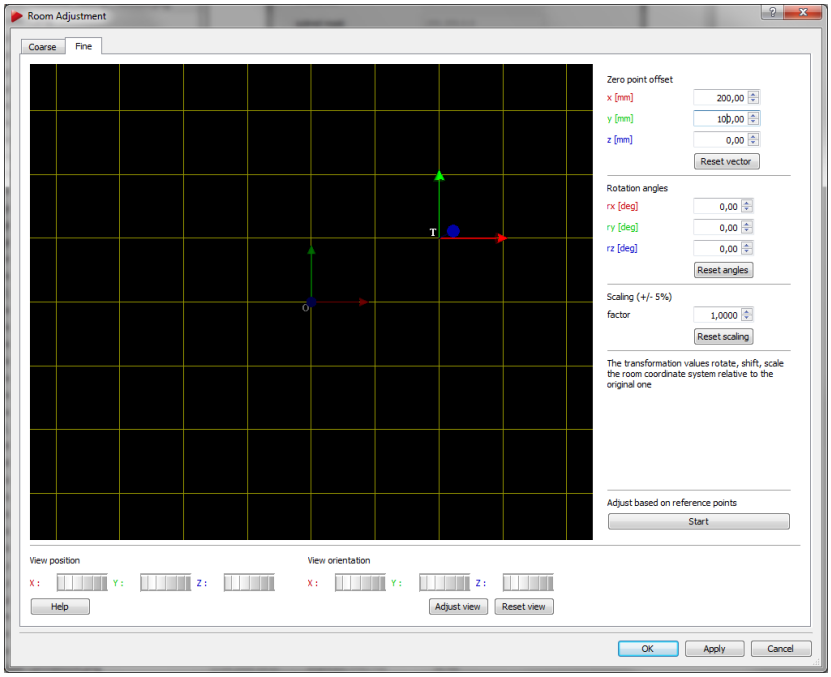


Figure 8.28: Room adjustment dialogue (fine)

The *View position* and *View orientation* may be moved along and / or rotated around all axes in two different ways:

1. hold down the "Ctrl" key and the left / right mouse button to change the position / orientation

2. use the six control dials (below the graphical view) to adjust position and orientation

To center the current room coordinate system, press '*Adjust view*'. To restore the default view (shift and orientation), press '*Reset view*'. The visualisation itself can be changed by clicking the right mouse button to open a menu with the following options. (De-)select the appropriate ones by (un-)ticking.

Option	Description
'*Long axes*'	extends the coordinate axes of the body coordinate system by infinite dashed lines
'*Show XY plane*'	shows the XY plane (yellow grid)
'*Show YZ plane*'	shows the YZ plane (cyan grid)
'*Show XZ plane*'	shows the XZ plane (magenta grid)

On the right side of the window the room coordinate system may be customized freely, i.e. user-specific.

Action	Description
Zero point offset [mm]	translate the room coordinate system along its axes in steps of 1mm
Reset vector	reset the zero point offset to the unmodified state (0.00 mm)
Rotation angles [deg]	rotate the room coordinate system around its axes (from -180 to +180 °)
Reset angles	reset the rotation angles to the unmodified state (0.00 °)
Scaling factor	enlarge / shrink the room coordinate system uniformly by a factor of +/-5 percent
Reset scaling	reset the scaling factor to the unmodified state (1.0000)
Start	start up a module for transforming & matching to a reference coordinate system (Measurement Tool & license provided)

All entered transformation values are relative to the original room coordinate system, i.e. in a standard coordinate system (xy plane on the ground, z axis facing upwards) the origin is placed 42mm above the ground (due to height of calibration angle + radius of spherical marker). If the new desired origin is to be placed 1 m above the ground, then the *Zero point offset* for z is 958mm (1000 mm - 42 mm).

8.6.4.1 Transform the room coordinate system

Press *Start* in the *Fine* tab to open the room matching dialogue (see figure 8.29 on page 175). This functionality depends on the Measurement Tool license.

If the Measurement Tool is not tracked (calibration provided) matching cannot be performed. Use an authorised Measurement Tool by *ART* for best results.

Deselect any previously assigned Measurement Tool References prior to matching of the coordinate systems. Otherwise matching results will be erroneous.

The purpose of the coordinate transformation is to convert the origin and orientation of the initial camera coordinate system (indicated with 'O') into a reference coordinate system (indicated with 'T'), e.g. given by a certain object or CAD model. All measurement data will be transformed with respect to the reference coordinate system ('T'). To this end a three-step calibration procedure has to be performed:

1. Add measurement data from the reference coordinate system ('T') by manually entering the coordinates into the table *reference points* using the button *Add*. A minimum of three (3) data points is necessary for calculations. Delete single data points by selecting the corresponding row and press *Remove*. Alternatively load the coordinates from a text file (ASCII) using the button *Load*. The text file must comply to the following format:

```
1 1.00 20.00 300.00 <CRLF>
2 4.00 50.00 600.00 <CRLF>
3 7.00 80.00 900.00 <CRLF>
# x    y     z      <CRLF>
```

The import strictly follows the sequence from the ASCII text file. Still in some cases the data might be ambigous regarding its 3-D orientation. Toggle the tickbox *preserve order of points* to lock the order in the table *reference points*. The current set of reference points can be saved by pressing *Save*.

2. Select a calibrated and tracked Measurement Tool from the drop-down menu and measure all points (e.g. on the corresponding object) which directly relate to the reference points (e.g. from a CAD model) defined in step 1.
   Each measurement can be started by:
   - clicking the button *Measure*
   - clicking the start button on the Measurement Tool (if applicable)
   - using the start button simulation of the Measurement Tool (refer to 6.5 on page 101)
   - clicking a button of an assigned Flystick

   For proper matching it is essential to acquire the data points in the exact sequence of the reference data

3. After having measured all corresponding points the calculation is started automatically and the result of the transformation is displayed in the textbox *transformation*. Double-check that all measured data points correspond to the correct reference data points. Delete single data points by selecting the corresponding row and press *Remove* or delete all data points to start all over by pressing *Clear*. The residual error (standard deviation) is a measure of the transformation quality, i.e. how well the measured data fit the corresponding reference points. It can be influenced mostly by the quality of data acquisition and by differences in scale of the camera and reference coordinate systems. Pressing *OK* accepts this transformation and closes the dialogue box.

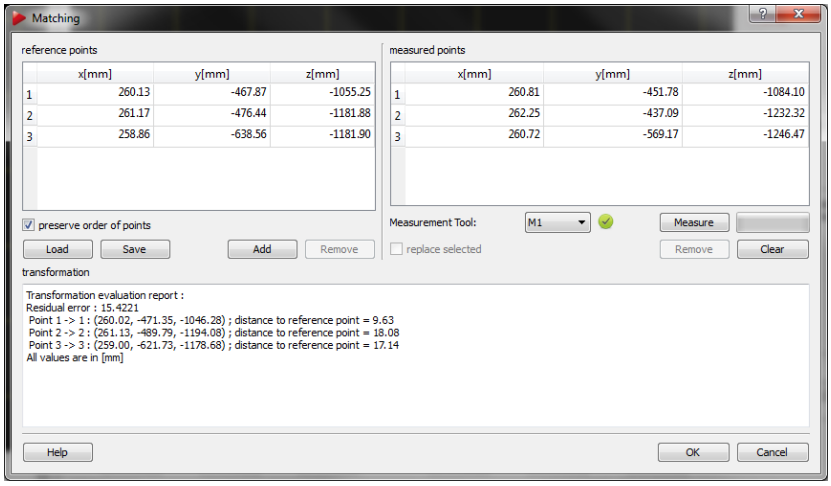


Figure 8.29: Room transform & matching dialogue

The calculated transformation is applied on both *zero point offset* as well as *rotation angles* in *Fine* tab. Do not further manipulate the values manually. Press *Enter* or click *OK*

to confirm the resulting transformation and to close the dialogue. Pressing *Apply* accepts the current changes and leaves the dialogue open. Discard all changes by pressing *Cancel*.

8.6.5 Body calibration

8.6.5.1 Body calibration overview

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 the IR cameras.
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 at least two cameras and should be seen by as many cameras as possible. If two markers, seen from one camera's point of view, are merging to one reflection, 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 using ***DTrack2***'s *Monitor 2DOF display*, which is opened automatically in the background after starting the body calibration. The following figure 8.30 on page 176 shows a rigid body with five markers that are all correctly seen by the IR camera.

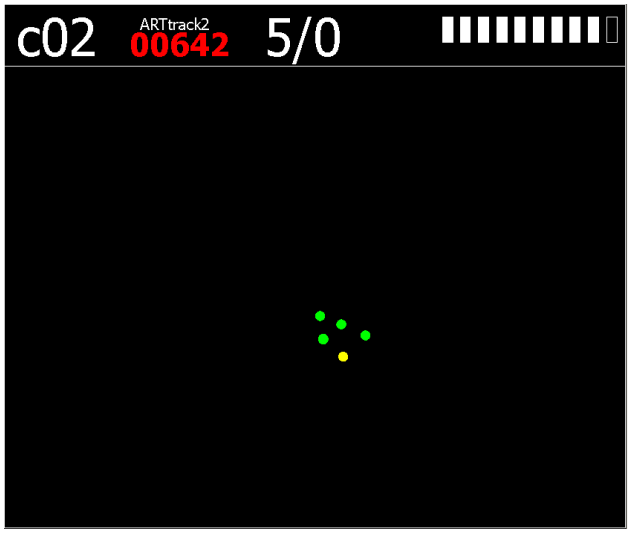
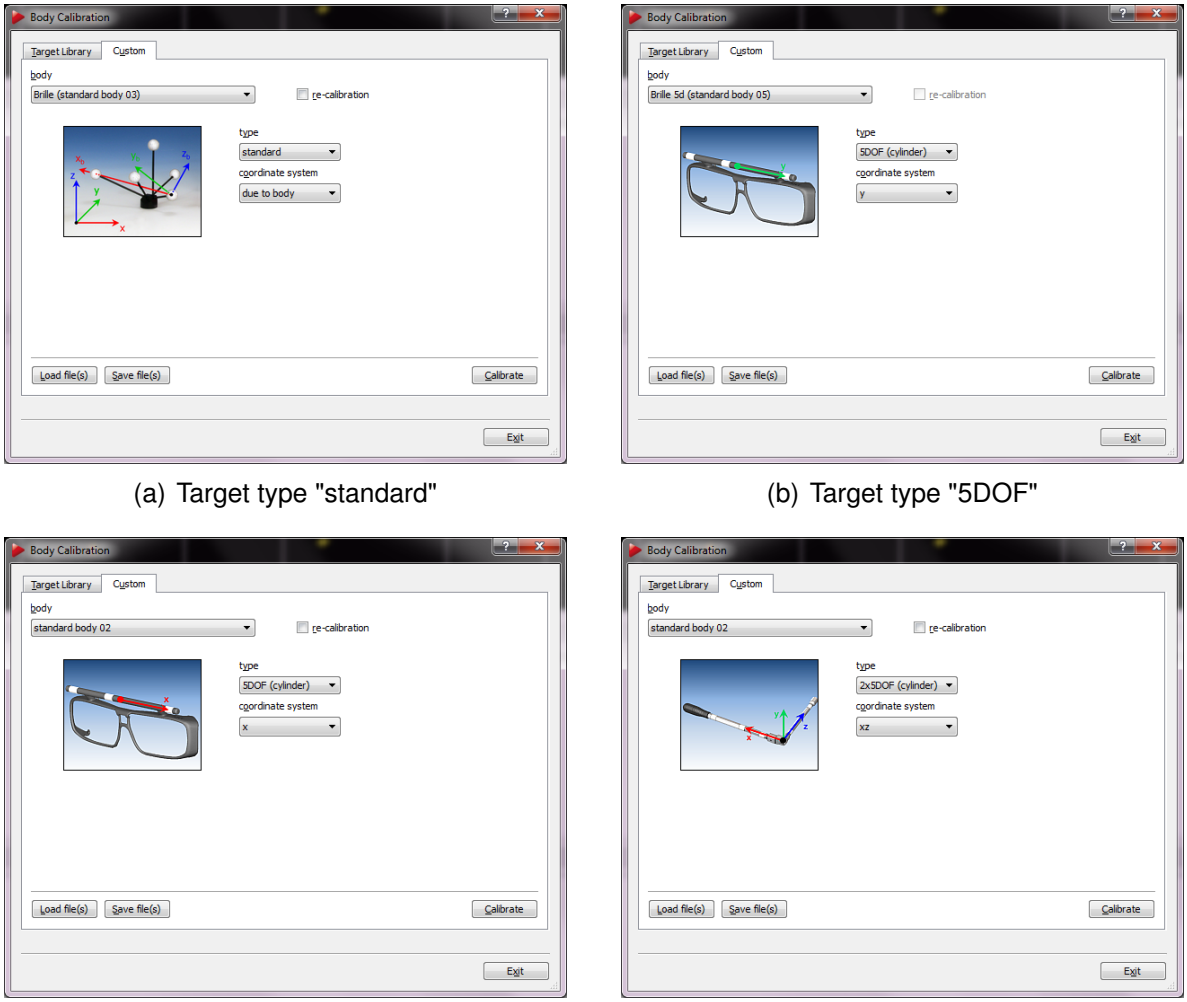


Figure 8.30: Recognized target in ***DTrack2*** *Monitor 2DOF display*

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.

8.6.5.2 Body calibration procedure

Open the dialogue *Calibration* → *Body* to start a body calibration .



(a) Target type "standard"

(b) Target type "5DOF"

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

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

Figure 8.31: 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.

To re-calibrate a body tick the checkbox *re-calibration* next to the drop-down menu. For more information about body re-calibration please refer to chapter 8.6.5.7 on page 182. After pressing *Calibrate*, the body calibration is started within five seconds delay.

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.

8.6.5.3 Body calibration result

After successfully calibrating a body a result window is displayed (see figure 8.32 on 178).

Figure 8.32: Body Calibration Result

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

Double-check whether all markers of the rigid body have been recognized. Then, confirm the result with *OK*. The information (i.e. geometry data) of the calibrated target will be stored inside the ***ART*** Controller in your personal configuration (see also 8.4.2 on 142).

8.6.5.4 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.

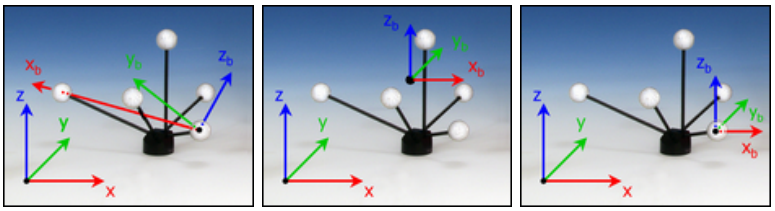
Body calibration setting due to body The body coordinate system is fixed by the markers of the rigid body according to a set of rules:

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 8.33: 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.

8.6.5.5 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. For these bodies the rotation around the body axis cannot be measured by the tracking system. Thus, the 5DOF central axis is 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 according to a direction which is the least often parallel to the tracked body axis (e.g. floor to celling for glasses targets). Please refer to chapter 8.5.5 on page 155 to select the central axis in the menu *Settings* → *Tracking*.

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

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.

Coordinate system setting for type '*5DOF*' and '*5DOF (cylinder)*' In this 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.

8.6.5.6 Calibration with a calibration file

To easily create backups of calibrated bodies, calibration files can be saved at a desired location on the remote PC. These files contain the dimensions of the target and the distances between all markers. Each file is specific for just one type of target.
Just click *Load file(s)* and select the appropriate calibration file(s) or click on *Save file(s)* respectively.

Press '*Save file(s)*' option in the *Body calibration* dialogue to store the calibration file(s) of the currently used bodies.

You can also load calibrations . Press *Load file(s)* (see figure 8.34) 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. ***DTrack2*** automatically assigns the calibration file to the respective target by using the identifier in the file name. Press '*Load*' again to confirm the import of the body calibration files.

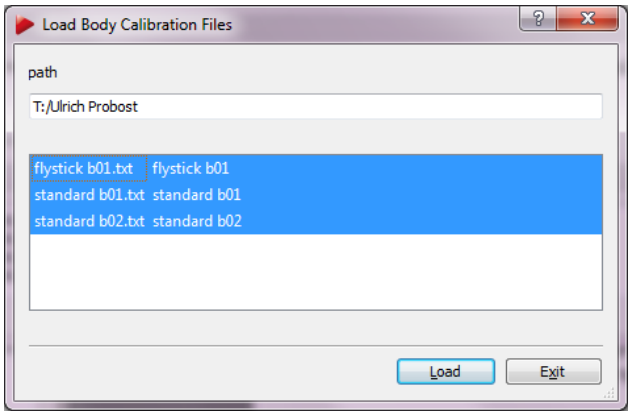


Figure 8.34: Import of calibration files

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

Invalid or corrupt files are not loaded by *DTrack2* . This is indicated by an error message in the confirmation dialogue.

In the upcoming window (see figure 8.32 on page 178) the coordinates of all identified markers are listed together with the body's label as well as the number of markers. It is analogue to the body calibration result.

By clicking *Show details* additional information can be displayed.

- '*Distances*' shows all possible combinations of distances for all markers (min. distances are important for customer-specific geometries, call ***ART*** for further information)
- '*Emissions*' shows normalised emission vectors x, y, z and emission aperture for bodies with restrictions of visibility (calibration files available on request by ***ART***)
- '*Cylinder*' shows coordinates and radii for bodies with (cylindrical) ring markers

Restricted Visibility / Emission Cones Optionally a restricted visibility can be defined for each marker of a body. This is performed setting up so called 'emission cones'; in essence, a 2DOF observation from a camera has to be inside this cone so that tracking data can be used later for pose estimation. Currently the only way to equip markers with

emission cones is to import an appropriate calibration file which are available on request. These files are created at ***ART*** on site performing a body calibration in a defined environment or measurement volume respectively.

8.6.5.7 Body re-calibration

DTrack2 provides a possibility to re-calibrate a rigid body in case its geometry is affected due to e.g. mechanical impact. Tick the checkbox *re-calibation* and perform a routine body calibration as described in 8.6.5 on page 176.

Only during a re-calibration the origin and orientation of the initial coordinate system, as well as specific information (predefined emission vectors, cylindrical marker) are preserved.

8.6.5.8 Target Library

With the introduction of ***DTrack2*** v2.8.1 it is possible to make use of an integrated library that contains calibration data for most ***ART*** standard targets (e.g. Motion Capture, glasses targets, etc.). When you go to *Calibration* → *Body* choose '*Target Library*' (refer to figure 8.35). 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 (e.g. Motion Capture).

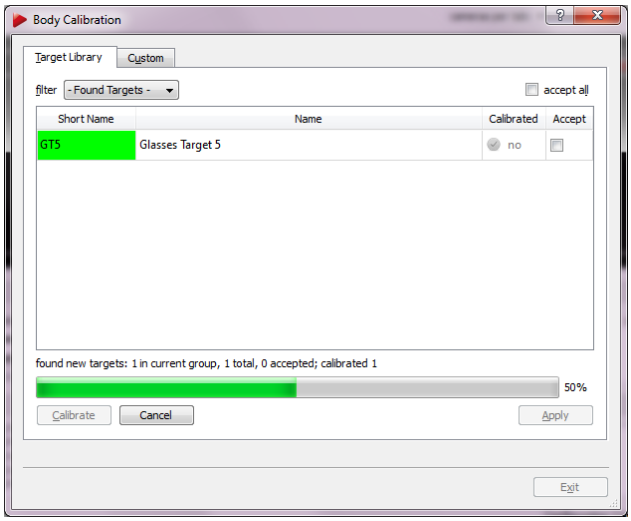


Figure 8.35: Calibrate bodies with the target library

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.

Typical usecase: Motion Capture targets without Inertial sensors For this description we're assuming that a room calibration for eight cameras has already been carried out and that the "full-featured" or "max. 8 cameras" license is available.
First, fit the targets to the test person and make sure that the person is in the calibrated volume. Then, start the calibration (*Calibration* → *Body* → '*Target Library*' → '*Calibrate*') and allow the test person to move around. While this movement the targets must be visible for the tracking system.
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)*.

8.6.6 Body adjustment

The *Body adjustment* function is a tool to visualise and manipulate calibration data of rigid bodies, i.e. the body coordinate system may be changed relative to the markers of the body. Just select the desired body from the drop-down list at the top of the window (see figure 8.36 on page 184).

Body adjustment is not available for 5DOF targets or measurement tools.

The main features of *Body adjustment* are:

- adjust the body coordinate system of each target within the ***DTrack2*** frontend,
- online mode (i.e. the 3D-representation of the target in the '*Graphic view*' is depicting movements / rotation of the target in the "real world"),
- visualise (optionally) predefined emission cones due to restrictions of visibility (directional and angular dependence) for all markers
- aligning the axes of body and 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 a selected marker,
- delete selected markers from the target geometry.

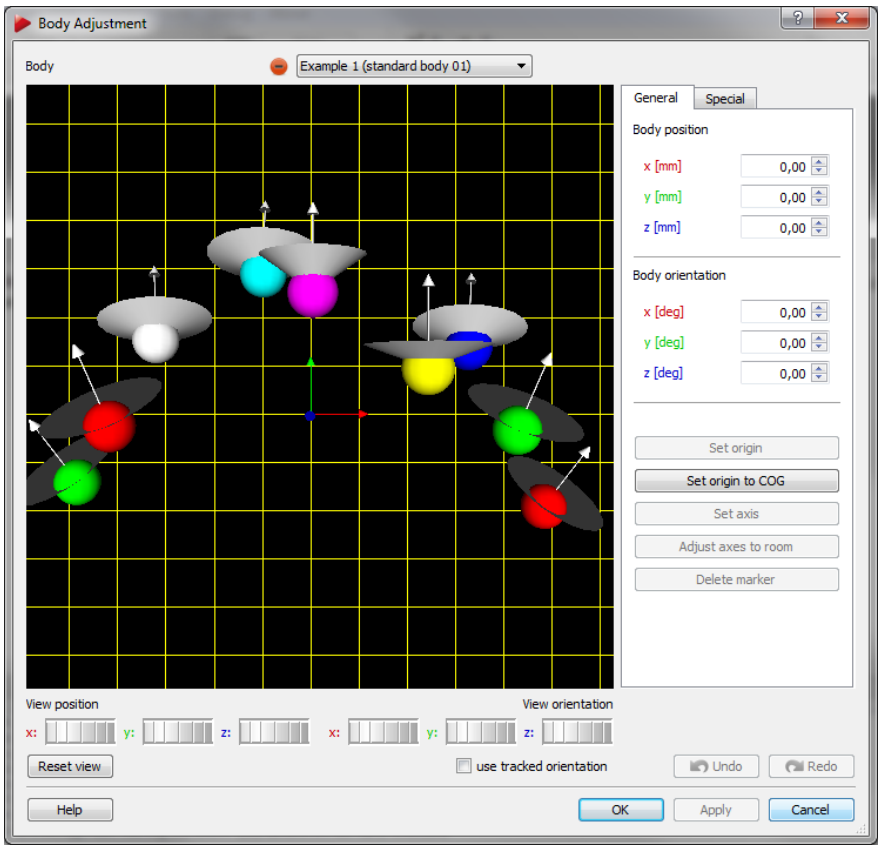


Figure 8.36: Body Adjustment

8.6.6.1 Graphic View

By default a cartesian coordinate system is displayed on the left side of the window depicting the selected rigid body's geometry ('*Graphic view*'). On the right hand side the body's coordinate system can be manipulated. The body coordinate system is shown as a triplet of arrows with a defined color-coding (x-axis: red, y-axis: green, z-axis: blue), while the xy-plane is shown as a yellow grid. All markers, however, are visualised by sequentially colored spheres (RGB) for better identification. In case the selected rigid body features visibility restrictions, emission cones may have been predefined. Direction of visibility (emission vector) is depicted as an arrow (white) for each marker, while the angular restriction (emission aperture) is shown as a cone (grey).

The *View position* and *View orientation* may be moved along and/or rotated around all axes in two different ways:

1. hold down the "Ctrl" key and the left / right mouse button to change the position / orientation

2. use the six control dials (below '*Graphic view*') to adjust position and orientation

To restore the default view, just press '*Reset view*'. Tick the '*use tracked orientation*' checkbox to switch to online mode (i.e. the 3D-representation of the target in the '*Graphic*

view' is depicting movements / rotation of the target in the "real world").

The visualisation can be changed by clicking the right mouse button to open a menu with the following options. (De-)select the appropriate ones by (un-)ticking.

Option	Description
'*Small markers*'	reduces the size of the markers
'*Colored markers*'	shows the markers in different colors (untick: greyish)
'*Emissions*'	shows predefined direction (arrows) and angular restriction (cones) of visibility (if applicable)
'*Long axes*'	extends the coordinate axes of the body coordinate system by infinite dashed lines
'*Show COG*'	shows the body's center of gravity (white square)
'*Show XY plane*'	shows the XY plane (yellow grid)
'*Show YZ plane*'	shows the YZ plane (cyan grid)
'*Show XZ plane*'	shows the XZ plane (magenta grid)
'*Show room orientation*'	shows the room coordinate system (only available when checkbox '*use tracked orientation*' is ticked)
'*Add line between markers*'	adds a line between two selected markers (option greyed out until two markers are selected)
'*Delete line between markers*'	removes a line between two selected markers (option greyed out until line is selected)
'*Data view*'	switches to the data view

8.6.6.2 Changing of body geometry

For manipulating the body geometry you have the choice between *General* or *Special* options:

General The body coordinate system may be customized freely, i.e. user-specific.

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 collinear to the room coordinate system
Delete marker	activate a marker in the '*Graphic view*' by left-clicking with the mouse. The marker is highlighted and the button *Delete marker* is activated. Pressing this button removes the selected marker from the target geometry.

Special Choose from the following predefined transformations:

- *due to body*
  The body coordinate system is completely defined by the target geometry (see page 178).

- *due to room (origin in COG)*
  The coordinate system is rotated and aligned collinear to the room coordinate system with the origin set in the center of gravity (COG) (see page 179). 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 and aligned collinear to the room coordinate system with the origin set in one specific marker (see page 179). In order to use this function, the checkbox '*use tracked orientation*' has to be ticked.

Predefined visibility restrictions (emission vectors and angles of aperture) are retained along all body transformations.

Whenever you press *Enter* or click *OK*, all changes so far for all bodies will be confirmed (changes are sent to the controller) and the dialogue closes. Pressing *Apply* only results in changes of the currently selected body - the body will be redrawn afterwards and the dialogue is left open. Discard all changes by pressing *Cancel*. Press *Reset* to switch back to the unmodified state.

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.

8.6.7 Hybrid Body Calibration

This function performs a hand-eye calibration to combine an inertial sensor with its corresponding optical target. Please refer to chapter 7.2.3 on page 115 for more information.

8.6.8 Fingertracking Calibration

This dialogue is for calibration of fingertracking devices. Please refer to chapter 6.4.6 on page 92 for more information.

8.6.9 Measurement Tool Calibration

Perform a tip calibration for the Measurement Tool that is currently inside the tracking volume. Please refer to chapter 6.5.1 on page 102 for more information.

8.7 Menu Display

Display	Shortcut
Monitor 2DOF	
Data	F10
Fingertracking	
Flystick	
Measurement Tool	
Events	
Set to default	

Table 8.18: Menu *Display*

Monitor 2DOF The *Monitor 2DOF display* is a graphical display of the field of view of the cameras to visualise all markers that are seen by the cameras. It is activated by default. A more detailed description can be found in chapter 8.3.3.1 on page 135.

Data On the left hand side the *Data Display* shows the 6DOF measurement results (i.e. position and orientation of the body relative to the room coordinate system). Additional information for inertial sensors are also shown, if applicable. On the right hand side the results for 3DOF calculation of single markers (e.g. from not calibrated targets) is shown, if activated.

Fingertracking The *Fingertracking* display shows the measurement results for the hands - i.e. of back of the hand + each finger (thumb, index, middle, ...).

Flystick The *Flystick* display shows the measurement results of the position and orientation of the Flystick.

Measurement Tool The *Measurement Tool* display display shows the measurement results of the position and orientation of the Measurement Tool .

Events The *Event Display* shows the status of the tracking system. All messages and entries shown here are also stored in event logs on the remote PC. These files are necessary for tech support by ***ART*** (please refer to chapter 8.4.2 on page 142).

Set to default This function resets the appearance of the ***DTrack2*** frontend, i.e. all views and the size of the windows are reverted to default values. Only the *Monitor 2DOF* and the displays *Data* and *Events* are shown.

Tools	*Shortcut*
Controller Update	
Measurement Tool Demo	

Table 8.19: Menu *Tools*

8.8 Menu Tools

8.8.1 Controller Update

After updating the ***DTrack2*** frontend software the controller and cameras are updated automatically, if necessary. In case you aborted this process you can re-open the update assistant by clicking *Tools* → *Controller update*.

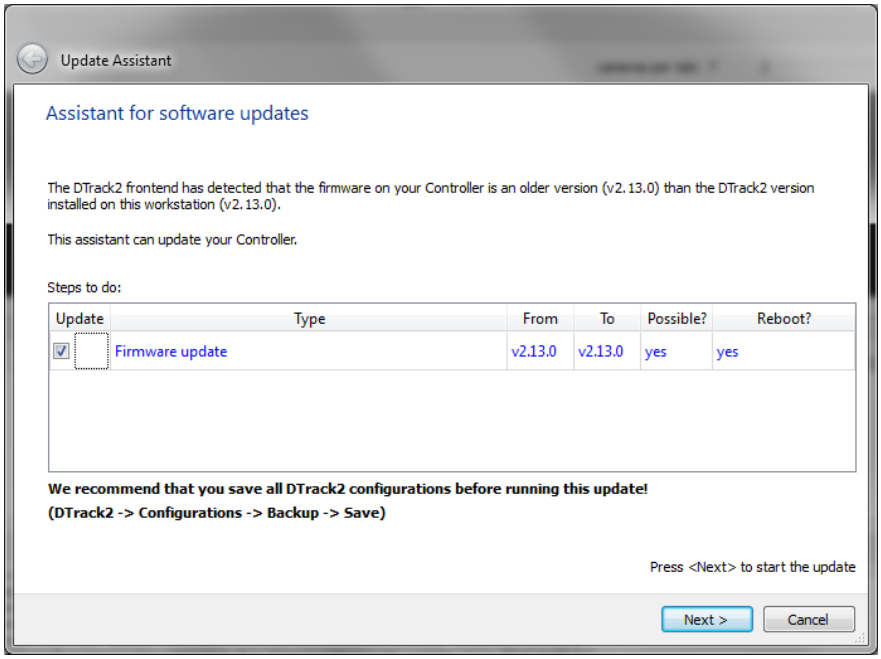


Figure 8.37: Update Assistant

An assistant (see figure 8.37 on page 188) will start up to guide you through the process of software update. Closely follow the instructions given during this process. The controller will be restarted to finish the update process.
In case of firmware updates the cameras need to be turned off separately. You can always abort the update by cancelling.

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

8.8.2 Measurement Tool Demo

This demo (see figure 8.38 on page 189) provides a simple acquisition tool to perform measurements with the Measurement Tool . Up to four Measurement Tool devices are

supported.

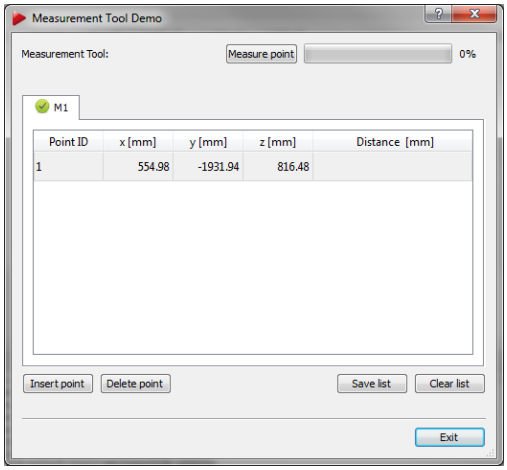


Figure 8.38: Measurement Tool Demo

The measurement of a point is started either by pressing the button *Measure point* performing a gesture with the Measurement Tool . Tilt over the Measurement Tool as defined in 8.5.10 on page 162.

Control	Description
Measure point	Place the Measurement Tool at the position you want to measure and press this button.
Insert point	Add an additional measurement to the list (above the selected point).
Delete point	Remove the selected measurement from the list.
Save list	Export the list of measurements to a file (e.g. for import in a spreadsheet program).
Clear list	Delete all entries of the list.

The distances between adjacent points are computed automatically. You may insert or delete points from the list and you may save the list to a file.

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

8.9 Menu About

DTrack2 Offers information about the software version and release date of the ***DTrack2*** frontend software and backend software running on the controller (see figure 8.39 on page 190). Additionally name and serial number of the controller are shown. By clicking on the button *Show details* a list of all included software modules is shown together with their respective software versions. Information regarding licensing of ***DTrack2*** can be found under *Open-Source software*.

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

Table 8.20: Menu *About*

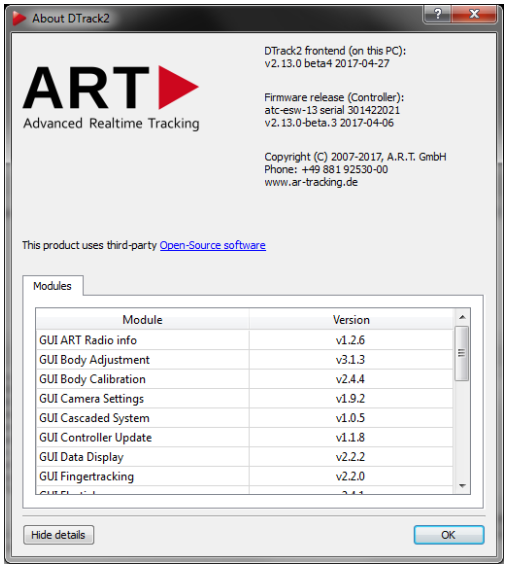


Figure 8.39: About DTrack2 Information

About Qt Offers information about the Qt software toolkit used in ***DTrack2*** .

What's new? Provides information about the new features that have been released with the current version. By clicking on '*Show more*' you can access the history of introduced features in previous versions (see figure 8.40 on page 191).

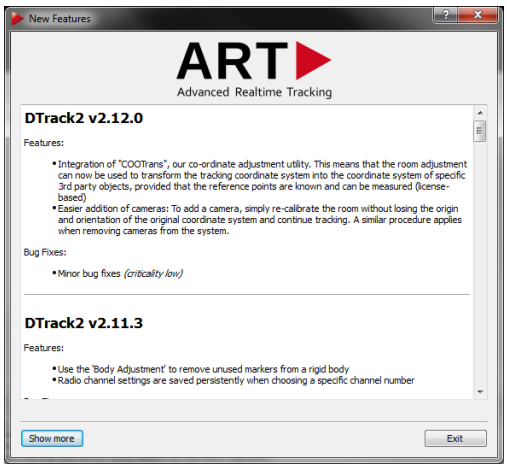


Figure 8.40: What's new Information

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

9 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. Additionally we will need details about your system. Please refer to chapter 8.4.2.2 on page 144 for details how to export a system information file. Please include it in your mail when you contact tech support.

9.1 Backup

⇨ How do I create a backup of important configurations?

From ***DTrack2*** v2.8.1 it is possible to export and import configurations. Please refer to chapter 8.4.2.1 on page 143 for details how to export and backup your configurations. In case of an accidental deleting of a configuration it will be possible to restore it presuming that an export had been carried out before. In the unfortunate event of repairs this data could also be restored to a replacement controller.

Please note that a room (re-)calibration might be necessary especially in case the amount of cameras or the camera models have changed.

9.2 Cameras

⇨ *DTrack2* doesn't recognize the correct number of cameras connected. What can I do?

- First of all, please check whether cabling is correct.
- Please make sure that all cameras are powered up, indicated by their status LEDs.
- Within ***DTrack2*** press '*F2*' in order to perform a search for new hardware. The cameras should be detected now.
- In case of ***ARTTRACK2*** (discontinued): please make sure that the camera's fan

is working. If the fan stops, rising temperatures inside the camera will cause an emergency shutdown of the internal control unit.

- If you are using an external switch, please make sure that no camera is connected to the uplink port and, if applicable, the switch is powered up.
- Finally, reboot the cameras, the external switch and the controller.

⇨ What is the meaning of the red LEDs at the front of the camera?

They are indicating the status of the camera:

- ***ARTTRACK2*** / ***ARTTRACK3*** (discontinued): The left LED shows that the camera is powered up and booted. Whereas, the right LED indicates that the measurement is active. In case of an error (e.g. sync loss), the left LED extinguishes and the right LED starts flashing. Please refer to figures 4.7 and 4.8 on pages 38 and 40 for the visualization of the cameras.
- ***ARTTRACK5*** : The lower LED shows that the camera is powered up and booted. Whereas, the upper LED indicates that the measurement is active. In addition to the two status LEDs the 2-digit LED-matrix on the left displays the assigned camera ID (default) and the number of markers in the camera's corresponding field of view (when activated under camera settings). Please refer to figure 4.1 on page 29 for the visualization of the camera.
- ***ARTTRACK5/C*** : The red LED on the camera body shows that the camera is powered up and booted. Please refer to figures 4.4 on page 33 for the visualization of the cameras.
- ***TRACKPACK/E*** : The lower left LED show that the camera is powered up and booted. Measurement active is indicated by the lower right LED. Please refer to figure 4.6 on page 35 for a visualization of the camera.
- ***TRACKPACK*** (discontinued): The lower left LED show that the camera is powered up and booted. Measurement active is indicated by the lower right LED. Please refer to figure 4.9 on page 43 for a visualization of the camera.

⇨ 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 in chapter 4.8.2 on page 48.

⇨ How many cameras may be connected to the tracking system?

Starting with ***DTrack2*** version v2.10 a new license model has been established.
You may use 2, 4, 8, 16 or up to 50 cameras in any combination with 4, 10, 30 or up to 50 targets depending on the license purchased.

Please refer to table 8.6 on page 141 for a complete license overview.
Based on the now obsolete license model the number of cameras depends on the used license and the tracking system itself:

	max. bodies	number of cameras
ARTTRACK system		
Extended	4	2
Full-featured	50	50
TRACKPACK system		
Basic	4	2
Extended	4	4
Full-featured	50	4

⇨ I'd like to expand my system. Is it possible?

Tracking systems with ***ARTTRACK*** cameras are expandable up to a total number of 50 cameras (from ***DTrack2*** v2.8.1). A tracking system with ***ARTTRACK1*** - ***ARTTRACK5*** can be expanded by simply adding additional ***ARTTRACK*** cameras. Please double-check your current license and the need to purchase a license for more cameras (e.g. 8 or 16) and an additional PoE+ switch.

TRACKPACK/E systems can be expanded up to 16 cameras through means of cascading 2 separate systems. One ***ART*** Controller will function as master, while the other works in slave mode. The master controller needs to have a dedicated "cascaded systems" license as well as a sufficient license for ALL cameras inside the cascade, i.e. 16 cameras.

The ***TRACKPACK*** system (discontinued) can also be extended up to 16 cameras, however more equipment is needed in this case. One separate ***ARTTRACK*** Controller with a license for cascaded systems is needed to merge the data output streams of the separate stand-alone ***TRACKPACK*** systems into one single stream.

Please refer to chapter 5.4 on page 66 for more information.

⇨ Which upgrade possibilities do I have?

Please refer to table 5.1 on page 54.

9.3 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).
Please refer to chapter 8.2.3 on page 126 for more information.

⇨ 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 8.2.4 on page 127.
- In case you are using a firewall, please do not block ***DTrack2*** communication.

For more information, please also refer to chapter 8.2 on page 124 or chapter 5.2 on page 60 or chapter 5.3 on page 63.

⇨ What is the IP address of my controller?

You may use a standard USB pen drive 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 8.2.4.1 on page 128 for more information.

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

You may configure a static IP address the following ways:

- using ***DTrack2*** (refer to chapter 8.2.2 on page 125)
- without the ***DTrack2*** frontend (refer to chapter 8.2.4 on page 127)

9.4 Synchronization

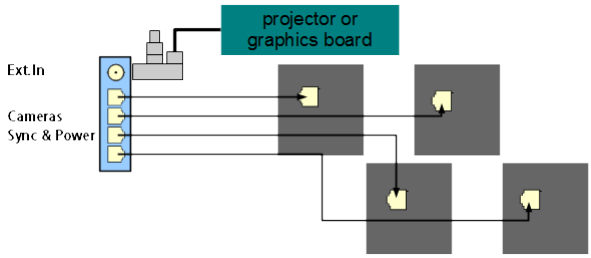
⇨ Synchronization failed in *ARTTRACK5* systems

If you have connected ***ARTTRACK5*** or ***ARTTRACK5/C*** cameras via a PoE+ switch, please check the model of the switch. Some acquirable PoE+ switch models might not be suitable for usage with ***ART*** cameras. Use the recommended 'Netgear Prosafe GSM7212P' or – if not possible – contact ***ART*** support.

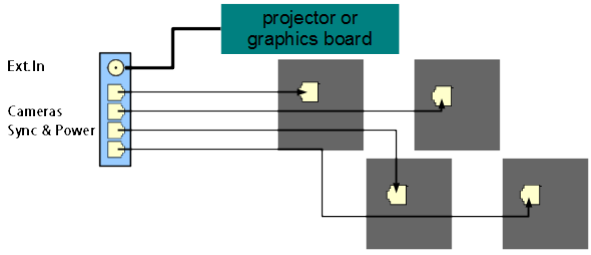
➪ Synchronization failed in *ARTTRACK5* & *TRACKPACK/E* systems

Due to the single cable solution, the camera is both powered and synchronized over Ethernet. There is no need to guide or check additional cables dedicated to synchronisation of the cameras. Still hardware issues regarding the controller can arise when using external trigger units, e.g. projectors or graphics cards.

1. **Check the cabling (hardware issue):**
   - Please make sure that the coaxial cables are not damaged.
   - Take care of using the correct ports:
     - EXT.In: input of the external synchronization
   - **Active stereo**: when using external synchronization (video) the correct cabling would look as follows:



   - **Active stereo**: when using external synchronization (TTL) the correct cabling would look as follows:

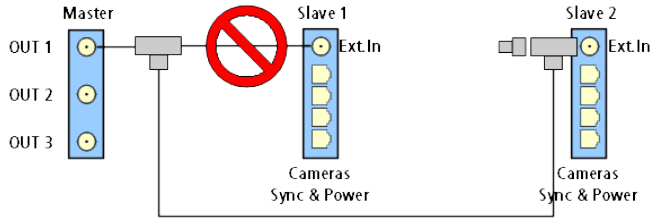


2. **Check the synchronization settings (software issue):**
   - Go to *Settings* → *Synccard* and double-check the settings (external video signal or TTL) for the Synccard.
   - In case of external synchronization, please make sure that the synchronization signal is being sent by the external source.

➪ Synchronization failed in cascaded systems

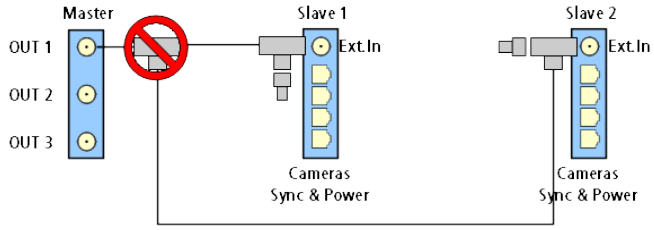
Cascading means that two or more stand-alone tracking systems are combined to one large system in order to have only one consolidated data output. Therefore, the system is subdivided into one master and up to eight slaves.
The task of the master is to synchronize all slave controllers attached and gather all single data outputs from all slaves and to merge them into one single data output.
Please refer to chapter 5.4 on page 66.

1. **Check the cabling (hardware issue):**
   - Please make sure that the coaxial cables are not damaged.
   - Take care of using the correct ports:
     - EXT.In: input of the external synchronization (slaves)
     - OUT1: output for synchronization of slave controllers (Do not use OUT2 or OUT3 !)
   - Double-check if no extensions between slave controller and terminating resistor have been made.



   - Double-check if the terminating resistor is missing at the end of the signal line.

   - Splitting of the synchronization line is not allowed.

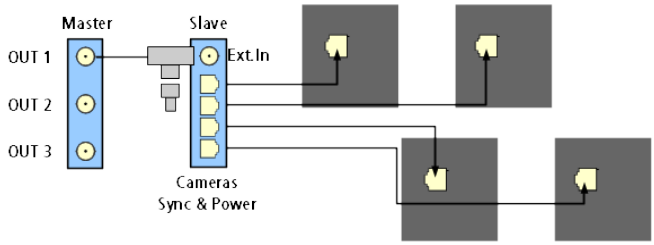


   - Do not connect the cable directly to the slave controller.

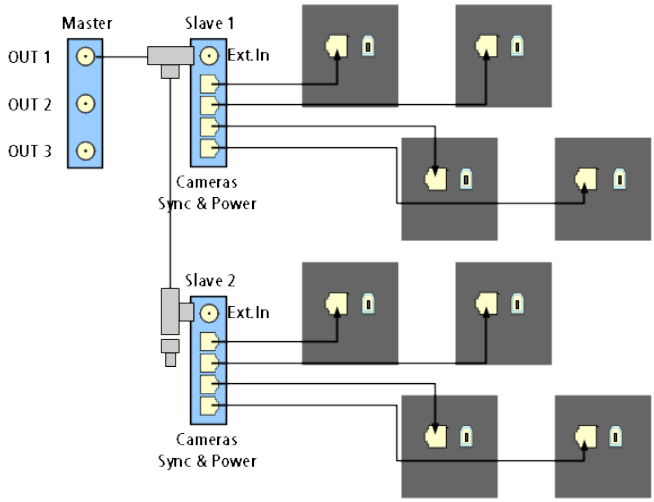
2. **Check the cascade settings (software issue):**
   - Go to *Settings* → *Cascaded System* and double-check the attached slave controllers. Please refer to chapter 5.4 on page 66.
   - In case of simultaneous external synchronization, please install the synchronization on the master controller according to the instructions for ***ARTTRACK5*** and ***TRACKPACK/E*** systems. Please refer to chapter 5.1 on page 55.

➪ How do I guide the synchronization cables correctly in cascaded systems ?

- When using one ***TRACKPACK/E*** master and one ***TRACKPACK/E*** slave controller the correct cabling would look as follows:



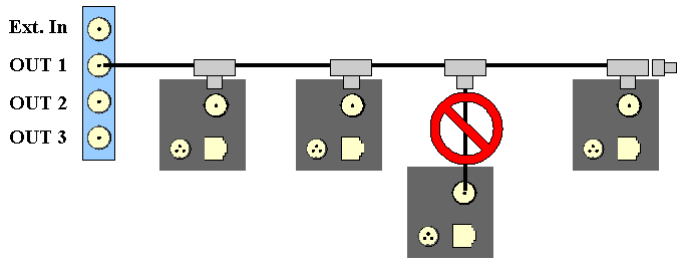
- When using one ***ART*** Controller as master and two ***TRACKPACK*** slave controller the correct cabling would look as follows:



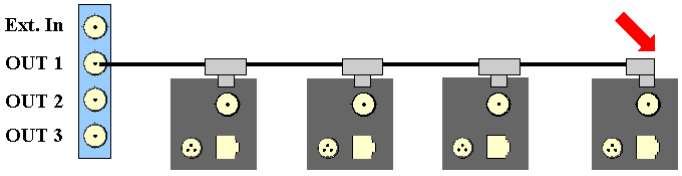
➪ Synchronization failed in ***ARTTRACK*** 2 & 3 systems (discontinued)

Here we have to distinguish between hardware issues (camera and external synchronization) and software issues:

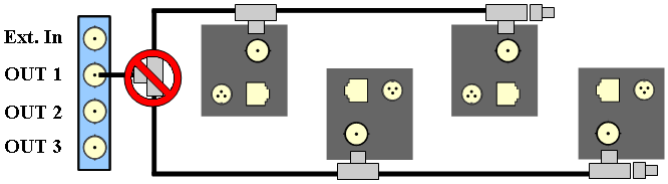
1. **Check the cabling (hardware issue):**
   - Please make sure that the cables themselves are not damaged.
   - Take care of using the correct ports:
     - OUT1 to OUT3: synchronization of the cameras
     - EXT.In: input of the external synchronization
   - Double-check if no extensions between camera and terminating resistor have been made.



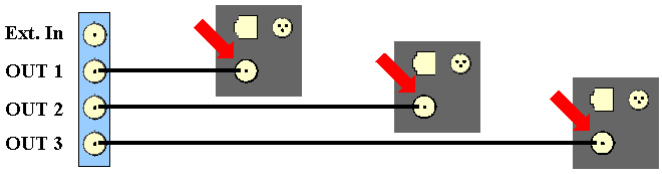
- double-check if the terminating resistor is missing at the end of the signal line.



- Splitting of the synchronization line is not allowed.



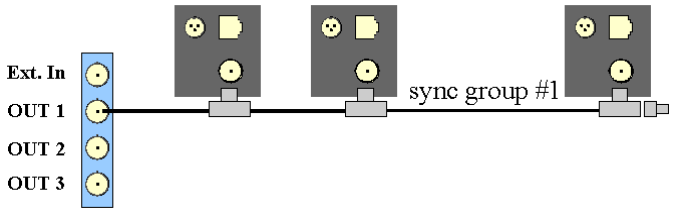
- Do not connect the cable directly to the camera.



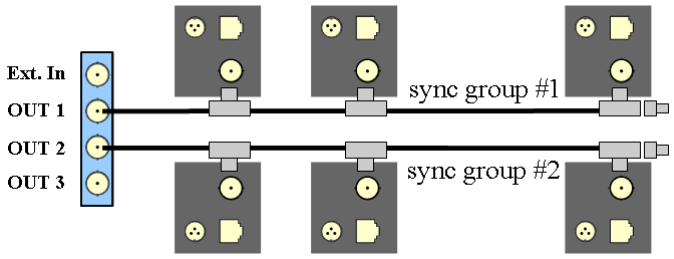
2. **Check the synchronization settings (software issue):**
   - Go to *Settings* → *Synccard* and double-check the settings (internal or external synchronization) for the synccard.
   - In case of external synchronization, please make sure that the synchronization signal is being sent by the external source.

➪ How do I guide the synchronization cables correctly in *ARTTRACK* 2 & 3 systems (discontinued)?

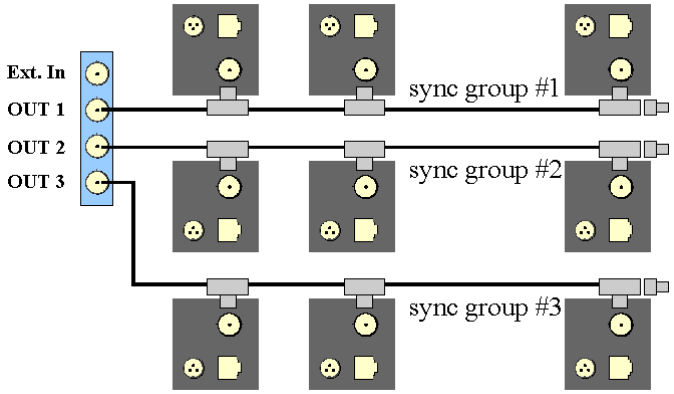
- When using only one syncgroup the correct cabling would look as follows:



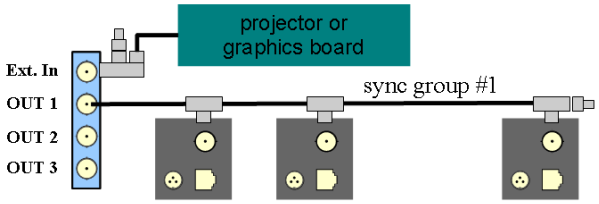
- When using two syncgroups the correct cabling would look as follows:



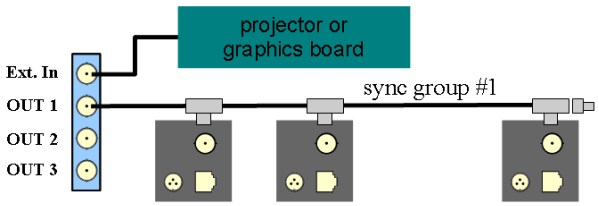
- When using three syncgroups the correct cabling would look as follows:



- **Active stereo**: when using external synchronization (video) the correct cabling would look as follows:



- **Active stereo**: when using external synchronization (TTL) the correct cabling would look as follows:



➪ Synchronization failed in *TRACKPACK* systems (discontinued)

Here we have to distinguish between hardware and software issues:

1. **Check the cabling (hardware issue):**
   - Please double-check whether the cables are connected correctly and that they are not loose.
   - Please make sure that the cables themselves are not damaged.
   - Take care of using the correct ports:

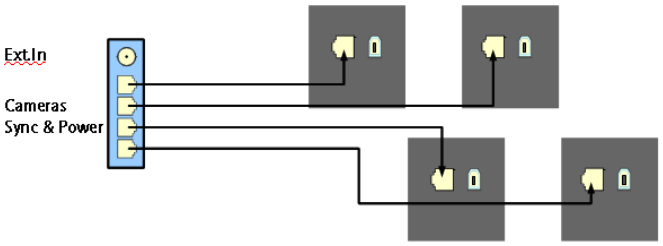
  - the RJ45 plugs below the BNC plug must be used for connecting the cameras
  - EXT.In: input of the external synchronization

2. **Check the synchronization settings (software issue):**
   - Go to *Settings* → *Synccard* and double-check the settings (internal or external synchronization) for the synccard.
   - In case of external synchronization, please make sure that the synchronization signal is being sent by the external source.

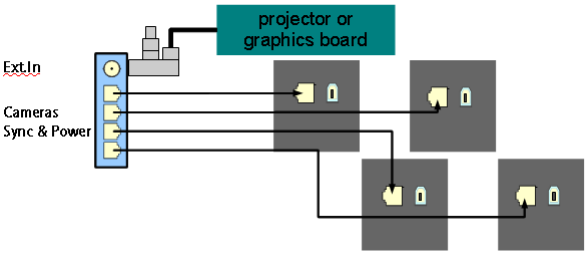
⇨ How do I guide the synchronization cables correctly in *TRACKPACK* systems (discontinued) ?

TRACKPACK systems do not have hardware-based syncgroups. Up to three syncgroups may be defined within the ***DTrack2*** software: *Settings* → *Cameras* → '*syncgroup*'

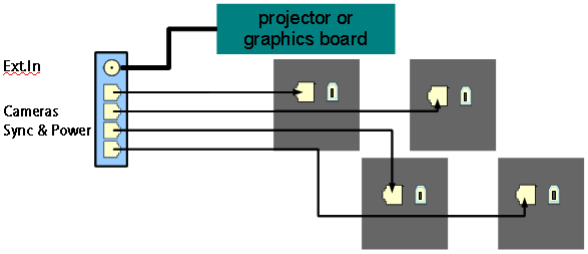
- The cables should be guided according to the following sketch:



- **Active stereo**: when using external synchronization (video) the correct cabling would look as follows:



- **Active stereo**: when using external synchronization (TTL) the correct cabling would look as follows:



9.5 *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 5.2 on page 60 or chapter 5.3 on page 63.

⇨ 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.

9.6 *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 8.14 on page 161). 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*' of Flystick1. Please refer to chapter 6.3.2 on page 81 for more details.

9.7 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.6 on page 244 for a list of supported operating systems.
- If using Windows XP: This is no longer supported as of ***DTrack2*** 2.13.0. Please update to Windows 7 or newer.
- If using Linux: some newer Linux distributions do not install the library `libpng12.so.0` by default, although it is 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.6 on page 244 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.6 on page 244 for a list of supported operating systems.

⇨ Why is the Monitor 2DOF display crossed out for some cameras?

- Please check if all the cameras used during room calibration are connected.
- Please refer to section 9.2 on page 192 for the common reasons of disconnected cameras.
- Please refer to section 8.3.3.1 on page 135 for more information about Adding / removing cameras.

⇨ Why does the "(re-)calibration required" message appear in Monitor 2DOF?

- Please make sure you have performed a correct room calibration using all connected cameras.
- Please refer to section 8.3.3.1 on page 135 for more information about Adding / removing cameras.

⇨ 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 8.5.1 on page 146).
- In case you are using active targets, please make sure that you have activated the modulated flash. Please refer to chapter 6.2.4 on page 79 for further details.

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

Go to *Settings* → *Body Administration* and change the '*number of 6DOF bodies*'. Please refer to chapter 8.5.6 on page 155.

⇨ 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 8.6 on page 141 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.
Go to *DTrack2* → *Licenses*.
Please refer to chapter 8.4.1 on page 141 for further details.

⇨ Where do I enter a new license code?

Go to *DTrack2* → *Licenses* and enter the code in line '*new license code*'.
Please refer to chapter 8.4.1 on page 141 for further details.

⇨ 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).
Please refer to chapter 8.4.2.1 on page 143 for further details.

⇨ How do I run a software update?

Please contact ***ART*** to receive the latest software release and follow the instructions in chapters 8.1.3 on page 123 and 8.8.1 on page 188.

⇨ 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.
Please refer to chapter 8.4.2 on page 142 for further details.

⇨ 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*'. Please refer to chapter 8.5.5 on page 155 for further details.

⇨ 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 and the backend software on the controller. Please refer to chapter 8.9 on page 189 for further details.

⇨ 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 8.6.1 on page 165 for more information.

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

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

Please refer to chapter 8.3.3.1 on page 135 for more information on the additional *Monitor 2DOF display* settings.

⇨ 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?

Please check that the cameras are not in the field of view of each other to avoid mutual blinding. Please refer to chapter 4.8.2.1 on page 49 for more information. Furthermore, remove other strong IR radiation sources from the tracking volume or, at least, prevent them from interfering with the tracking system. Please refer to chapter 4.8.2 on page 48 for more information.

⇨ Monitor 2DOF and/or Data Display are 'freezing' after some time, although tracking didn't stop.

This can be caused by a firewall that is running on the ***DTrack2*** PC and blocking (UDP) output data.

Please check your firewall settings and ensure that it is not blocking ***DTrack2*** application, even partly.

9.8 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 8.17 on page 169.

DTrack2 offers the possibility to adjust the room coordinate system after the room calibration. Please refer to chapter 8.6.4 on page 171 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 4.8.3 on page 51 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 refer to chapter 8.6.3 on page 166 for details.
- 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 refer to chapter 4.8.2 on page 48 for more information.
- 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). Please refer to chapter 8.5.1 on page 146.

Restart the room calibration. 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 4.8.3 on page 51 for more information.

⇨ 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 *Calibration → Room* and click *Show details*. There you can extend the duration for the calibration process. Please refer to chapter 8.6.3 on page 166 for more information.

⇨ How shall I evaluate the room calibration results?

Please refer to chapter 8.6.3.2 on page 169 for a detailed explanation.

⇨ *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.

⇨ 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 as well as specific information (predefined emission vectors, cylindrical marker).

You may perform a room re-calibration from time to time or if a camera moved slightly (e.g. due to mechanical instabilities).Please refer to chapter 8.6.3.3 on page 170.

If your body fell down or if the structure is bent you should carry out a body re-calibration. Please refer to chapter 8.6.5.7 on page 182 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 on page 250).

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* → *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. Check in the *Event Display* if there is a warning saying 'no valid room calibration', additionally the button *Calibrate* is greyed out and cannot be clicked. 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 are inside the tracking volume other than the one you want to calibrate.
- 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. Check in the *Event Display* if there is a warning saying 'no valid room 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.
Go to *DTrack2* → *Licenses* to see which license you have.

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.

⇨ 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 8.6.5.4 on page 178 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 8.6.6 on page 183 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. Please refer to chapter 8.5.6 on page 155 for more information.

⇨ I cannot increase the number of targets anymore.

The maximum number of targets to be tracked (including Flysticks and Fingertracking hand devices) depends on the license 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. Go to *DTrack2* → *Licenses* to see which license you have.

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 8.6 on page 141 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 8.6.5.3 on page 178).

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

9.9 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*'. Only one camera can emit the modulated flash, thus the selected one should have unobstructed view of the whole tracking area. Furthermore it has to be assigned to syncgroup #1 ! ***ARTTRACK5*** , ***ARTTRACK5/C*** , ***TRACKPACK/E*** , & ***TRACKPACK*** systems may be configured via software, while ***ARTTRACK2*** & ***ARTTRACK3*** have to be connected to 'OUT1' on the controller's Synccard.
- Also, take into account that the distance between active target and cameras should not exceed 4.5m.
- 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. See also the FAQ section: Operation near plasma screen.
- 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*** .
- If mutual blinding is possible please either try to adjust the cameras differently or try to arrange them in different syncgroups.

⇨ 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 are no restrictions on using passive and active targets simultaneously. But you will need an external modulated flash if you are using ***ARTTRACK1*** (discontinued) or ***ARTTRACK2*** (SN < 320, (discontinued). Please contact ***ART*** in that case.

⇨ 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*.

9.10 Flystick

⇨ The *ART* radio transceiver cannot be found.

Please make sure that the ***ART*** radio transceiver is plugged in. Then, simply press '*F2*' in order to perform a search for new hardware. The radio transceiver should be detected now.

⇨ My Flystick is not listed under 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.
- Go to *Settings* → *ART Radio Info* to see if the ***ART*** radio transceiver has been recognized.
- Go to *Settings* → *ART Radio Info* → *Show details* and set the channel number manually.

⇨ 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* → *ART Radio Info* to see if the ***ART*** radio transceiver has been recognized.
- Go to *Settings* → *ART Radio Info* → *Show details* and set the channel number manually.
- 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
Flystick1	3
Flystick2	5
Flystick3	2

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 6.3.2 on page 82 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.

9.11 Fingertracking

⇨ The Fingertracking hand target is not recognized sporadically or even not at all.

- Make sure that the battery is charged and the hand target is switched on.
- Go to *Settings* → *Cameras* and tick the checkbox '*modulated flash*'. Only one camera can emit the modulated flash, thus the selected one should have unobstructed view of the whole tracking area. Furthermore it has to be assigned to syncgroup #1 ! ***ARTTRACK5*** , ***ARTTRACK5/C*** , ***TRACKPACK/E*** , & ***TRACKPACK*** systems may be configured via software, while ***ARTTRACK2*** & ***ARTTRACK3*** have to be connected to 'OUT1' on the controller's Synccard.
- The configuration dial has to be turned to the proper position. Please refer to chap-

ter 6.4.1 on page 85.

- Increase the brightness of the LEDs on FINGERTRACKING2 devices. Please refer to chapter 6.4.2 on page 87.

⇨ When using Fingertracking, there are always some markers that are flashing alternately in the Monitor 2DOF display.

This is not bug, but rather it is due to the sequential activation of the finger thimble markers in order to achieve a separation of the fingers.

⇨ What's the meaning of the status LEDs on the Fingertracking hand target?

For Fingertracking please refer to 6.4.1 on page 85. For FINGERTRACKING2 please refer to chapter 6.4.2 on page 87.

⇨ What is being configured when turning the configuration dial?

Please refer to 6.4.1 on page 85.

⇨ What's the maximum number of hands to be used?

You may use two Fingertracking sets (i.e. four hands) in your tracking system at the same time. However, the targets of the hand devices must be different.

⇨ How do I assign a hand geometry to a hand ID?

Go to *Settings* → *Fingertracking*. Please refer to chapter 6.4.6 on page 92 for further details.

⇨ The finger calibration fails. What do I do wrong?

- The configuration dial has to be turned to the proper position. Please refer to chapter 6.4.1 on page 85.
- Go to *Settings* → *Cameras* and tick the checkbox '*modulated flash*'. Only one camera can emit the modulated flash, thus the selected one should have unobstructed view of the whole tracking area. Furthermore it has to be assigned to syncgroup #1 ! ***ARTTRACK5*** , ***ARTTRACK5/C*** , ***TRACKPACK/E*** , & ***TRACKPACK*** systems may be configured via software, while ***ARTTRACK2*** & ***ARTTRACK3*** have to be connected to 'OUT1' on the controller's Synccard.
- Please observe the calibration procedure defined in chapter 6.4.6.5 on page 96.
- Make sure that you selected the correct handedness and type of fingerset (3-finger VR vs. 3-finger AR vs. 5-finger AR) in *Calibration* → *Fingertracking* → *Hand geom-*

etry calibration.

- Double-check that the diffusor spheres (not applicable for FINGERTRACKING2) are not broken or missing.

⇨ The Fingertracking output data is not transmitted.

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

- data receiver defined ('*send to*'),
- identifiers '*gl*' and '*glcal*' selected.

⇨ Is it possible to upgrade to the 3-finger or the 5-finger version?

Yes, if you are currently using the non-tactile 3-finger version you may also use 5-finger thimble sets and vice versa. Tactile thimbles are available for 3 fingers only. Please contact ***ART*** to receive more information.

9.12 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.

9.13 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. active Flystick3 (discontinued), Fingertracking). Thus, active targets may not work properly near plasma screens. If possible use passive targets as alternative.

9.14 *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.

9.15 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. The protocol is proprietary, no other devices should work with 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.

10 General Information

10.1 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.

10.2 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.

10.3 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.

10.4 Declaration of conformity

ART
Advanced Realtime Tracking

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

To whom it may concern

Weilheim, 2013-05-28

European Declaration of Conformity CE

Manufacturer:
Advanced Realtime Tracking GmbH
Am Öferl 6
D – 82362 Weilheim i. OB
Germany

Directives:
We the manufacturer hereby confirm, that the products are in compliance with the general requirements of the following directives
- EMC-Directive 89/336/EEC
- Low Voltage Directive 73/23/EEC modified by 93/68/EEC

Products :
ARTTRACK2 (infrared optical tracking camera)
ARTTRACK3 (infrared optical tracking camera)
TRACKPACK (infrared optical tracking camera)
SMARTTRACK (integrated infrared tracking system)
Flystick2 (Flystick input device and receiver)
Flystick3 (Flystick input device, charging unit and receiver)
Fingertracking (Finger interaction device and chargers)
Controller with synccard and software DTrack2
Any related accessories (cables, Ethernet switch etc)

Standards compliance with:
DIN EN 60950-1
EN 61000 -2 / -3
EN 55103 -1 / -2
EN 55022

A.R.T. GmbH
Dr.-Ing. K. Zürl

Advanced Realtime Tracking GmbH
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Managing Directors
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Dr. Armin Weiß
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Amtsgericht München
HRB 128 437
Tax-ID: 11912180990
VAT-no.: DE205356303

Kreissparkasse
München Starnberg Ebersberg
Bank account no. 520 66 77
Bank Code 702 501 50
IBAN DE40 7025 0150 0005 2066 77
SWIFT-BIC BYLADEM1KMS

ZERTIFIKAT ◆ CERTIFICATE ◆ 認証書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

TÜV SÜD Product Service

CERTIFICATE

No. U8 05 01 52228 001

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

Production Facility(ies): 52228

Certification Mark:

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

Model(s): **ARTtrack 1**
ARTtrack 2

Parameters:

	ARTtrack 1	ARTtrack2
Rating voltage:	100-240 VAC	12 VDC
Rated frequency:	50/60 Hz	--
Rating Current:	max. 230mA	max. 2A
Protection class:	I	III

Tested according to: UL 60950-1:2003
CAN/CSA-C22.2 No. 60950-1:2003

The product was voluntarily tested according to the relevant safety requirements and mentioned properties. It can be marked with the certification mark shown above. See also notes overleaf.

Test report no.: 028-70086175-000

196977

Date, 2005-01-27

Page 1 of 1

TÜV Product Service GmbH · TÜV SÜD Gruppe · Zertifizierstelle · Ridlerstrasse 65 · 80339 München · Germany

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America

CERTIFICATE

No. U8 12 10 52228 006

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

Certification Mark:

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

The product was voluntarily tested according to the relevant safety requirements noted above. It 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 system 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.: 028-71317852-200

Date, 2012-10-16

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America

CERTIFICATE
No. U8 12 10 52228 006

Model(s): ARTtrack 3

Parameters:

Type:	ARTtrack 3
Rated voltage:	48Vdc
Rated power:	max. 25W
Weight:	1.5 kg
Protection class:	III

Options:

Type:	Flystick2 Basisstation
Rated voltage:	24Vdc
Rated power:	max. 10W

Type:	Flystick2
Rated voltage:	3.6Vdc
Rated current:	33mA (supplied by battery pack)

Type:	Flystick3
Rated voltage:	5.0Vdc
Rated current:	150mA

Type:	Charging Unit
Rated voltage:	5.3Vdc
Rated current:	1.0A

Tested according to: UL 60950-1-07:2011
CAN/CSA-C22.2 No. 60950-1A-07:2011

Production Facility(ies): 52228

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TÜV SÜD America

CERTIFICATE

No. U8 11 06 52228 005

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

Production Facility(ies): 52228

Certification Mark:

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

Model(s): **Trackpack**
- ARTtrack/TP
- ARTtrack/TPC
- PC-ATC1

Parameters:

Rated voltage:	12 Vdc
Rated power:	max 6W
Protection class:	III

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

The product was voluntarily tested according to the relevant safety requirements and mentioned properties. It can be marked with the certification mark shown above. The certification mark must not be altered in any way. This product certification system operated by TÜV SÜD America Inc. most closely resembles that described by ISO/IEC Guide 67, Conformity assessment - Fundamentals of product certification, System 3. See also notes overleaf.

Test report no.: 028-71338616-100

Date, 2011-06-27

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ART
Advanced Realtime Tracking

CE

EUROPEAN DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

ARTTRACK5

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

2014/35/EC (Low Voltage Directive):	EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011 + A2:2013
2014/30/EC (EMC Directive):	EN 55032:2015 + AC:2016 EN 55024:2010 + A1:2015
2011/65/EC (RoHS Directive):	EN 50581:2012

Weilheim i. OB, 16.01.2018

Dr. A. Weiss (Managing Director)

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

ART
Advanced Realtime Tracking

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MANUFACTURER'S FEDERAL COMMUNICATION COMMISSION DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

ARTTRACK5

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, 14.11.2014

Dr. A. Weiss (Managing Director)

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

ART
Advanced Realtime Tracking

CE

EUROPEAN DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

ARTTRACK5/C

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

2014/35/EC (Low Voltage Directive):	EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011 + A2:2013
2014/30/EC (EMC Directive):	EN 55032:2015 + AC:2016 EN 55024:2010 + A1:2015
2011/65/EC (RoHS Directive):	EN 50581:2012

Warning: Operation of this equipment in a residential environment could cause radio interference.

Weilheim i. OB, 16.01.2018

Dr. A. Weiss (Managing Director)

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

ART
Advanced Realtime Tracking

MANUFACTURER'S FEDERAL COMMUNICATION COMMISSION DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

ARTTRACK5/C

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

FCC 47 CFR Part 15, Subpart B
Class A 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.

This is a class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

Weilheim i. OB, 28.10.2015

Dr. A. Weiss (Managing Director)

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

ART
Advanced Realtime Tracking

CE

EUROPEAN DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

TRACKPACK/E

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

2014/35/EC (Low Voltage Directive):	EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011 + A2:2013
2014/30/EC (EMC Directive):	EN 55032:2015 + AC:2016 EN 55024:2010 + A1:2015
2011/65/EC (RoHS Directive):	EN 50581:2012

Weilheim i. OB, 16.01.2018

Dr. A. Weiss (Managing Director)

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

ART
Advanced Realtime Tracking

MANUFACTURER'S FEDERAL COMMUNICATION COMMISSION DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

TRACKPACK/ E

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, 11.12.2014

Dr. A. Weiss (Managing Director)

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

ART
Advanced Realtime Tracking

CE

EUROPEAN DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

ART Controller

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

2014/35/EC (Low Voltage Directive):	EN 60950-1:2006 + A11:2009 + A1:2010 + A12:2011 + A2:2013
2014/30/EC (EMC Directive):	EN 55032:2015 + AC:2016 EN 55024:2010 + A1:2015 EN 61000-3-2:2014 EN 61000-3-3:2013
2011/65/EC (RoHS Directive):	EN 50581:2012

Weilheim i. OB, 16.01.2018

Dr. A. Weiss (Managing Director)

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

ART
Advanced Realtime Tracking

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MANUFACTURER'S FEDERAL COMMUNICATION COMMISSION DECLARATION OF CONFORMITY STATEMENT

Advanced Realtime Tracking GmbH

declares under its sole responsibility that the product

ART Controller

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, 14.11.2014

Dr. A. Weiss (Managing Director)

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

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America

CERTIFICATE

No. U8 15 08 52228 013

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

Production Facility(ies): 52228

Certification Mark:

C US

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

Model(s): **ARTTRACK5**
ARTTRACK5/C
TRACKPACK/ E

Parameters:

ARTTRACK5
ARTTRACK5/C

Rated voltage:	**57 V DC**
Rated power:	**17 W**
Protection class:	**III**

TRACKPACK/ E

Rated voltage:	**57 V DC**
Rated power:	**5 W**
Protection class:	**III**

Tested according to: UL 60950-1:2007/R:2014-10
CAN/CSA-C22.2 No. 60950-1:2007/A2:2014-10

The product was voluntarily tested according to the relevant safety requirements noted above. It 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 system 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.: 028-713035454-100

Date, 2015-08-06

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America

CERTIFICATE

No. U8 17 02 52228 016

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

Production Facility(ies): 52228

Certification Mark:

Product: **Computer**

Model(s): **Controller**

Parameters:

Rated voltage:	100-240 VAC
Rated frequency:	50/60 Hz
Rated current:	4A
Protection class:	I

Tested according to:
UL 60950-1:2007/R:2014-10
CAN/CSA-C22.2 No. 60950-1:2007/A2:2014-10

The product was voluntarily tested according to the relevant safety requirements noted above. It can be marked with the certification mark above. The mark must not be altered in any way. This product certification system operated by TÜV SÜD America Inc. most closely resembles system 3 as defined in ISO/IEC 17067. 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.: 028-713041124-100

Date, 2017-02-16

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A Technical specifications

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

A.1 Cameras

A.1.1 *ARTTRACK5*

IR Source

invisible IR	850nm
flash intensity adjustable in 100 steps	

Performance

Sensor resolution	1.3 MPixels
Frame rate	up to 300 Hz

Field of view (FoV)

Lens		Camera mode Resolution 1.3 MPix 150 Hz	Medium 0.8 MPix 240 Hz	Speed 0.5 MPix 300 Hz
F = 3.5mm	FoV (horizontal x vertical)	98° × 77°	77° × 57°	60° × 44°
	Max. tracking range (12mm markers)	5.5m	5.5m	5.5m
F = 4.5mm	FoV (horizontal x vertical)	75° × 60°	60° × 45°	47° × 35°
	Max. tracking range (12mm markers)	6.3m	6.3m	6.3m
F = 6.0mm	FoV (horizontal x vertical)	54° × 44°	44° × 33°	34° × 26°
	Max. tracking range (12mm markers)	7.5m	7.5m	7.5m

Connectivity & Power Supply

single cable solution via Gigabit Ethernet, RJ45, PoE+ (IEEE 802.3at Standard)	
max. cable length	100m
Voltage	44 - 57 V (defined by the Standard)
max. power consumption	17 W
Protection category	III
Interface connectors	RJ45 (hosts data, synchronization and power)

Operating conditions

Temperature	0 .. 38°C

Relative humidity	5 .. 50% (non-condensing)
Cooling system	passive

Dimensions

Length	92mm
Width	100mm
Height	100mm
Weight	0.96 kg

A.1.2 *ARTTRACK5/C*

IR Source

invisible IR	850nm
flash intensity adjustable in 100 steps	

Performance

Sensor resolution	1.3 MPixels
Frame rate	up to 300 Hz

Field of view (FoV)

Lens		Camera mode		
		Resolution 1.3 MPix 150 Hz	Medium 0.8 MPix 240 Hz	Speed 0.5 MPix 300 Hz
F = 4.0mm	FoV (horizontal x vertical) Max. tracking range (12mm markers)	89°× 71° 4.5m	71°× 52° 4.0m	56°× 42° 3.5m

Connectivity & Power Supply

single cable solution via Gigabit Ethernet, RJ45, PoE+ (IEEE 802.3at Standard)	
max. cable length	100m
cable length to remote camera head	60cm
Voltage	44 - 57 V (defined by the Standard)
max. power consumption	12 W
Protection category	III
Interface connectors	RJ45 (hosts data, synchronization and power)

Operating conditions

Temperature	0 .. 38°C
Relative humidity	5 .. 50% (non-condensing)
Cooling system	passive

Dimensions remote camera head

Diameter	37mm
Length	73mm
Weight	160g

Dimensions camera body

Length	55mm
Width	100mm
Height	100mm
Weight	540g

A.1.3 *TRACKPACK/E*

IR Source

invisible IR	850nm
flash intensity adjustable in 100 steps	

Performance

Sensor resolution	1.1 MPixels
Frame rate	up to 120 Hz

Field of view (FoV)

Lens		Camera mode		
		Resolution 1.1 MPix 60 Hz	Medium 0.7 MPix 90 Hz	Speed 0.5 MPix 120 Hz
F = 3.5mm	FoV (horizontal x vertical)	97°× 79°	97°× 51°	97°× 36°
	Max. tracking range (12mm markers)	4.5m	4.5m	4.5m

Connectivity & Power Supply

single cable solution via Gigabit Ethernet, RJ45, PoE (IEEE 802.3af Standard)	
max. cable length	100m
Voltage	44 - 57 V (defined by the Standard)
max. power consumption	5 W
Protection category	III
Interface connectors	RJ45 (hosts data, synchronization and power)

Operating conditions

Temperature	0 .. 38°C
Relative humidity	5 .. 50% (non-condensing)
Cooling system	passive

Dimensions

Length	103 mm
Width	70 mm
Height	59 mm
Weight	0.51 kg

A.1.4 *ARTTRACK* cameras (discontinued)

	ARTTRACK2.2 from S/N #1800	ARTTRACK3.2 from S/N #400	*ARTTRACK2*	*ARTTRACK3*
IR flash	880nm	850nm	880nm	850nm
Power supply				
Nominal voltage	12V	48V	12V	48V
Maximal current	2A	1.4A	2A	1.4A
Maximal power	25W	35W	25W	35W
Ext. power supply	12.2V / 3A / 40W 12.5V / 3A / 40W	48V / 0.8A / 40W 48.2V / 0.8A / 40W	12.2V / 3A / 40W 12.5V / 3A / 40W	48V / 0.8A / 40W 48.2V / 0.8A / 40W
Protection category				
Ext. power supply	I	I	I	I
Camera	III	III	III	III
Interface connectors				
data	RJ45	RJ45	RJ45	RJ45
synchronization	BNC	BNC	BNC	BNC
power	external	external	external	external
Operating conditions				
Temperature	0 .. 38°C	0 .. 38°C	0 .. 38°C	0 .. 38°C
Relative humidity	5 .. 50% non-condensing	5 .. 50% non-condensing	5 .. 50% non-condensing	5 .. 50% non-condensing
Cooling system	active (fan) → noise level of the fan: 16.5dB(A)	passive	active (fan) → noise level of the fan: 16.5dB(A)	passive
Dimensions				
Length	140mm	140mm	140mm	140mm
Width	78mm	106mm	78mm	106mm
Height	109mm	120mm	109mm	120mm
Weight	0.96kg	1.45kg	0.96kg	1.45kg
‘ **Performance**				
Frame rate	max. 60fps (adjustable)	max. 60fps (adjustable)	max. 60fps (adjustable)	max. 60fps (adjustable)
Max. working distance with 12mm passive markers (F .. focal length in mm). Greater distances achievable with bigger passive markers (e.g. 30mm) or active markers.				
@ F = 2.6mm	4.5m	4.5m	4.5m	4.5m
@ F = 3.5mm	4.5m	4.5m	4.5m	4.5m
@ F = 4.5mm	4.5m	6m	4.5m	6m
@ F = 6.0mm	4.5m	7m	4.5m	7m
Maximum number of 6DOF targets (simultaneously)				
@ 60fps	50	50	50	50
Field of view (FoV, horizontal × vertical)				
@ F = 2.6mm	88°× 58°	88°× 58°	-	-
@ F = 3.5mm	67°× 45°	67°× 45°	72.8°× 58.2°	72.8°× 58.2°

IR flash	ARTTRACK2.2 from S/N #1800 880nm	ARTTRACK3.2 from S/N #400 850nm	*ARTTRACK2* 880nm	*ARTTRACK3* 850nm
@ F = 4.5mm	-	52° × 35°	57.9° × 45.3°	57.9° × 45.3°
@ F = 6.0mm	-	-	42.9° × 33.0°	42.9° × 33.0°
other focal lengths on request				

A.1.5 *TRACKPACK* cameras (discontinued)

IR flash	*TRACKPACK* 850nm	*TRACKPACK/C* 850nm
Power supply		
Nominal voltage	12V	12V
Maximal current	0.5A	0.5A
Maximal power	6W	6W
Ext. power supply	-	-
	-	-
Protection category		
Ext. power supply	-	-
Camera	III	III
Interface connectors		
data	IEEE1394	IEEE1394
synchronization	RJ45	RJ45
power	RJ45	RJ45
Operating conditions		
Temperature	0 .. 38°C	0 .. 38°C
Relative humidity	5 .. 50% non-condensing	5 .. 50% non-condensing
Cooling system	passive	passive
Dimensions		
Length	77.8mm	228mm
Width	76.9mm	76.9mm
Height	60mm	58mm
Weight	0.45kg	0.45kg
Performance		
Frame rate	max. 60fps (adjustable)	max. 60fps (adjustable)
Max. working distance with 12mm passive markers (F .. focal length in mm).		
Greater distances achievable with bigger passive markers (e.g. 30mm) or active markers.		
@ F = 2.6mm	2.5m	-
@ F = 3.5mm	3.5m	3.5m
@ F = 4.5mm	3.5m	-
@ F = 6.0mm	3.5m	-
Maximum number of 6DOF targets (simultaneously)		
@ 60fps	4 - 50	4 - 50

	TRACKPACK	*TRACKPACK/C*
IR flash	850nm	850nm
Field of view (FoV, horizontal × vertical)		
@ F = 2.6mm	93.5° × 77.2°	-
@ F = 3.5mm	72.8° × 58.2°	72.8° × 58.2°
@ F = 4.5mm	57.9° × 45.3°	-
@ F = 6.0mm	42.9° × 33.0°	-
other focal lengths on request		

A.2 Flysticks

	Flystick2	**Flystick3**
Power supply		
Rechargeable battery [1]	3 Micro-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] valid for new batteries

A.3 Standard Fingertracking

Function	
Synchronization	via modulated IR flash
Battery	NB-4L Li-Ion battery, 3.7V, 700 mAh
Battery charger	
Input	12V, 500mA
Power supply	230V, 50Hz, 12W
Continuous operation [1]	approx. 10 hours
Weight (incl. power supply)	380g
Operating conditions	
Operating temperature	0 .. 38°C
Relative humidity	5 .. 50%, non-condensing
Dimensions	
Thimble set	available in 3 different sizes (small, medium, large)
Weight	60g
Performance	
Frame rate (handtarget)	60Hz
Frame rate (thimbles, 3-finger version)	20Hz
Frame rate (thimbles, 5-finger version)	12Hz
Tracking range	4m (depending on focal length of the cameras)

[1] only valid for new batteries

A.4 FINGERTRACKING2 Tactile

Function	
Synchronization	via modulated IR flash
Battery [1]	2 Micro-AAA batteries, each 1.2 - 1.5 V, typ. 900 mAh
Continuous operation with tactile feedback [2]	typ. 6 hours
Continuous operation no tactile feedback [3]	typ. 7 hours
Battery charger	
Input	AC 100-240V, 50/60Hz, 0.35A or DC 12V
Charging time [1]	approx. 2 hours
Weight (without batteries)	approx. 0.2 kg
Operating conditions	
Operating temperature	10 .. 40°C
Relative humidity	5 .. 50%, non-condensing
Dimensions	
Thimble set	available in 4 different sizes (extra-small, small, medium, large)
Weight	60g
Performance	
Frame rate (handtarget)	up to 300Hz
Frame rate (thimbles, 3-finger version)	100Hz
Tracking range	4m (depending on focal length of the cameras)

[1] valid for new batteries
[2] 300 Hz tracking frequency, LED brightness setting high, 1 vibration per second
[3] 300 Hz tracking frequency, LED brightness setting high

A.5 ART Controller

Dimensions	
Rackmount (19")	
Size	480mm × 345mm × 135mm
Weight	9.75 kg
Power Supply	
Voltage	110 - 240 V
max. power consumption	360 W
Connectors	
Synchronization in	1, BNC: Video Signal (75Ω), TTL, LVTTL
Camera ports	8, Ethernet 1 GBit/s, PoE+
Data out	1, Ethernet 1 GBit/s
USB	6
Operating conditions	

Operating temperature	0 .. 38°C
Relative humidity	5 .. 50%, non-condensing

Hazard notes for service personnel:

Risk of explosion if the mainboard battery is incorrectly replaced. Replace only with the same or from manufacturer recommended similar type.

In order to replace a main fuse of the *ART* Controller always unplug the power cord. Two main fuses are existing since two power supplies are installed. So the device is possibly still under power although a fuse has blown.

A.6 Overall system

System parameters	
number of cameras	2 - 50 (max. 16 for ***TRACKPACK/E*** and ***TRACKPACK*** systems (discontinued)
max. number of targets	50
max. number of hands	4
max. number of Flysticks	
- Flystick2	5
- Flystick3	1
Scalability	***ARTTRACK*** system: fully scalable (2 - 50 cameras) ***TRACKPACK/E*** and ***TRACKPACK*** systems (discontinued): cascadable up to 16 cameras (additional controller necessary)
Accuracy	
- of the timestamp	with a Synccard2/3: $\Delta t_{err} \sim \pm 0.01ms$ with a SynccardTP: $\Delta t_{err} \sim \pm 0.5ms$ with a 3-Space wired inertial sensor: $\Delta t_{err} \sim \pm 0.1ms$

Operating conditions	
Temperature	0 .. 38°C
Relative humidity	5 .. 50%, non-condensing

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 7 32/64 Bit
	Windows 8/8.1 32/64 Bit
	Windows 10 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)

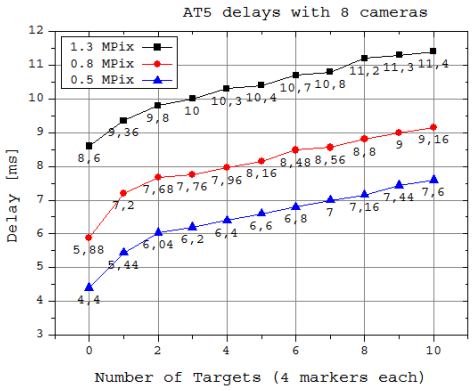
A.7 System latency

System Latency

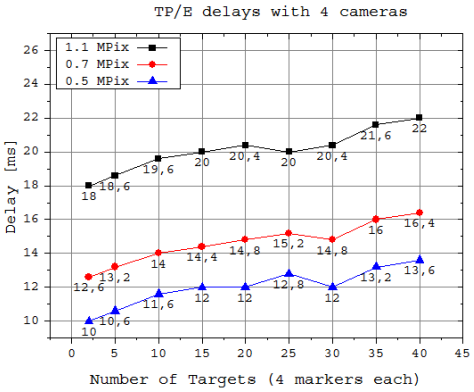
Definition of the system latency:
The system latency is defined as the time delay between sending out the IR flash by the cameras and the availability of the tracking data at the Controller's Ethernet output. The latency is a function of the number of cameras, the number of targets, enabled or disabled 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 ***ARTTRACK5*** , ***ARTTRACK5/C*** and ***TRACKPACK/E*** : The ATC is triggered externally with an arbitrary function generator at 20 Hz. The output network card on the ATC is set-up with 10 MBit (ethtool -s eth0 speed 10 duplex full), so that the network package with the tracking results can be triggered with an oscilloscope.

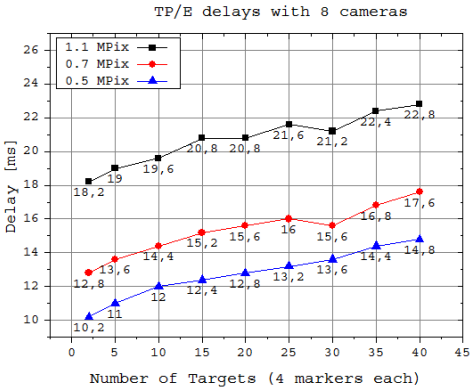
ARTTRACK5 + ARTTRACK5/C



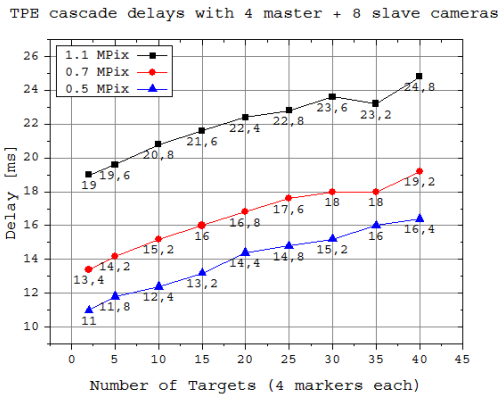
TRACKPACK/E 4 Camera System



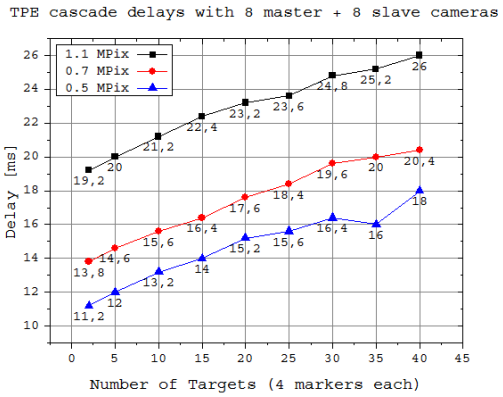
TRACKPACK/E 8 Camera System



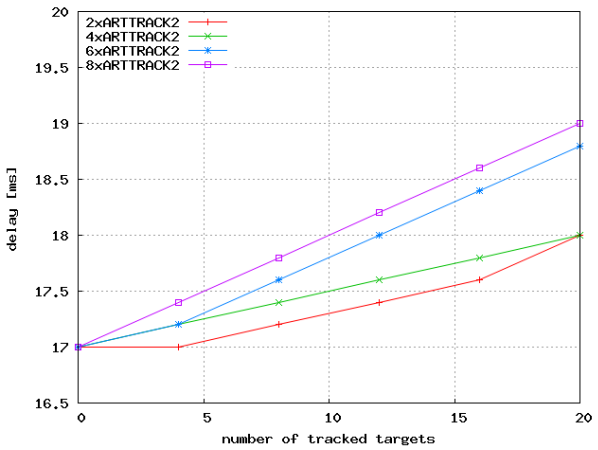
TRACKPACK/E 12 Camera Cascade (4 Master + 8 Slaves)



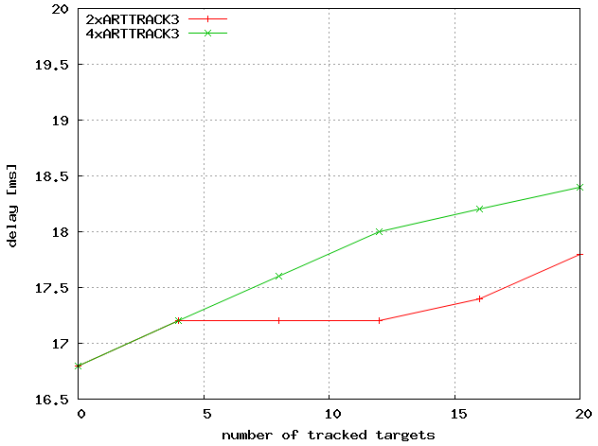
TRACKPACK/E 16 Camera Cascade (8 Master + 8 Slaves)



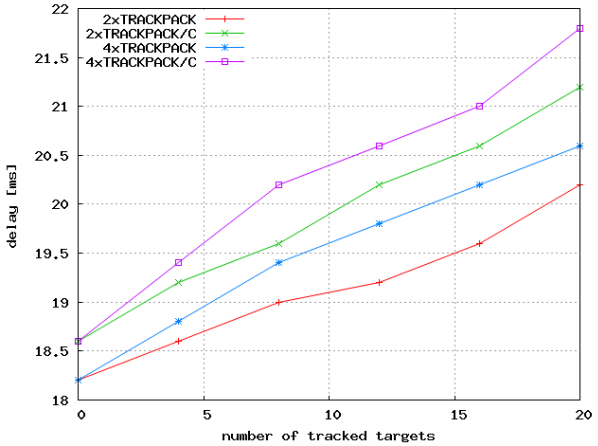
ARTTRACK2 (discontinued)



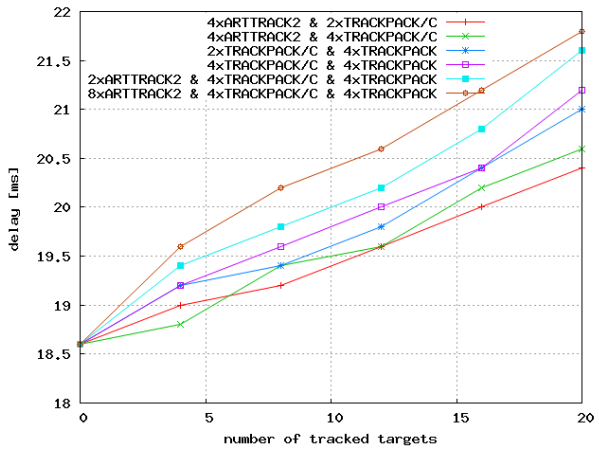
ARTTRACK3 (discontinued)



TRACKPACK (discontinued)



TRACKPACK Cascade (discontinued)



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.

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 252). 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:

$$-180° \leq \phi \leq 180°, -90° \leq \theta \leq 90°, -180° \leq \eta \leq 180°$$

☞ **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 (so called "Gimbal Lock").**

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:

- Flystick1,
- 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 261 and chapter B.2.6 on page 262); 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 Flystick1

The Flystick1 carries eight switches (buttons); four of them form the so-called hat switch. When using output format `6df2`, hat switch actions are transferred into two analogue controller values (getting the values -1.0, 0.0 and 1.0). The following table shows, how each input action appears in the output data:

Switch	`6df` Output	`6df2` Output
front switch (red)	code 01 (hex)	button code 01 (hex)
right switch on backside (red)	code 02 (hex)	button code 02 (hex)
center switch on backside (red)	code 04 (hex)	button code 04 (hex)
left switch on backside (red)	code 08 (hex)	button code 08 (hex)
hat switch (black) to the left	code 20 (hex)	first controller 1.0
hat switch (black) to the right	code 80 (hex)	first controller -1.0
hat switch (black) up	code 40 (hex)	second controller 1.0
hat switch (black) down	code 10 (hex)	second controller -1.0

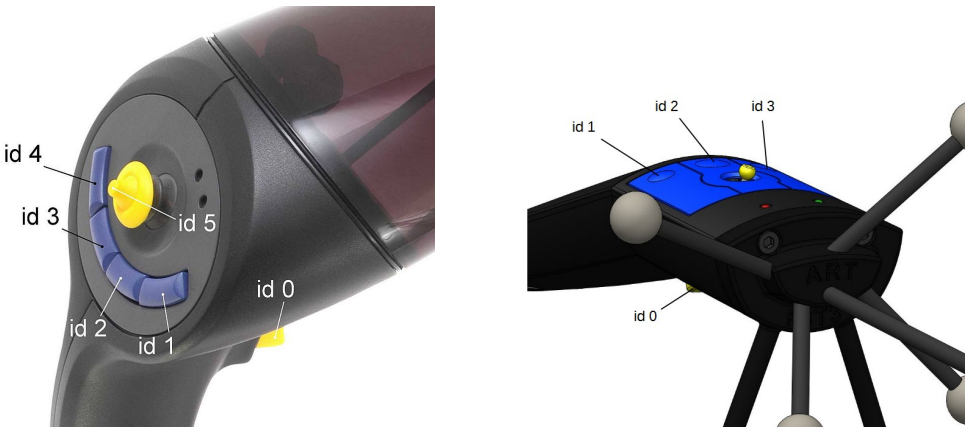
B.1.5.2 Flystick2

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

B.1.5.3 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.



(a) Flystick2 (b) Flystick3

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

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

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.1.6.3 Covariance of Measurement Tool tip

DTrack2 provides an estimation for the current uncertainty of the measured position of the tool tip, expressed as a 3×3 covariance matrix Σ . Assuming a translational vector $\vec{e}^S$ representing the error of the measured tip position, the covariances are calculated as the 'expected values' ($E()$) of:

$$\vec{x}^S_{meas} = \vec{x}^S + \vec{e}^S$$
$$\sigma_{ij} = E(e^S_i \cdot e^S_j)$$

Intuitively, the diagonal entries of Σ_{tip} can be interpreted as the positional uncertainty in world coordinates. Off-diagonal values describe the statistical dependency between two values.

B.1.7 Fingertracking

The Fingertracking device allows to track a human's entire hand, including fingers. The output data consists of:

- position and orientation of the back of the hand (given in room coordinate system),
- number of the tracked fingers (3 or 5) and a value to distinguish between right and left hand,
- position and orientation of the outermost phalanxes, given in the hand coordinate system; the radius of the finger tip to identify its position and orientation (more exactly its surface),
- angles between the single phalanxes as well as their respective lengths. These values are calculated using tracked markers and empirical data.

Hand coordinate system The hand coordinate system is defined as follows:

- the origin is in the joint, where the index finger is connected to the back of the hand.
- the +X axis is oriented in direction of the outstretched index finger.

- the +Y axis is defined parallel to the back of the hand, indicating towards the ring finger.
- the +Z axis is defined with these specifications, resulting in a right-handed coordinate system.

For the left hand see figure B.2 on page 257, for the right hand see figure B.3 on page 257):

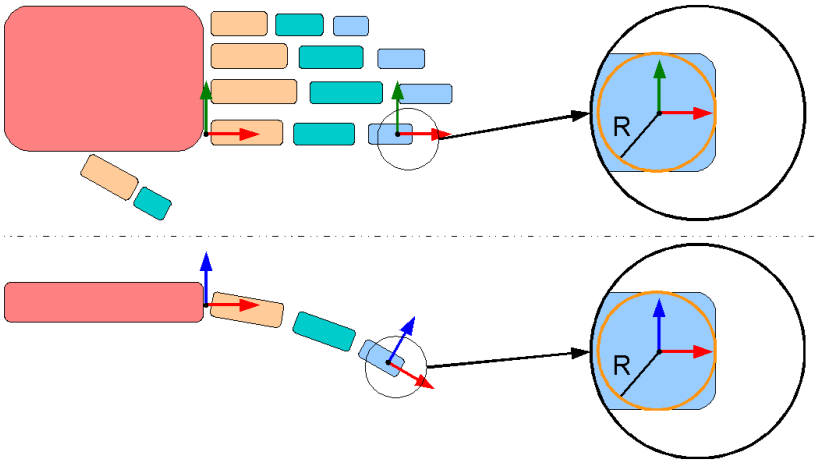


Figure B.2: Model of a human left hand

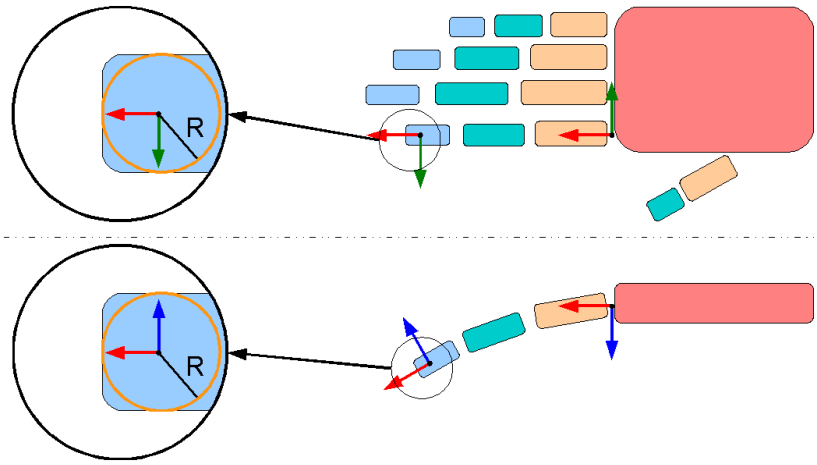


Figure B.3: Model of a human right hand

☞ **Please note that the +Z axis points up towards the back of the hand for a left hand, but down for a right hand!**

Finger coordinate system The finger coordinate system (used to measure the orientation of the outermost phalanx relative to the hand coordinate system) is defined by these rules:

- origin is the center of the (partial) sphere that forms the finger tip,
- the +X axis is oriented in direction of the outstretched finger,
- the +Z axis is defined to form a normal on the finger nail, pointing upwards,
- the +Y axis is defined with these specifications, resulting in a right-handed coordinate system.

For the left hand see figure B.2 on page 257, for the right hand see figure B.3 on page 257): Given the length of each phalanx and the angles between them, it is possible to reconstruct the entire finger.

☞ **The data shown in the Fingertracking display is NOT the position of the finger tip! For calculating the finger tip position you need to consider radius R like shown in figure B.2 on page 257.**

☞ **Note that the joint between innermost phalanxes and back of the hand can move! This corresponds to a bending of the hand's back.**

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 ('DTrackSDK', 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*')
`gl/glcal`	Fingertracking hands (6DOF + fingers)	*Settings* → *Output* ('*gl / glcal*')

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

[1] Coordinated Universal Time = Greenwich Mean Time

Flysticks, Measurement Tools ...). Bodies, that are not tracked by the system at that moment, don't appear in the output.

- 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:

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

  They contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, 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 $b_0 \ldots b_8$ form the rotation matrix R:

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

Note: to avoid problems with different definitions of the angles, we recommend to use only 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`.

Measurement data of all tracked standard 6DOF bodies (i.e. all 6DOF bodies except Flysticks, Measurement Tools ...) and all hybrid bodies. The output data contain values especially for hybrid bodies (tracking status, drift error), but can be used for any standard 6DOF body. 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:

`[id st er]`[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), status of the tracking (`st`, 0: not tracked, 1: inertial tracking, 2: optical tracking, 3: inertial and optical tracking), current drift error estimation (`er`, unit: [deg], estimate rising by 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 261) whenever possible.

Refer to chapter B.1.5.2 on page 254 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:

  `[id qu bt]` $[s_x\ s_y\ s_z\ \eta\ \theta\ \phi]$ $[b_0\ b_1\ b_2\ b_3\ b_4\ b_5\ b_6\ b_7\ b_8]$

  They contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, see below) and button information (`bt`, 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 with sphere tip

Identifier `6dmt2`.

Note: this format version replaces the older `6dmt` format (see B.2.9). Use it whenever possible.

Only available, if the Measurement Tool license is present for *DTrack2* (available since version v2.9.1).

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]` $[\sigma_{11}\ \sigma_{12}\ \sigma_{13}\ \sigma_{22}\ \sigma_{23}\ \sigma_{33}]$

  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. Covariance matrix (σ_{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.
- $b_0 \dots b_8$ form a rotation matrix according to the scheme described in chapter B.2.3 on page 259.
- $\sigma_{11} \dots \sigma_{33}$ denote the (symmetric) covariance matrix Σ of the Measurement Tool tip, given in units mm^2 :

$$\Sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{pmatrix}$$

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]
[8.178e-04 9.166e-04 1.084e-03 4.463e-02 9.025e-03 1.286e-02]
```

B.2.8 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:

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

  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 259.

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.2.9 Measurement Tools (Old Format)

Identifier `6dmt`.

Note: supported just for compatibility. It is recommended to use the newer Measurement Tool format `6dmt2` (see chapter B.2.7 on page 263) whenever possible.

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:

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

  They contain:

  1. ID number (`id`, starting with 0), quality value (`qu`, see below) and button information (`bt`, 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.
- $b_0 \ldots b_8$ form a rotation matrix R according to the scheme described in chapter B.2.3 on page 259.

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.2.10 Fingertracking

Identifier `gl` and `glcal`.

Only available, if the Fingertracking license is present for *DTrack2*

The output data include all necessary data to reconstruct the hand with all fingers and phalanxes. The output format in detail:

- The first number gives the number of tracked hands
- The data for each hand show up in blocks (several consecutive `[]`) like:

  `[id qu lr nf]` $[s_x\ s_y\ s_z]$ $[b_0\ b_1\ b_2\ b_3\ b_4\ b_5\ b_6\ b_7\ b_8]$ $[s_x^f\ s_y^f\ s_z^f]$ $[b_0^f\ b_1^f\ b_2^f\ b_3^f\ b_4^f\ b_5^f\ b_6^f\ b_7^f\ b_8^f]$ $[r_o^f\ l_o^f\ \alpha_{om}^f\ l_m^f\ \alpha_{mi}^f\ l_i^f]\ldots$

  They contain:

  1. ID number (`id`, starting with 0), a quality value (`qu`, unused), a number to distinguish left and right hands (`lr`, 0 to denote a left, 1 a right hand) and the number of tracked fingers (`nf`, always 3 or 5 with current hardware),
  2. Position of the back of the hand (s_i),
  3. Orientation of the back of the hand, given as rotation matrix (b_i, like standard bodies),
  4. For each finger (starting with the thumb):
     a) Position of the tip of the finger (s_i^f), given in the hand's coordinate system,
     b) Orientation of the outermost phalanx (b_i^f, like standard bodies), given in the hand's coordinate system,
     c) Radius of the tip of the finger (r_o^f), lengths of the phalanxes from the outermost (l_o^f) to the innermost (l_i^f) phalanx; angles between the outermost and the middle phalanx (α_{om}^f) as well as between the middle and the innermost phalanx (α_{mi}^f).

Note that the number of blocks vary because of the variable number of supported fingers per hand.

Example (one line):

```
gl 1 [0 1.000 1 5][-25.835 -221.498 135.999][0.603034 0.783519 0.149826 -0.729406
0.617627 -0.294114 -0.322981 0.068077 0.943954][1.4 -42.4 46.7][0.6110 0.3126 0.7273
-0.5609 -0.4773 0.6764 0.5586 -0.8212 -0.1163][11.6 23.7 -42.9 39.6 -22.6 59.4][36.4
-12.8 56.0][-0.4019 -0.0429 0.9147 -0.1640 -0.9794 -0.1180 0.9009 -0.1975 0.3865][9.2
18.2 -24.5 27.6 -73.2 46.0][39.1 14.8 58.1][-0.6598 -0.1451 0.7373 0.0650 -0.9885
-0.1364 0.7487 -0.0421 0.6616][10.4 20.7 -46.2 31.3 -74.7 52.2][36.3 31.3 55.9][-0.64
-0.0294 0.7627 0.0779 0.9915 0.1042 -0.7593 0.1268 -0.6383][9.2 18.5 52.0 27.8 65.0
46.3][30.1 52.2 39.9][-0.4985 -0.0406 0.8659 0.1099 0.9879 0.1096 -0.8599 0.1499
-0.4880][6.7 13.4 50.7 20.1 63.3 33.6]
```

Additional Informations

An optional extra output line (with own identifier) carries the number of defined hands. Example (one line):

```
glcal 1
```

B.2.11 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.2.12 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`.**

B.3 Input of Special Control Data via Ethernet

DTrack2 is using ethernet (UDP/IP datagrams) to receive special control data from other applications. They have to be sent to the fixed port 50110 of the corresponding *ART* Controller.

The following data types are supported:

Identifier	Type of data
`tfb`	Fingertracking Tactile control

B.3.1 Fingertracking Tactile Control Commands

Identifier `tfb`.

Only available, if the Fingertracking license is present for *DTrack2*

This command sets the strength of the feedback of tactile feedback devices, like FINGERTRACKING2 Tactile. General format:

```
tfb <n> [ <hand id> <finger id> <penetration depth> <strength> ] ...
```

- The first number 'n' after the identifier 'tfb' gives the number of tactile commands followed hereafter
- Each tactile command allows to change the feedback of one finger at one hand; it shows up in a block (within brackets []) that contains:
  1. Hand ID number ('hand id'): starting with 0, corresponds with H1...H4 of the DTrack2 frontend.
  2. Finger ID number ('finger id'): running from 0 (thumb) to 4 (pinkie).
  3. Penetration depth ('penetration depth'): a value between 0.0 and 1.0, denoting how deep the finger penetrates the virtual object.
  4. Strength ('strength'): a value between 0.0 and 1.0, corresponding to the strength of the feedback.

Feedback is turned off when time-out is reached (i.e. several seconds without sending commands). So repeat control commands even if values are not changing!

Please note, that with *DTrack2* prior v2.13.0 the protocol format was limited to just one tactile command per UDP packet (so <n> had to be 1).

Please note, that vibro-tactile feedback devices (i.e. 'FINGERTRACKING2 Tactile') do not show a penetration depth. For compatibility with legacy code, a given penetration depth is multiplied with the strength. This results in a down-scaling of the strength by a low penetration value.

Example (one line):

```
tfb 2 [0 0 1.0 0.5][0 1 0.8 0.5]
```

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