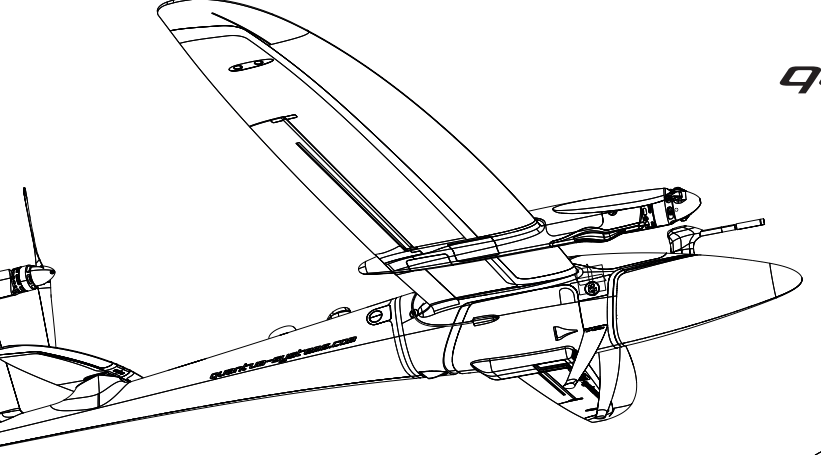
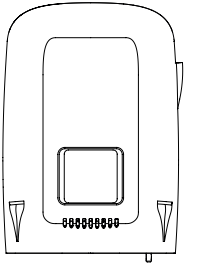


quantum systems

LIDAR
QUBE 240
USER MANUAL



01 GENERAL INFORMATION

Please read and follow these instructions carefully. All Quantum-Systems products are made for professional use only.

With the purchase of a Quantum-Systems product you agree with the terms and conditions. The applicable terms and conditions can be found at www.quantum-systems.com. These terms and conditions include regulations about liability and warranty.

Quantum-Systems GmbH reserves the right to make changes to specifications and product descriptions presented in this manual at any time without notice.

Applicable regulations
When using Quantum-Systems products always follow civil aviation regulations. Regulations can vary depending on the country and the region where the product is operated. Inform yourself about the applicable laws before using a Quantum-Systems product.

"Beyond Visual Line of Sight" (BVLOS) operations might be prohibited depending on the country or area. In some areas, the use of UAVs is completely prohibited. Inform yourself about the privacy laws concerning the use of Quantum-Systems products equipped with cameras. The use of the products and the compliance of the regional laws is the user's sole responsibility.

Technical support
For technical support please contact your reseller.

CE
Quantum-Systems GmbH declares that the products: UAV Battery pack, UAV aircraft system, QS RC Transmitter, QS Battery Charger and QBase Modem are in conformity with the CE regulations.

Address
Quantum-Systems GmbH
Dornierstrasse 11
82205 Gilching
Germany

www.quantum-systems.com

Disclaimer
The system and all components, including software and this description, have been manufactured with great care to ensure its proper function. They are provided on an “as is” and “as available” basis.

The system is guaranteed against malfunction in the framework of a normal use. The housing of the system is sealed and any unauthorized opening will void the guarantee.

02 SAFETY INFORMATION

Power supply

The Qube 240 must be powered only through the Trinity aircraft. Power specification is provided in the table below (Power supply specifications Table 1).

There is a risk of fire if the power supply does not meet the specifications or if the system is used outside of its operating temperature range. Quatum-Systems cannot be held responsible for any damage occurring while using any other power supply not recommended by the company.

Electrical Parameters	
Tension	9-36 VDC
Power	21.67 W

Table 1 : Power supply specifications

Laser Safety

The laser scanner instrument embedded in the Qube 240 is classified as Class 1 laser product in compliance with International Standard IEC 60825-1:2014 and the European Standard EN 60825-1:2014 Safety of Laser Products – Part 1: Equipment Classification and Requirements.

Class 1: Laser products that are safe during use, including long-term direct intra-beam viewing, even when exposure occurs while using telescope optics. Class 1 also includes high power lasers that are fully enclosed so that no potentially hazardous radiation is accessible during use (embedded laser product). (IEC 60825-1:2014, Sub-clause C.2).

Notice regarding overheating hazard

The Quatum-Systems systems were designed to be used while in motion. The use of Quatum-Systems LiDAR systems in static recording mode during period exceeding 25 minutes could lead to overheating-related damages. Such an operative mode must be avoided by the operator.

Hot Surface

Two silver aluminium dissipators are installed on the Qube 240. They are made to allow dissipation of internal temperature to the outside. It is therefore normal for these parts to be hot after a long mission. It is recommended not to touch the dissipator surfaces after a mission. Please consider their locations on the product shell below.

03 GENERAL SPECIFICATIONS

Weight	750 g (1.65lbs) (no power supply)
Size	L 14.3 x W 6.80 x H 9.30 cm
Power consumption	21.67 Wh
Max. relative humidity (at temperatures up to 31°C)	80 %
Pollution level	3

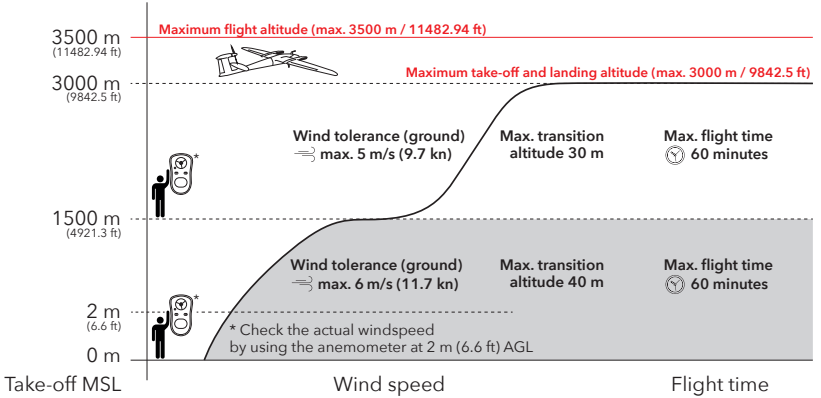
04 TECHNICAL SPECIFICATIONS

Scanner	Livox Avia
Wavelength	905 nm
Precision (1)	2 cm
Accuracy (2)	30 mm
Scanner Horizontal field of view	70.4°
Scanner Vertical field of view (Repetitive scanning)	4.5°
Point rate	240,000 / s
Echoes per shot	Up to 3
GNSS-Inertial solution	Applanix APX-15 UAV

(1) Precision, also called reproducibility or repeatability, accounts for the variation in successive measurements taken on the same target. Here precision value is obtained by averaging the precision from 3 flight levels @60, 90 and 120 mAGL. At each flight level, the precision is considered as the mean value of absolute elevation differences between 2 flight lines recorded in opposite directions over a nadir-located 40m² hard surface area.
(2) Accuracy is the degree of conformity of a measured position to its actual (true) value. Here accuracy value is obtained by averaging the accuracy from 3 flight levels @ 60, 90 and 120mAGL. At each flight level, the accuracy is considered as the RMSE value of the elevation differences between targets and the point cloud extracted from 2 flight lines recorded in opposite directions. Validation targets are located within a 40m wide corridor centered along the flight line axis.

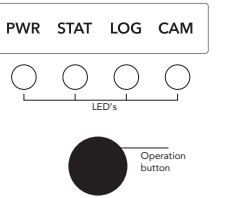
Maximum flight altitude and wind tolerance

These specifications differ from the use of the Trinity F90+ with other payloads.



05 PREPARATIONS

05.1 Qube 240 LED overview



1. **Power indicator (PWR):** It turns ON as soon the system is switched ON. Still green when battery is charged over 33%, alternating green and red when between 10% and 33% and still red when less than 10%.

2. **Operation button:** Quick press to start / stop recording (refer to Logging indicator). Long press (3 seconds) to shut the system down.

3. **Status indicator (STAT):** It turns ON few seconds after the system is switched ON. Its colour depends on its status:
   - **Orange flash** when the IMU is in synchronization phase and is acquiring satellites.
   - **Still orange** once the IMU is synchronized but needs more satellites for better accuracy (SBAS lock). A recording can be started at this stage.
   - **Still green** once the IMU is synchronized and enough satellites are visible. It can take several minutes for the LED to turn green.
   - **Still red** or off when problems in acquisition of satellites: impossible to fly and a message is written into the log file.

4. **Logging indicator (LOG):** It turns ON as soon as the system is switched ON. Starts to flash when the acquisition is launched. Its colour depends on the space available in the USB stick:
   - **Green** if the space available is > 30 GB.

- **Orange** if the space available is < 30 GB.
- **Still red** if less than 1 GB or USB stick is missing: no data is written.
  The LED status will be flashing after stopping a recording which means that the INS data is repatriated to the USB drive.
  Please note that several minutes are required for this process for long flights (1 hour recording = 4 min copy time).

- **Solid:** Ready to start recording or to turn off the system
- **Slow flashing:** recording
- **Fast flashing:** The data is written to the USB stick after stopping the recording. Then turns to solid green or orange light.

5. Camera indicator (CAM): CAM is not relevant of the operation of Qube 240 with the Trinity F90+.

05.2 Accessories provided

Qube 240 comes with several accessories, including:

- 1x Qube 240 payload compartment including GNSS antenna Trimble AV14
- 2x 128 GB USB stick
- 1x Ethernet cable
- 1x D-Sub cable
- 1x USB card for software installation
- 1x Quantum-Systems Microfiber Cloth
- User Manual

05.3 Mechanical installation & recommendations

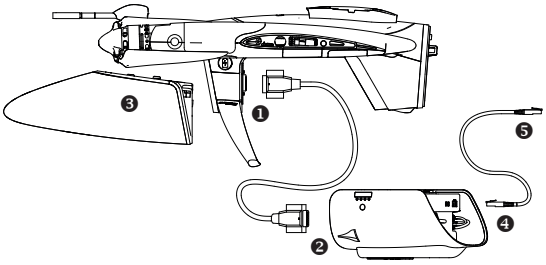
The Qube 240 was conceived to be perfectly integrated into the Trinity F90+ payload compartment. The Qube 240 is mounted inside the Trinity F90+ payload compartment and attached with x4 M4 screws. The Qube 240 is isolated from the aircraft vibrations through silicon dampers.

05.4 Lever arms

These settings are preconfigured upon delivery and do not have to be adjusted. This is only relevant for troubleshooting.
All lever arms are considered in the Qube 240 system (body) coordinate frame and are measured FROM the optical center of the scanner TO the GNSS antenna. The optical center of the scanner is located in the middle of the glass.

Lever arms input
By default, the Qube 240 is supplied with lever arms accurately measured for its integration inside the payload compartment of the Trinity F90+: X: -0.100 Y: 0.000 Z: -0.219

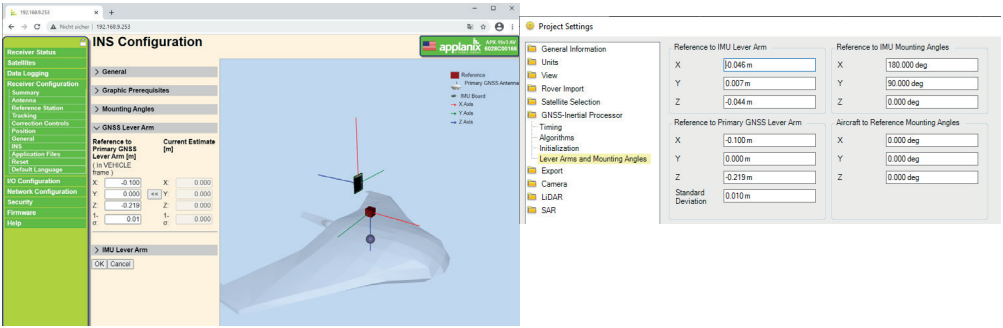
To check or input these values within the APX15 IMU please follow these steps:



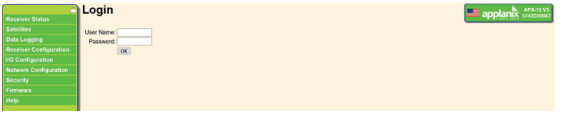
Step 1: Please connect the D-Sub cable to the main body.
Step 2: Please connect the otherside of the D-Sub cable to the payload compartment.
Step 3: Connect the battery to the UAV, the Qube 240 will turn on.
Step 4: Please connect the ethernet cable to the Qube 240.
Step 5: Please connect the other side of the ethernet cable to your computer/laptop.
Step 6: Set the PC to a static IP address.

Windows:

- Open Control Panel / Network and Internet / Network Connections
- Right-click on your Ethernet adapter and select Properties
- In the new window, select Internet Protocol Version 4 (TCP/IPv4) and click on Properties.
- In the Internet Protocol Properties window, tick “Use the following IP address:” and enter the desired IP address in the range 192.168.9.10 to 192.168.9.120.
- The Subnet mask will automatically be configured in 255.255.255.0, which is fine.
- Click OK and then Close.

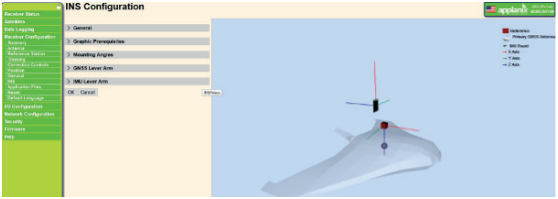


Step 7: Open a web browser and type in the address bar the IP address: 192.168.9.253

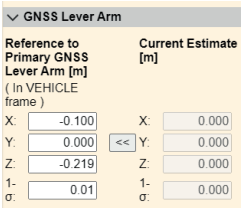


Step 8: Enter login (admin). The password “password”. DO NOT CHANGE THESE CREDENTIALS.

Step 9: In the menu on the left side, select Receiver Configuration > INS

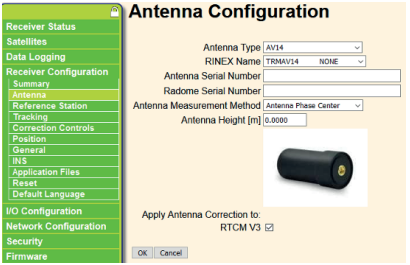


Step 10: Enter there the values measured previously in the GNSS lever arm section:

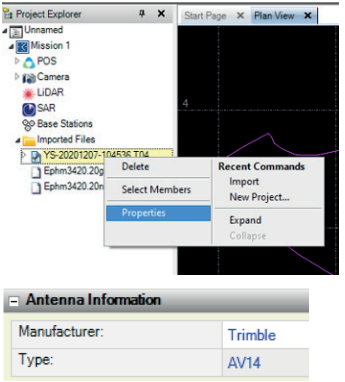


Step 11: Press OK on the bottom of the web page to validate your lever arms. The APX needs to reboot to consider the new values.

Step 12: Check if the antenna model is correct: on the menu go to Receiver Configuration > Antenna.
Check that your antenna type is AV14 and the "Antenna Measurement Method" is set to "Antenna Phase Center". The antenna height should be left to 0.



It is also possible to check the antenna model after the acquisition and eventually change it in the Applanix software solution. After having loaded the T04 in POSPac, go to "Imported Files" in the Project Explorer; right-click the T04 file and choose Properties. The Properties panel open on the right, in the "Antenna Information" panel you can change your GNSS antenna model:



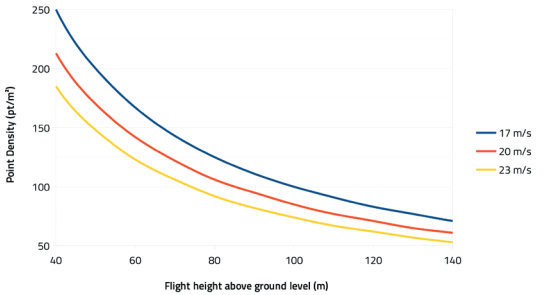
05.5 Mission planning

This section details flight planning recommendations when using the Qube 240 on the Trinity to ensure the best LiDAR results.

General

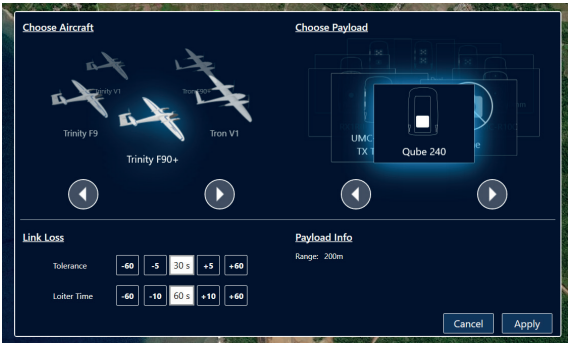
- The field of view of the Qube 240 is 70.4°. It is recommended using the entire field of view and not reducing it. The swath is then approximatively 1.4 times the flying height.
- Please consider the varying ground speed when flying the Trinity F90+ in headwind or tailwind. The graph below indicates the density, over all the extent of the swath, in respect of the flight altitude for three different ground speeds: 17,20 and 23 m/s. It may vary upon the characteristics of the surveyed terrain in terms of vegetation, slope, reflectivity.

Point density by ground speed and altitude.



QBase – Mission Settings

Please open Mission Settings in the QBase planning view and select the Trinity F90+ and the Qube 240.
By default the side overlap is set to 30 % and the airspeed to 18 m/s.
To facilitate the adjustment process which can be conducted with the CloudStation Strip Adjustment module we recommend to increase the overlap to 35 % – 40 %.

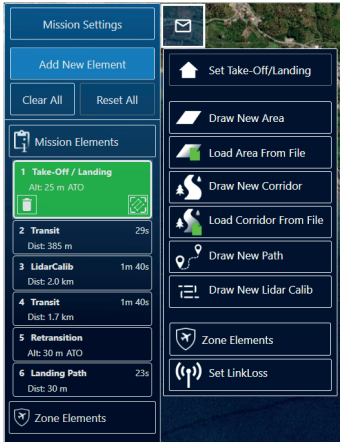


IMU Initialization Figure
For the IMU to be correctly initialized, it is mandatory for the Trinity F90+ fly the initialization figure at the beginning AND at the end of the flight. The main objective is to provide enough acceleration to initiate the IMU.

QBase provides the possibility to integrate the pre-planned initilization figure before and after the actual mission.

1. Add New Element

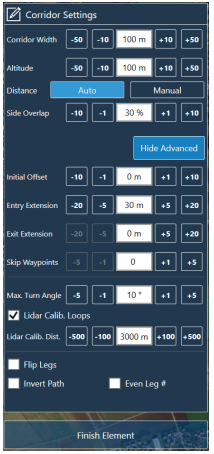
2. Draw New Lidar Calib: The path is created by defining one waypoint trough a click on the map.
Dont't forget to insert the calibration figure before and after the mission.



Area and Corridor Mission Planning

For the general instruction of planning an area mission or a corridor mission please follow the chapter 7.3 of the Trinity F90+ user manual.

When performing a corridor mission it is recommended to activate the Lidar Calib Loops and set the distance to 3000 meters. This procedure keeps the IMU correctly initialized during the flight.



In addition please consider that the recommended flight altitude is 100 meters.
(AGL) when using the Qube 240 (default setting).

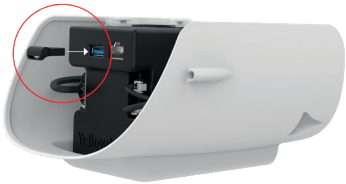
The maximum flight altitude in order to obtain good results is 140 meters (AGL).
For the survey of powerlines it is recommended to not fly higher than 40 meters above the lines.

06 FIELD OPERATIONS

06.1 Running Qube 240

Step 1: Please setup the Trinity F90+ including the payload compartment and the battery according to to chapter 8 in the Trinity F90+ user manual.
Remove the red protection cover from Qube 240 “Remove Before Flight”.

Step 2: For the post processing of the Lidar data it is mandatory to have a PPK suitable Rinex file. This can either be recorded during the flight via iBase or an external GNSS station or be downloaded after the flight via a remote reference station if available in the flying area.



Step 3: Make sure the USB stick (128 GB) is plugged into the system, named YELLOWSCAN and is formatted in NTFS format. Make sure there is enough available space for the flights. A **orange flash** will indicate there is less than 30 GB of memory available on the USB stick.
Please make sure to only use the provided USB stick.

Step 4: The Status LED turns ON: **orange blinking** when IMU is in synchronization phase.
The Logging LED lights ON: **red flash** first to check that the USB stick is present and correctly engaged. Then its colour depends on the space available in the USB stick.
Still green when the available space is over 30GB.
If **still orange**, check your USB stick has enough available space for your flight (600 MB per minute). If **still red**, please check there is an USB stick in the system or if it is correctly inserted. Otherwise, change for an USB stick with enough available space. A reboot might be necessary for the lidar to consider the newly inserted USB drive.

Step 5: Depending on the satellite's reception and SBAS correction availability, the Status LED switches to orange and eventually to green after a few minutes.
Step 6: The system is now ready to operate.
Step 7: Press the black button once. Successful begin of measurement is indicated by „LOG" LED **flashing slowly green.**
Step 8: Please allow few minutes of static recording before take-off. Continue with the flight operation according to chapter 9 (Trinity F90+ user manual).
Step 9: After landing please press the black button to stop recording.
Step 10: The Log LED will flash fast until the data is transfered to the USB stick. Log completion is indicated by "LOG" LED turning to **solid green.**
Step 11: To turn off the Qube 240 please keep the black button pressed for 3 - 4 seconds until STAT, LOG and CAM LEDs are off.
Step 12: Wait an additional 5 seconds before disconnecting the battery from the UAV.

Do not disconnect the battery from the Trinity F90+ before having switched off the Qube 240 as this will shut the power feed to the lidar unit!

06.2 Data files

Per mission there are three files in a folder on the USB stick named YS-YYYYMMDD-HHMMSS, according to the date and time of the start of the record. The files are named like the folder in which they are stored:

- *.ys: the IMU+GPS data (decimated for quick post-processing), in binary format
- *.lvx: the scanner data. Its size is approximately 600 MB / min
- *.t04: the complete IMU+GPS data in Applanix (Trimble) binary format

At the root of the USB stick there is a log file, named **logfile.txt.** It contains events about the system behavior during the acquisition. It is made up of several fields on each line:

[SECONDS] [INFO|WARNING|ERROR] [CODE] : Description [SECONDS]
The field [SECONDS] indicates when the corresponding event occurs according to the Applanix time setting: GPS seconds of the week. Therefore, it will be possible, in case of errors or warnings, to observe closely in POSPac what happened at this time and so to look at the incidence of the problem in the acquisition. See the annexe for all the possible message and the corresponding explanation.

In case of a missing T04 file in the USB stick, it is possible to retrieve it directly in the system. To do so you must connect to the APX15 following the procedure explained in chapter 9.4.

Once on the welcome Applanix page:
- In the menu on the left side, select Data Logging.
- Click on /Internal and browse the daily folder to find the record with the name corresponding to your date of acquisition. Please note that time is in UTC reference.
- Click on the file name to start downloading the file and save it in your project folder.

07 PROCESSING

To generate and visualize the point cloud from the retrieved data, please refer to the software documentation provided, including CloudStation and POSPac user manuals.

In order to postprocess the following data is required.
.21n
.21o
.ys (from Qube 240 USB stick)
.lvx (from Qube 240 USB stick)
.t04 (from Qube 240 USB stick)

The .21n and .21o can be generated from a Rinex file via QBase 3D. Therefore please select Tools → iBase Converter within QBase.
The converter is suitable for any Rinex file including the Rinex file generated from the iBase.

08 MAINTENANCE

08.1 Health check

Purpose
If the unit has experienced a brutal shock during a crash or a hard landing, the system will likely need to be re-calibrated as the shock might have introduce a shift to the existing alignment. Depending on the intensity of the crash it might be essential to return the unit back for repairs where it will undergo a thorough check and calibration process.

To complete the yearly health check calibration process, required to fly over an area, adopting a certain flight plan as described below and transferring the data back to support team who will be checking the calibration angles.

Flight route
The calibration process produces the 3 attitude angles required to correct the alignment of the IMU relative to the scanner: roll, pitch and yaw. These angles are measured by comparing how 3D features display from one flight line to another.

The calibration process therefore requires that:

- the calibration site is not completely flat and contains 3D objects such as buildings (ideally with double pitched roofs)
- the flight plan needs to be conducted according to a certain pattern
- the flight altitude should be around 90m above the ground

To complete the calibration flight plan please perform the Lidar Calib procedure as per normal mission flight. This should include the IMU initialization method.
Best calibration angles are generated from flying over double pitched roof buildings with a specific flight pattern.

Prior completion of the flight, please get in contact with your reseller.

Data Transfer
Once the flight has been completed, gather the data from the USB stick (.ys, .lvx and .T04) and from the GNSS base station (.YYO for RINEX). It is recommended to zip the files and use a file transfer website (Dropbox, Wetransfer,...) Please get in contact with your reseller for the further procedure.

08.2 System cleaning

In order to preserve the integrity of the scanner glass it is recommended to clean its surface regularly. To do so, use pressurized air directed to the glass to remove particles from the glass surface. Subsequently use a dry clean cloth and wipe the glass gently (microfiber cloth supply with the system). When not in use, make sure to slide the scanner cover in its closed position to ensure the protection of the scanner glass.

09 TROUBLESHOOTING

09.1 Field operations

Issue observed	Corrective measure
Power LED does not light up	Check power connection from Trinity to Qube 240
After pressing switching the Trinity ON, the status LED keeps blinking and never stays still	Check GNSS connection is correctly made between antenna and LiDAR unit. Check connectors, cables and antenna.
The Logging LED is red.	Check the USB stick is correctly plugged in and the scanner slide is open. Otherwise, there is only 1GB left on the USB stick. Change it.
Upon return of the UAV, all LEDs are off	Data is probably incomplete and would need a re-flight. Check power connection with the Trinity
Upon return of the UAV, the logging LED is red.	USB stick is full. Empty it and complete the flight again.
Upon return of the UAV, the status LED is red.	Check the log file. If you have the E026 error, you have encountered a PTP (Precision Time Protocol) error. If the flight was short or if the error happened at the end, the drift of time should not be problematic. Check your data in the field.
The Status LED is red for a few seconds and then green or orange.	Check the log file. It is probably due to a E027 error. The scanner is disconnected for a few seconds. Depending on your flight pattern, speed and AGL you may not see any differences because of the Mapper's high density. Check your data in the field.

09.2 Data quality and coverage

Issue observed	Corrective measure
I do not have all the data in the raw files.	Your USB stick is probably not in NTFS format therefore there is a limitation in the size of files. You must format it in NTFS and redo the acquisition.
I have missing returns over patches of the AOI (water, tare material, coal-like rocks, train ballast….)	Check for water saturated patches or dark materials including bitumen road (new bitumen tends to be darker and does not generate much returns at higher altitude), coal & dark sand, dark train ballasts, black plastic tarpaulin... Fly lower and potentially slower
I can't see the electric power lines…	Power lines should be visible under certain flight conditions Recommendations are to fly parallel to the line as much vertical from the line as possible less than 40m from the line.
Data is very weird looking, things are in place but angles seem to be wrong	This could orientate the trouble towards a non-initialized IMU which would suggest that the initialization figure was not well completed – not enough acceleration, not enough turns.

09.3 Log file

The lines with a date at [000000.00] are about events that take place before the time synchronization of the system.

Warning messages

Code	Explanation
W001	Battery is overheating. The temperature is over 68°C (155°F).
W002	Battery charge is under 10%.
W003	Computer is overheating. The temperature is over 70°C (158°F)
W004	GPS SPS mode, fix valid. The acquisition has been launched while Status LED was orange.
W005	The IMU alignment status is “coarse leveling”
W006	The IMU alignment status is “degraded solution”. This is the status before the IMU initialization.
W007	The IMU alignment status is “aligned”. You should have this status after the IMU initialization.
W008	Scanner is overheating.
W009	Low space available on the USB stick. Under 2GB.
W010	System is overheating. The internal sensor is over 60°C (140°F).
W011	80% of humidity. The internal sensor is over 80% of humidity.

Error messages

Code	Explanation
E001	GNSS fix not available. No GNSS.
E002	The IMU alignment status is "GPS only".
E003	The IMU alignment status is "unknown".
E004	Can't ping IMU. This error happens when the system is initializing after having switch on the system.
E005	No data received from the scanner. Scanner does not send any data.
E006	Can't synchronize time for the scanner. Scanner does not send any data. Therefore, the time synchronization is not possible.
E007	IMU SetTime failed to receive APX data. IMU does not send any data. Therefore, the time synchronization is not possible.
E008	IMU runs, failed to receive APX data. IMU does not send any data while running.
E009	USB stick is almost full. Available space is under 500MB.
E010	Failed to init HMI. Cannot initialize the HMI (LEDs, buttons …)
E011	Set_system_time data link socket error. Cannot connect to the IMU in for setting the time.
E012	runAPX error: cannot get APX info. Cannot get serial or model from the IMU.
E013	runAPX data link socket error. Cannot connect to the IMU.
E014	Failed to start T04 recording.
E015	APX failed to log data.
E016	Failed to stop T04 recording.
E017	Cannot connect to APX command socket.
E021	Statvfs is not working. Cannot get information for USB stick.
E022	Can't connect to the battery. Impossible to get the temperature and the charge level of the battery.

E023	Error can't set system time. The system cannot set the computer clock with the IMU time.
E024	Error scanner not properly initialized. The system time of scanner is not correct.
E025	Camera discovery error.
E026	Scanner is not in sync with time. Error if the PTP is down.
E027	Scanner is disconnected. Check your data if you have empty areas.
E028	Error retrieving T04 file. Check the warning.log file.

09.4 T04 copy warning.log file

Should the T04 file transfer from the Applanix to the USB stick encounter a problem, a warning.log file is created. It contains the origin of the problem. Remember to not change anything in the INS parameters, apart the lever arms. Do not change the password. Remember that the USB stick must be called YELLOWSCAN and be in NTFS format.

"T04 ERROR : Can't get Month" // Error in save format on APX (Param have changed)
"T04 ERROR : Can't get Day" // Error in save format on APX (Param have changed)
"T04 ERROR : Can't get file" // File not found on APX (The APX folder is empty)
"T04 ERROR : File not found" // File not found on APX (File in the APX folder not found)
"T04 ERROR : Can't download file" // Can't download the file from the APX
"T04 ERROR : Can't move file" // Can't move / rename the T04 file
"T04 ERROR : Can't cd /YELLOWSCAN" // Can't access the USB Stick
"T04 ERROR : Incorrect login" // Can't login into the APX
"T04 ERROR : Size of T04 is not the same between APX and USB Stick"

Examples

As an example, here the log file after a mission with no problems:

[000000.00] INFO ********** YELLOWCOMMANDER **********
[000000.00] INFO [I001] : Starting system OQ240XX - #Name of your system
[138362.06] INFO [I037] : Unit ready
[138456.73] INFO [I019] : Quick press on yellow button
[138456.73] INFO ********** /YELLOWSCAN/YS-20210308-142718/YS-20210308-142718 **********
[138456.73] INFO [I008] : Starting acquisition
[138456.74] INFO [I003] : GNSS good fix
[138456.74] WARNING [W006] : IMU lock degraded solution
[138456.74] INFO [I013] : Recording T04 file...
[138456.74] INFO [I014] : APX logging data to /YELLOWSCAN/YS-20210308-142718/YS-20210308-142718.ys
[138456.78] INFO [I028] : Livox logging data to /YELLOWSCAN/YS-20210308-142718/YS-20210308-142718.lvx
[138476.88] WARNING [W007] : IMU lock aligned #Initialization phase
[139219.33] INFO [I019] : Quick press on yellow button
[139219.37] INFO [I007] : Stopping acquisition
[139219.38] INFO [I015] : We have to stop logging
[139219.38] INFO [I030] : Livox is stopping logging
[139219.38] INFO [I035] : T04 file successfully copied
[139253.02] INFO [I011] : Long press on yellow button
[139253.03] INFO [I016] : Stopping T04 file record.
[139253.03] INFO [I017] : APX disconnected.
[139253.03] INFO [I012] : HMI disconnected
[139253.03] INFO [I009] : Stopping system
[139253.03] INFO ********** THE END **********

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