User Manual

xNAV
GNSS-aided inertial
measurement system

Measure with confidence ⟳**OXTS**

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Revision

Document Revision: 210310 (See Revision History for detailed information).

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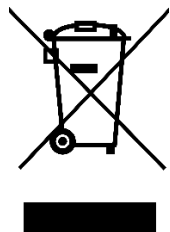Fax: +44 (0) 1869 251 764

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Contents

Scope of delivery

Table 1 lists the standard items delivered with each xNAV. Everything required to operate the xNAV successfully is included. Please ensure everything is present upon delivery.

Table 2 lists a number of optional parts that may be used with an xNAV. For more information on these components please contact your OxTS representative or email sales@oxts.com.

Table 1. Summary components supplied with an xNAV

Qty.	xNAV200 xNAV500	xNAV250 xNAV550
1	xNAV system unit	xNAV system unit
1	USB with software and manuals	USB with software and manuals
4	90° mounting brackets	90° mounting brackets
1	xNAV user manual	xNAV user manual

Table 2. Compatible xNAV accessories

Part	Description
RT-Strut	Designed to quickly and securely provide a mounting location inside a road vehicle.
RT-Strut mounting bracket	Quickly attach the xNAV to an RT-Strut.
RT-UPS	An uninterruptible power supply capable of powering the xNAV for up to 1 minute after power is lost. Input 9 - 48 V dc.

Introduction

Thank you for choosing the xNAV. It is a high-performance GNSS-aided inertial navigation system designed to meet the tough demands of aerial and ground-based surveying applications - especially where space and weight are important. As a one-box solution it is quick and easy to install and configure but does not compromise on accuracy or reliability.

Utilising dual antennas, DGPS corrections, tight-coupling and advanced gx/ix processing technology the xNAV delivers up to 2 cm position and 0.1° heading accuracy (2 m antenna separation) with up to 250 Hz output for all measurements. 4 GB of raw data (max. 2 GB per file), corresponding to over 24 hours' worth of IMU+GNSS data can be logged and stored internally and quickly downloaded via Ethernet. The xNAV5** models can output all measurements in real-time with very low latency. The xNAV2** models log data automatically which can be post-processed later with the powerful software included with NAVsuite.

This manual covers the installation, configuration and basic operation of the xNAV. Separate manuals are provided for the post-processing and graphing software of NAVsuite. An xNAV quick start guide is available on the OxTS website, but we suggest reading the entire manual in order to become thoroughly familiar with the product. It is beyond the scope of this manual to provide details on service or repair. Contact OxTS support or your local representative for any customer service-related enquiries.

Related documents

Additional manuals provide further information on some of the software and communication types mentioned in this manual. TableTable 3 lists related manuals; all of which can be downloaded from the support website (https://support.oxts.com).

Table 3. Supplementary manuals

Manual	Description
NAVdisplay Manual	NAVdisplay can be used to view INS measurements on a PC in real-time or by replaying existing data files. It provides a useful method of checking the status of your INS
NAVgraph Manual	NAVgraph is used to plot, analyse and export measurement data once processed
NCOM Manual	NCOM is a propriety format developed by OxTS that is used in our products. The NCOM manual provides information about decoding and using the NCOM format
NCOM C Code Drivers	This ZIP file contains a collection of C functions that can be used to decode the binary protocols from the INS
NMEA 0183 Description	NMEA description manual for the NMEA outputs found on our INS products
NAVsolve Manual	NAVsolve can download data from an INS and process it using a number different technologies to extract the best possible accuracy. DGNSS corrections can also be applied
RT-Base S	Explains how to set-up and use the RT-Base S base station to achieve RTK integer operation mode

Conformance notices

The xNAV complies with the radiated emission limits for 47CFR15.109:2010 class A of part 15 subpart B of the FCC rules, and with the emission and immunity limits for class A of EN 55022. These limits are designed to provide reasonable protection against harmful interference in business, commercial and industrial uses. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Re-orient or relocate the receiving antenna

- Increase the separation between the equipment and the receiver

The xNAV incorporates a GNSS receiver. Any GNSS receiver will not be able to track satellites in the presence of strong RF radiations within 70 MHz of the GNSS frequencies.

The xNAV conforms to the requirements for CE.

Any use or misuse of the xNAV in a manner not intended may impair the protection provided. OxTS is not liable for any damages caused by the misuse of the equipment.

Regulator testing standards

- 47CFR15.109:2010 class A (radiated emissions)
- EN 300 440-1 v1.6.1, test methods 8.3.4 (radiated emissions)
- EN 55022:2010
- EN 55024:2010
- EN 61326-2-1:2006 according to the requirements of EN 61326-1:2006
- EN 61326-1-1:2013 according to the requirements of EN 61326-1:2013
- EN 301 489-3 v1.4.1 according to the requirements of EN 301 489-1 v1.9.2
- IEC 61010-1:2010 3rd ed. (safety)

Basic information

The xNAV has been designed to be simple and easy to operate. The front panel and LEDs convey some basic information that aid in configuration and troubleshooting. Once powered, the xNAV requires no further input from the user to start logging data. This section covers some basic information required to operate an xNAV.

Precautions

The xNAV is designed to dissipate heat into the case. As such it may be hot after periods of operation. The system should be allowed to cool after operation and caution should be taken when handling. If the system is used in situations with high operating temperatures, forced convection may be required.

Model variations

There are a number of models available in the xNAV series. All models use the same inertial measurement unit (IMU), have dual GNSS receivers as standard, and output data at up to 100 Hz as standard (or up to 250 Hz with an optional upgrade). The differences between models are summarised below.

- xNAV200: Single frequency (L1) receivers. GPS tracking, optional GLONASS tracking. Logging only.
- xNAV500: Single frequency (L1) receivers. GPS tracking, optional GLONASS tracking. Real-time outputs and logging.
- xNAV250: Dual frequency (L1, L2) receivers. GPS tracking, optional GLONASS tracking. Logging only.
- xNAV550: Dual frequency (L1, L2) receivers. GPS tracking, optional GLONASS tracking. Real-time outputs and logging.

Front panel layout

Figure shows the layout of the xNAV front panel and Table lists details of the parts labelled.

Figure 1. Layout of the xNAV front panel

The **main connector** (6) is keyed, so the user cable will only engage when correctly orientated. It is self-latching to avoid accidental removal. Do not pull on the user cable to remove it as damage may occur.

Table 4. xNAV front panel descriptions

Label no.	Description
1	GNSS LED
2	Status LED
3	Power LED
4	Primary antenna connector
5	Secondary antenna connector
6	Main connector

LED definitions

Three LEDs set into the front panel of the xNAV show the system's state when power is applied. Table 5, Table 6, and Table 7 give details on the meanings of the states of each LED.

Table 5. GNSS LED states

Colour	Description
Off	GNSS receiver fault (valid only after start-up).
Red flash	GNSS receiver is active, but has been unable to determine heading.
Red	The GNSS has a differential heading lock.
Orange	The GNSS receiver has a floating (poor) calibrated heading lock.
Green	The GNSS receiver has an integer (good) calibrated heading lock.

Table 6. Status LED states

Colour	Description
Off	The operating system has not yet booted and the program is not yet running. This occurs at start-up.
Red-green flash	The xNAV is asleep. Contact OxTS support for further information.
Red flash	The operating system has booted and the program is running. The GNSS receiver has not yet output a valid time, position, or velocity.
Red	The GNSS receiver has locked-on to satellites and has adjusted its clock to valid time (the 1PPS output will now be valid). The strapdown navigator is ready to initialise. If the vehicle is travelling faster than the value set for "Initialisation speed" during configuration then the strapdown navigator will initialise and the system will become active. If static initialisation has been enabled the system will initialise once the GNSS receiver has determined heading, even if the vehicle is stationary or moving slowly.
Orange	The strapdown navigator has initialised and data is being output, but the system is not real-time yet. It takes 10 s for the system to become real-time after start up.
Green	The strapdown navigator is running and the system is real-time.

Table 7. Power (PWR) LED states

Colour	Description
Off	There is no power to the system or the system power supply has failed.
Green	Power is applied to the system.
Orange	The system is powered and traffic is present on Ethernet.

Co-ordinate frame conventions

The xNAV uses a co-ordinate frame that is popular with most navigation systems. Figure 2 shows how the axes relate to the xNAV box. All measurements to and from the xNAV should be made from the measurement origin point shown in Figure 2. The origin point is the same for all xNAV models.

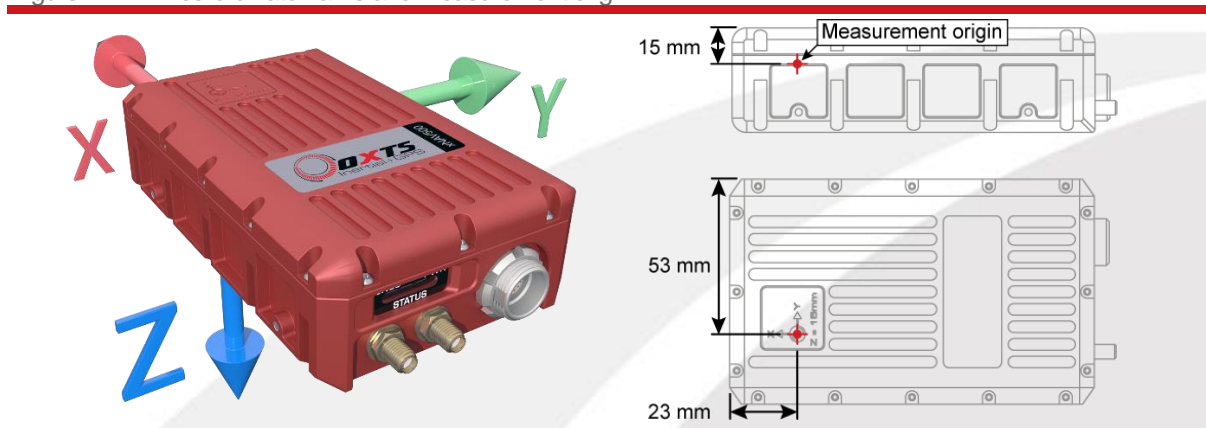Figure 2. xNAV co-ordinate frame and measurement origin

Table 8 lists the directions that the axes should point for zero heading, pitch and roll outputs when the default mounting orientation is used.

Table 8. Direction of axes for zero heading, pitch and roll outputs

Axis	Direction	Vehicle axis
x	North	Forward
y	East	Right
z	Down	Down

If the axes of the xNAV and the vehicle axes are not the same as those listed in Table 8, then they can be aligned by reconfiguring the xNAV for a different mounting orientation using the NAVconfig software.

If the RT-Strut is being used to mount the xNAV in the vehicle then NAVconfig will have to be used to configure the orientation or the xNAV will not work correctly. Page 19 gives more information on configuring the orientation of the xNAV in a vehicle.

Ethernet configuration

The xNAV communicates primarily via Ethernet. In order to communicate via Ethernet, each xNAV is configured with a static IP address that is shown on the delivery note. If the delivery note is unavailable, the default IP address normally takes the form 195.0.0.*sn* - where *sn* is the last two digits of the xNAV's serial number. The serial number can be found on the bottom of the xNAV or on the delivery note.

To transmit data between an xNAV and PC, the IP address of the PC must be in the same range as the xNAV. We suggest configuring the PC with a static IP address in the range 195.0.0.1 to 195.0.0.10 and a subnet mask of 255.255.255.0.

To change the IP address of the computer, follow these steps (applies to Windows Vista/7/8):

1. Open the **Control Panel** from the Start menu.
2. In category view, select **Network and Internet** and then **Network and Sharing Centre**.
3. Select **Change adapter settings** in the side panel.
4. Right-click the Ethernet option and select **Properties**.
5. In the window that opens, navigate the list to find **Internet Protocol Version 4 (TCP/IPv4)**. Select it and click **Properties**.
6. In the TCP/IPv4 Properties window (Figure 3), select **Use the following IP address** and enter the IP address and subnet mask to use.
7. Click **OK** when finished.

Figure 3. Configuring the computer's IP address
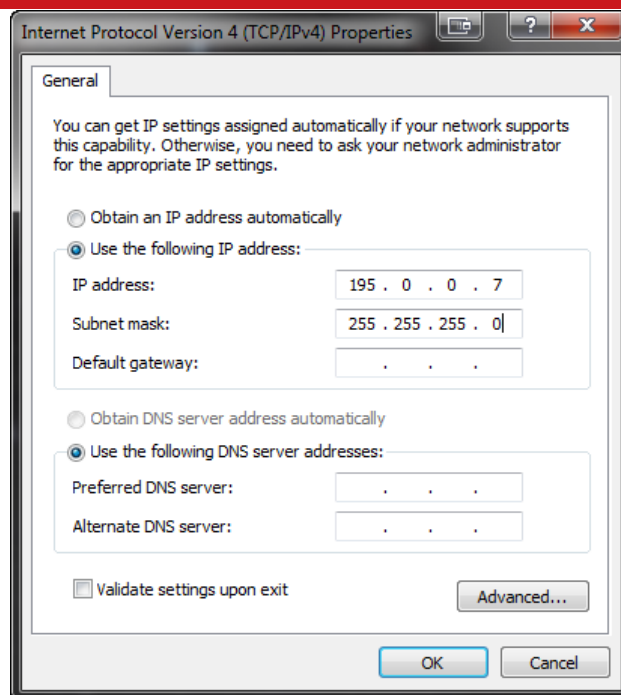
Once the computer is configured the IP address of an xNAV can be found by running NAVdisplay software; this will display the IP address of any system connected.

Note that it is possible to change the IP address of xNAV systems. If the IP address has been changed then NAVdisplay should still be able to identify the address that the xNAV is using as long as the PC has a valid IP address and this is not the same as the xNAV's.

PTP Master

Currently there is no GUI way of configuring precision time protocol (PTP) settings but this will be implemented in a future release of NAVsuite.

Use the following guide on our Support site for more information on setup:

https://support.oxts.com/hc/en-us/articles/360016515759-PTP-Quick-Start-Guide-Beta-

To use PTP on your xNAV v3 device ensure that you have the PTP feature code purchased and enabled and do the following:

- Upgrade the firmware of the OxTS INS
- Upload a ptpd.conf file and the leap-seconds.list file to the unit
- Ensure the PTP feature code is enabled
- Append -enable_ptp to mobile.cfg
- Reboot the unit

For the PTP functionality to work, the unit must have the primary GNSS antenna connected and be tracking satellites. For optimum performance, the unit must also be initialised.

All of the other PTP settings are configured with the "ptpd.conf" file. The options are documented (for example, https://manpages.debian.org/testing/ptpd/ptpd.conf.5.en.html), though some are not supported. See the above-mentioned support article for an example of this. To edit the configuration, edit the ptpd.conf file and then upload it again to the unit and reboot it.

PTP packets will be viewable in software such as Wireshark as PTPv2 protocol packets.

OxTS devices get their time solution from GNSS satellites which use very accurate atomic clocks. The time that OxTS devices receive from the satellites is the number of seconds since midnight on 5th January 1980. This is known as the GPS epoch and from this the device can calculate the current date and time.

By default, when an OxTS device is used with PTP, it will be using the GPS epoch.

Not all devices expect timestamps to be in the GPS epoch. Table 9 shows a list of commonly used time modes:

Table 9. Epoch time configurations

GPS	Time in seconds since the GPS epoch (1980-01-01 00:00:00 UTC), same as NCOM.
Unix	Time in seconds since the Unix epoch (1970-01-01 00:00:00 UTC).
UTC	Time in seconds since the Unix epoch (1970-01-01 00:00:00 UTC), including leap seconds.
PTP	Time in seconds since the PTP epoch (1969-12-31 23:59:51 TAI), including leap seconds.

To get the correct date and time from a timestamp, it is important to know which epoch is being used.

If the PTP device being synchronised to the OxTS device does not use the GPS epoch, it is possible to configure the OxTS device to output PTP timestamps from a different epoch (this will not change the timestamps in the NCOM stream).

This is done by adding the relevant advanced command in NAVconfig (Modify Configuration>Advanced>Commands). Table 10 shows time epoch advanced commands.

Table 10. Time epoch advanced commands

GPS	-ptp_time_mode_gps
Unix	-ptp_time_mode_unix or -ptp_custom_offset_315964800
UTC	-ptp_time_mode_utc or -ptp_custom_offset_315964782
PTP	-ptp_time_mode_ptp or -ptp_custom_offset_315964819

In Table 10, you can see that the different time modes can be reached by adding different offsets to the GPS timestamps. Similarly, the -ptp_custom_offset_%d command can also be used to access time modes not listed above by finding the correct offset (which will be the number of seconds between the different epochs).

For example, during internal testing of the PTP feature, a data was collected with a Hesai Pandar40P and an RT3000 v3.

Time synchronisation was achieved using PTP. The RT3000 v3 was in GPS mode but the Hesai Pandar40P was expecting timestamps in UTC. The following command was required to generate an accurate pointcloud:

- lidar_time_offset=315964785000000000

If the RT3000 v3 was instead in Unix time mode, the following command would be required:

- lidar_time_offset=-18000000000

Finally, ensure that your survey device is correctly configured to anticipate PTP time synchronisation.

Software installation

Included with every xNAV is a USB containing the software package NAVsuite. This package contains a number of programs required to take full advantage of the xNAV's capabilities. Table 11 lists the contents of NAVsuite.

Table 11. Installed software components

Icon	Software	Description
	NAVdisplay	Replacement for Enginuity. Features the same functionality with an updated GUI and improved usability.
	NAVconfig	Used to create, send, and receive configurations from OxTS products. As configurations vary between products there is no manual for NAVconfig. The options relevant to the xNAV are covered in this manual on page 21.
	NAVsolve	Used to download raw data files from the xNAV and post-process the data. The configuration can be changed and differential corrections can be applied before the data is reprocessed. It can export NCOM, XCOM and CSV file formats.
	NAVgraph	Used to graph NCOM, XCOM and RCOM files created in post-process. It can display graphs, cursor tables and map plots and data can be exported in CSV or KML (Google Earth) format.
	Manuals	This folder contains PDF versions of relevant OxTS manuals. Other manuals can be downloaded from the OxTS website, https://support.oxts.com/hc/en-us.

To install NAVsuite, insert the USB and run **NAVsetup.exe**. Follow the onscreen instructions to install the software. By default the installer creates the program files in C:\Program Files (x86)\OxTS on 64 bit operating systems or C:\Program Files\OxTS on 32 bit operating systems.

The first time some OxTS applications are run, a firewall warning message similar to that shown in Figure 4 may be triggered. This is because the program is attempting to listen for, and communicate with, OxTS devices on the network. The firewall must be configured to allow each program to talk on the network, or programs will not work as intended.
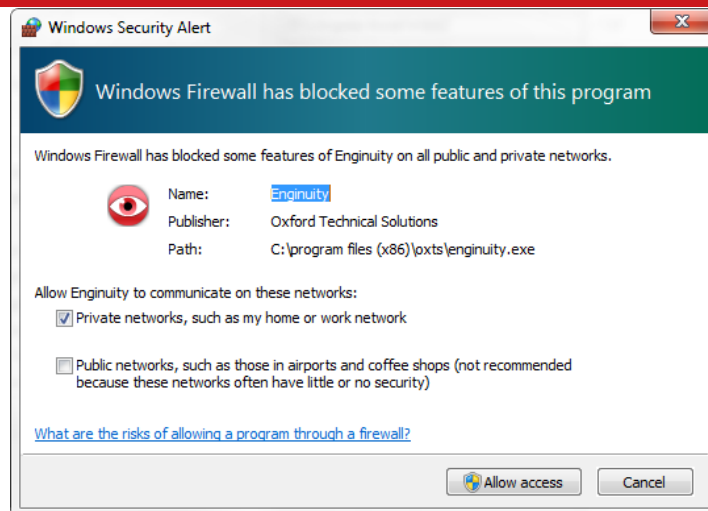
A firewall warning message may be triggered the first time OxTS software is run. Access must be allowed for each application that requires it, or the program cannot work properly. Sometimes a warning will not be triggered but the firewall may still block certain functions. If a program fails to display the IP address of a connected xNAV check the firewall settings for that connection.

Ensure both Private and Public networks are selected to ensure the software can continue functioning when moving from one type to another.

Hardware installation

Installing the xNAV is not difficult, but it is a precision instrument and care should be taken not to subject it to extreme shock, vibration or temperature. Bear in mind the minimum clearance required for the antenna connectors and user cable is 39 mm from the front panel (see Figure 1).

Figure 1. Clearance required for connectors and user cable

When mounting the xNAV a minimum of 39 mm is required for the user cable. At the minimum distance, it will not be possible to remove the main connector without also uninstalling the xNAV.

The xNAV does not need to be located at the desired measurement point as the outputs can be displaced using NAVconfig. However, any displacement should try to be kept to a minimum. Once configured, the xNAV's output will appear the same as if it were mounted at the displaced location.

It is essential to install the xNAV rigidly in the vehicle. It should not be able to move or rotate compared to either GNSS antenna, otherwise the performance will be reduced. The xNAV is compatible with the RT-Strut product from OxTS when used with additional mounting brackets. The RT-Strut can be used to provide a quick and secure vehicle mounting option.

The orientation of the xNAV's local axes is shown on page 9. For ease of use it is best to try and mount the xNAV so its axes are aligned with the vehicle axes. If the system must be mounted misaligned with the vehicle then the offsets must be measured and entered into NAVconfig. This allows the outputs to be rotated based on the settings entered to transform the measurements to the vehicle frame.

## Antenna placement and orientation

The placement and orientation of the GNSS antennas is important to the system accuracy. For optimal performance it is essential for the antennas to be mounted where they have a clear, uninterrupted view of the sky and on a suitable ground plane, such as the roof of a vehicle. For good multipath rejection the antennas must be mounted on a metal surface using the magnetic mounts provided; no additional gap may be used.

The antennas cannot be mounted on non-conducting materials or near the edges of conducting materials. If the antennas are to be mounted with no conductor below them then different antennas must be used. It is recommended to mount the antennas at least 20 cm from any edge where possible.

Antennas should be spaced between 1 m and 5 m apart and the antenna baseline should be aligned with one of the vehicle axes where possible, either inline or perpendicular to the vehicle's forward axis. It is possible to use a shorter antenna separation but the heading accuracy will degrade.

When mounting the antennas, the secondary antenna should be mounted in the same orientation as the primary, as shown in Figure 6. The direction the cable exits the antennas does not matter as long as it is the same for both.

Figure 2. Antenna placement
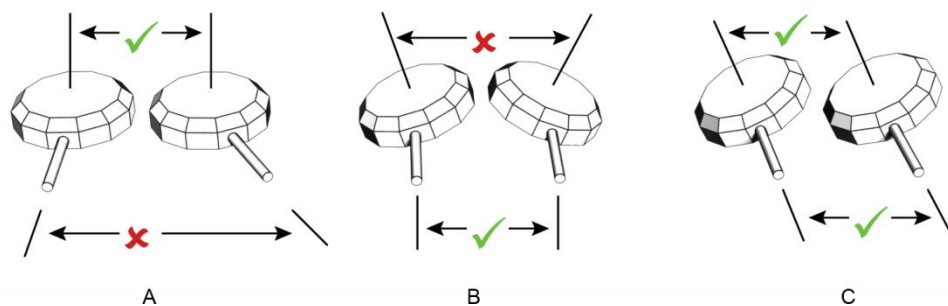
A) The bases of the antennas are parallel, but the cables exit in different directions.
B) The cables exit in the same direction, but the bases of the antennas are not parallel.
C) The bases of the antennas are parallel, and the cables exit in the same direction. This configuration will achieve the best results.

When measuring the antenna separation, if the antennas are level (i.e. within 15° of horizontal) then the separation should be measured to within 5 cm. If the antennas are not level then the separation must be measured to 5 mm.

Configuring the xNAV

To obtain the best results from your xNAV it will be necessary to configure it to suit the installation and application before using it for the first time. The program NAVconfig can be used to do this. This section describes how to use NAVconfig and gives additional explanations on the meanings of some of the terms used.

It is only possible to change the xNAV configuration using Ethernet. It is necessary to have the Ethernet on your computer configured correctly in order to communicate with the xNAV and change the settings. See the section "Ethernet configuration" on page 10 for more information.

The configuration file defines where the xNAV is and how it is orientated in relation to the host being measured. It also specifies any options to use while processing the data. Once a configuration has been committed to the xNAV, it will remain there and the system will use that configuration each time on start up. There is no need to reconfigure it unless the xNAV or an antenna is moved.

Selecting the operating language

The NAVconfig software can operate in several languages. To change language, select the language from the drop-down menu at the bottom of the page. The language is "hot-swappable" making it easy and fast to switch between languages.

The software will use the regional settings of the computer to choose whether numbers are represented in the English or European format (dot or comma for the decimal separator). The selected language does not change the format used for numbers.

Navigating through NAVconfig

NAVconfig provides a ten-step process to make configuring your product as easy as possible. After completing each step, click the **Next** button at the bottom of the window to proceed to the next step. The **Back** button can be used to return to the previous step at any time. Clicking **Cancel** will bring up a warning asking to confirm if you want to close the wizard and lose any changes you have not saved.

To quickly move between any of the steps, click on the step name in the sidebar to instantly jump to that page.

Measurements are always displayed in metric units in NAVconfig. However, when entering measurements alternate units can be used as long as they are specified, e.g. 10″ or 10 in. NAVconfig will then convert and display these in metric units.

Product selection

NAVconfig is a universal application used to configure several different OxTS products. The first page of the configuration wizard (see Figure 7) tells the application what type of sensor is being configured. The program then loads the correct options specific to that device.

Figure 3. NAVconfig Product Selection page
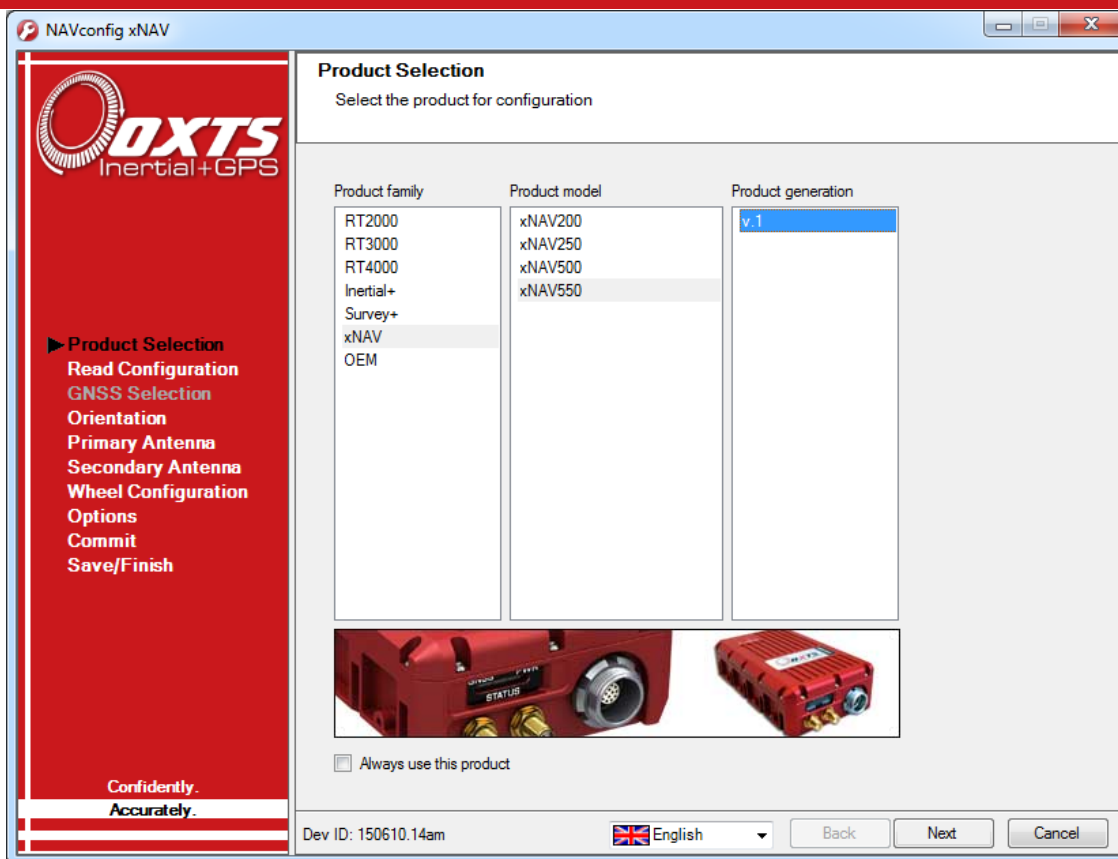
The configuration wizard can be run without a system connected so it is necessary to select the correct product for configuration. Some configuration pages are not available with some of the products. These will be displayed as grey in the sidebar.

In instances where the same product type will be used each time, the Product Selection page can be skipped in the future by clicking the **Always use this product** checkbox. If a different product needs configuring, the selection page can be returned to by clicking **Product Selection** in the sidebar

Read configuration

The Read Configuration page gives several options for reading the configuration from different places as shown in Figure 8.

Figure 8. NAVconfig Read Configuration page
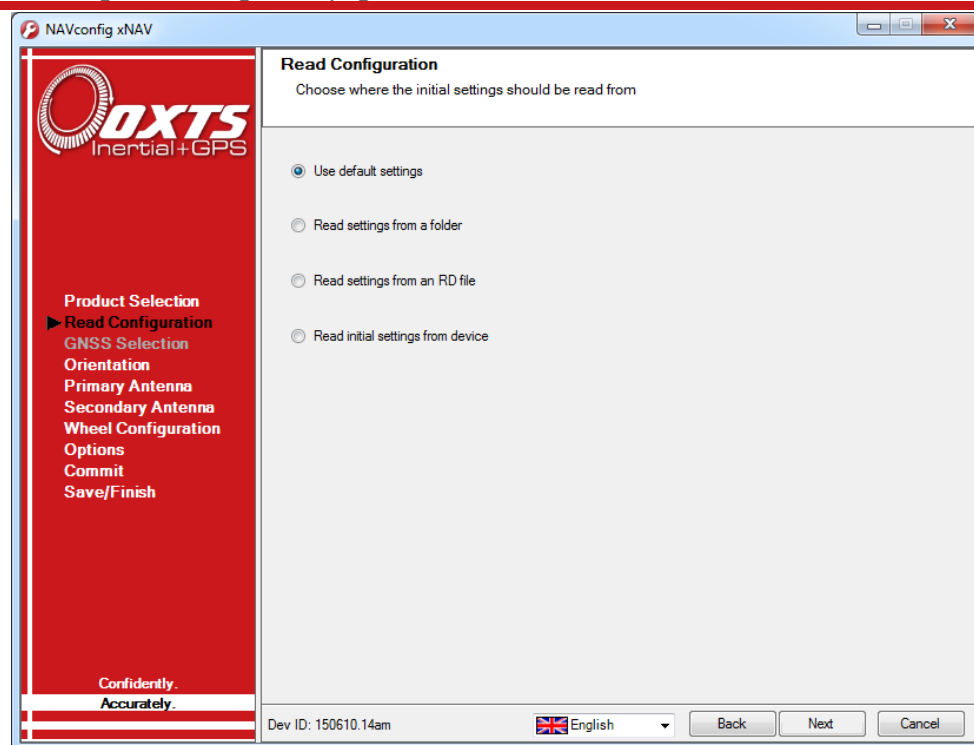
Use default settings: When configuring a new installation, this option should be selected. This forces NAVconfig to load a clean set of base settings, removing any advanced features that may have been previously committed.

Read settings from a folder: It is possible to store a configuration in a folder. The configuration requires several files so it is tidier to keep it in a folder by itself. To read the configuration from a folder select this option and specify a folder by clicking the **Browse** button.

Read settings from an RD file: The xNAV writes the configuration it is using to the internally stored RD file. This option extracts the configuration used for that data set and loads it in the configuration wizard. Specify an RD file by selecting this option and clicking the **Browse** button.

Read initial settings from device: If the xNAV is connected to the computer via Ethernet then it is possible to read the initial settings directly from the xNAV. The settings loaded are the settings that were last committed to the xNAV. Select this option and enter the IP address of your xNAV or select it from the drop-down list. The list will show all systems that are connected to the network, so if more than one is connected ensure you select the correct system.

Note: the list will not function correctly if NAVdisplay or other software is using the xNAV UDP port unless the OxTS UDP Server is running.

Orientation

The Orientation page, shown in Figure 9, is where the host vehicle co-ordinate frame is defined relative to the xNAV's co-ordinate frame. It is important to get the orientation correct as although settings entered on this page do not affect the accuracy of the xNAV, if the outputs are not properly rotated to the vehicle frame then the measurements will appear incorrect.

Figure 9. NAVconfig Orientation page
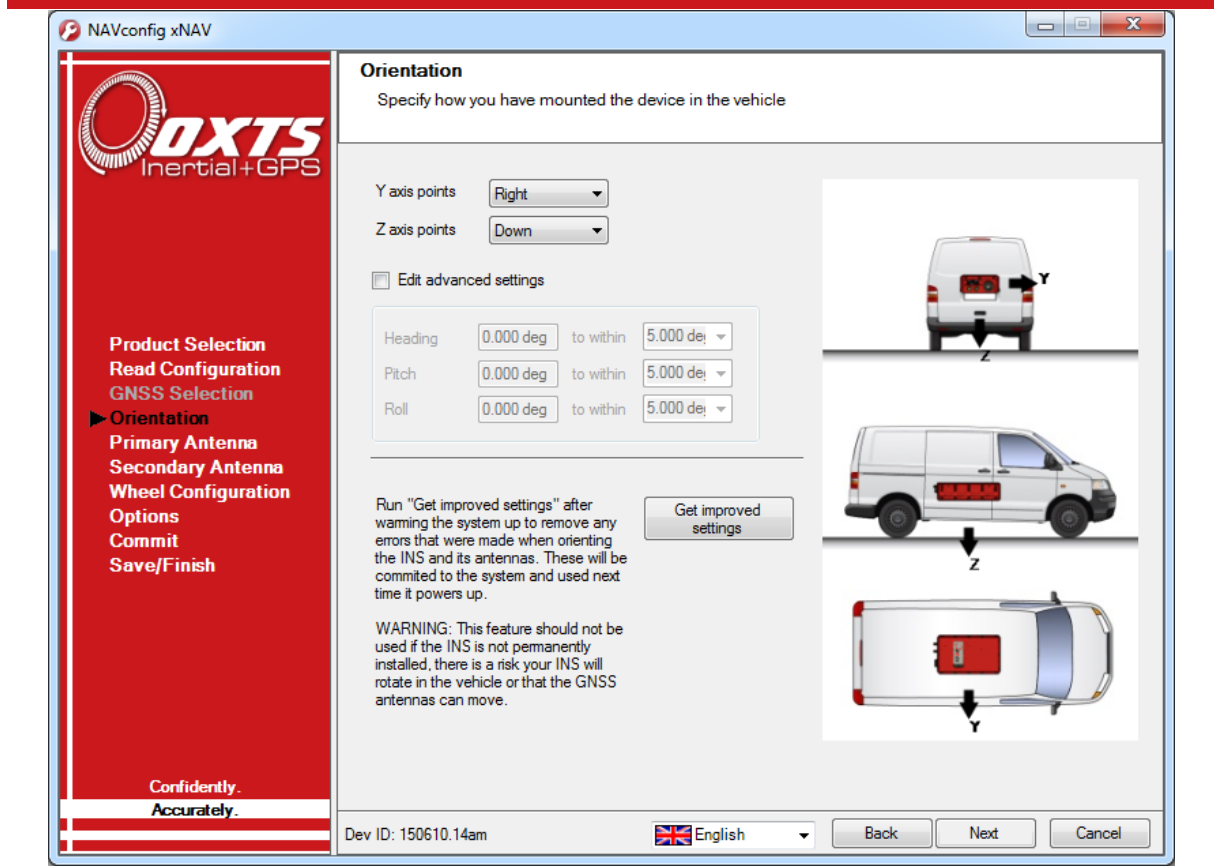
To define how the xNAV is mounted in the host vehicle it is necessary to tell NAVconfig which direction two of the xNAV's axes point. Select the correct option for **Y axis points** and **Z axis points** from the drop-down lists. The greyed out advanced settings will change to show the three rotations associated with orientation chosen.

If it is not possible to mount the xNAV squarely to the host's co-ordinate frame, select **Use advanced settings** and define the xNAV's orientation using those values.

For correct initialisation it is necessary to get the heading orientation correct. The xNAV gets its initial heading by assuming that the vehicle is travelling forwards in a straight line. If the definition of the vehicle's *x*-axis (forward direction) is incorrect then it will not initialise correctly when the vehicle moves forwards.

In permanent installations, the **Get improved settings** button can be used to import improved settings from a previously post-processed raw data file. Details of the process are given on page 38.

Primary antenna position

Accurately defining the position of the primary antenna in NAVconfig helps achieve better results sooner. It is recommended to measure the GNSS antenna position to an accuracy of 10 cm or better.

Measure the distances from the xNAV to the GNSS antenna along each of the axes in the vehicle's co-ordinate frame. On the Primary Antenna page, shown in Figur, select the directions (**Ahead/Behind**, **Right/Left,** and **Above/Below)** and enter each of the measurements**.** For visual confirmation, the position of the antenna in the image will change to reflect the specified configuration.

The **Overall accuracy** can be specified by choosing a value from the drop-down list or typing one in. Alternatively the accuracy of each measurement can be specified separately by clicking the checkbox to unlock the greyed out drop-down boxes.

The default accuracy is 10 cm which is sufficient for the xNAV to refine itself to specification during the warm-up period. Care should be taken if specifying a greater accuracy. Do not overstate the accuracy as doing so may cause the xNAV to look in the wrong place, increasing the time taken to find the correct solution.

Figure 10. NAVconfig Primary Antenna page

Secondary antenna position

The Secondary Antenna page, shown in Figure 11, is used to define the position of the GNSS antenna connected to the secondary receiver, relative to the primary one. The secondary antenna should be placed in accordance with the information given in the installation section on page 144.

Ensure to click the **Enable secondary antenna** checkbox to allow the configuration to be entered. If it is not enabled, the xNAV will ignore the secondary antenna and will not use it to compute a heading solution.

By default the **Antennas are level** box is checked. This means the antenna baseline should be within 15° of horizontal. When the antennas are level the separation should be measured to within 5 cm. If the antennas are not level, i.e. mounted with height offsets or on an incline, then the box should be unchecked. In this case, the separation should be measured to within 5 mm.

Enter the antenna separation and select the position of the secondary antenna relative to the primary antenna from the drop-down list. The measurement accuracy can also be specified with the **to within** drop-down box. The illustrations will change according to the settings you choose to help visualise the configuration of the antennas.

Figure 11. NAVconfig Secondary Antenna page

It is important to measure between the same point on each antenna, e.g. centre-to-centre, or from cable-to-cable.

If the antennas are mounted at significantly different heights, or if the mounting angle is not directly along a vehicle axis (forward or right), then click the **Edit advanced settings** checkbox to enable advanced settings and specify the orientation and height offset.

The **Enable static initialisation** option is useful for slow moving vehicles or when dynamic initialisation may be difficult. Static initialisation is 99% reliable in open sky, but the reliability decreases in environments with high multipath. Static initialisation is also faster when the antenna separation is smaller and the **Antennas are level** checkbox is ticked.

Wheel configuration

The **Wheel configuration** feature uses characteristics of land vehicle motion to improve heading and reduce drift. Specifying the position of the non-steered wheels makes a huge difference to the lateral drift performance of the xNAV when GNSS is not available. The vertical drift performance can also be improved by specifying some additional measurements.

This feature must be disabled for airborne and marine applications where the lateral velocity can be significant. It is also not suitable for land vehicles that have no non-steered wheels. The vertical settings should not be used if the vehicle can perform wheelies.

The xNAV uses the position of the non-steered wheels to reduce the lateral drift when GNSS is not available and to improve the heading accuracy. The Wheel configuration feature applies heading correction when the vehicle is not slipping; when the vehicle *is* slipping the lateral acceleration is usually large enough that the normal heading corrections provide excellent results. When combined with an odometer input (see "Odometer input" on page 26) the drift of the xNAV when GNSS is not available is drastically reduced.

Figure 12 shows the Wheel Configuration page.

Figure 12. NAVconfig Wheel Configuration page

For the **Lateral settings**, the system needs to know the position of the non-steered axle (rear wheels on a front-wheel steering vehicle and vice versa). Vehicles with all wheels steering cannot use this feature reliably, although minor steering of the rear-wheels does not significantly affect the results. The measurements entered are from the xNAV's measurement point, to the point shown in Figure 13.

Figure 13. Measurement point for wheel configuration

Measure the distances to the non-steered axle position in each axis in the vehicle co-ordinate frame. Select the direction from the drop-down lists and enter the distances.

Typically the measurements should all be made to an accuracy of 10 cm. Selecting an accuracy better than 10 cm does not improve results. Using an accuracy figure worse than 20 cm will increase the drift of the xNAV. Use the accuracy fields to select or specify the accuracy of the measurements.

The Wheel configuration feature also requires some knowledge of the road surface. Select one of the predefined options from the drop-down list, Normal or Low friction (ice).

For the **Vertical settings**, the system needs to know the position of the front axle. A position at road height, mid-way between the wheels should be used, as for the rear axle.

Measure the distances again from the xNAV and enter them into the cells, selecting the appropriate directions from the drop-down lists

Options

The Options page includes some important settings for getting the best results from your xNAV. Figur shows the options available for the xNAV550. Some options are not available on other models.

To adjust the settings, click the default value in the **Setting** column to activate the cell. A description on each option and how to adjust it is found below.

The Serial 1 output and 1PPS options are the only options to affect the real-time operation of the xNAV2** models. All other options are used during post-processing only.

The xNAV5** models output data in real-time so the options configured here will affect the real-time operation. The options can also be changed later in post-processing.

Figure 14. NAVconfig xNAV550 Options page
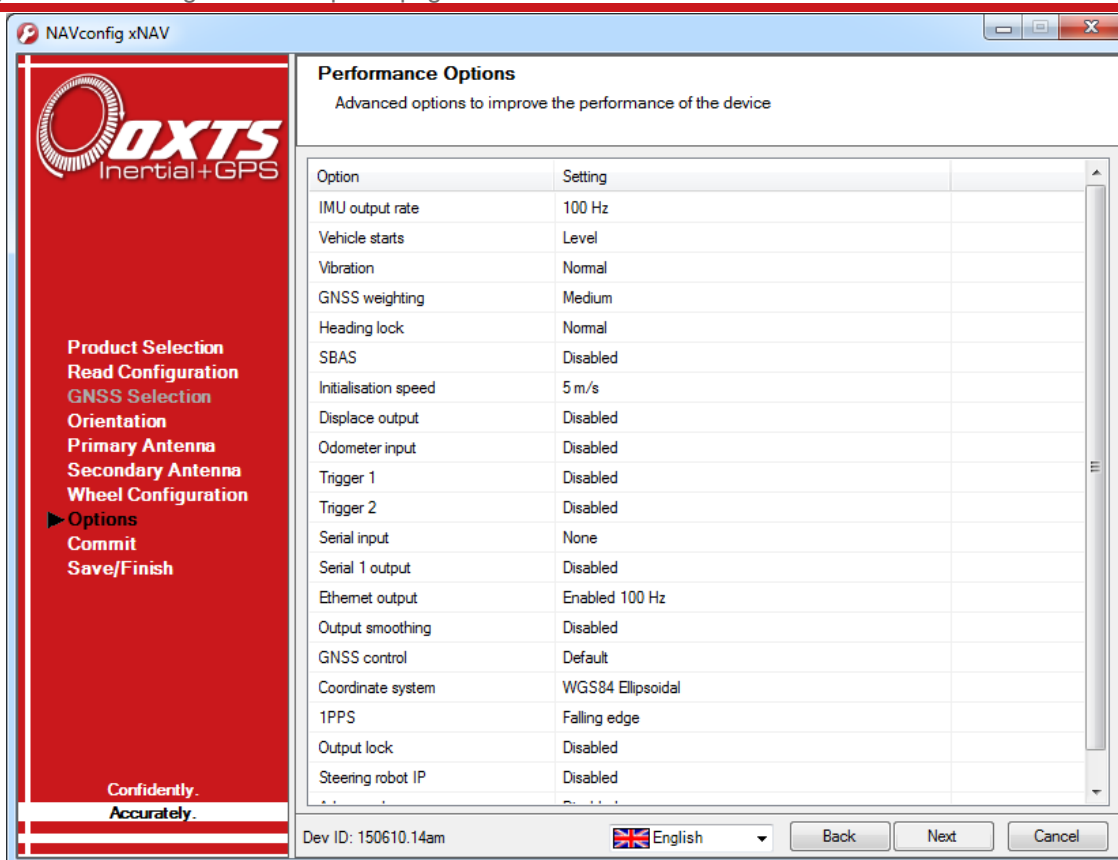
IMU output rate

The standard output rate of xNAV products is 100 Hz, however this can be increased to 250 Hz with the application of a special IMU high-rate feature code. On devices where the feature code has been applied, the **IMU output rate** option allows the output rate to be set to 100, 200 or 250 Hz. On devices where the IMU high-rate feature code has not been applied, this option is ignored, regardless of its setting.

Vehicle starts

If you know the vehicle being measured will be level when starting (to within about 5°) select **Level**. This saves about 40 seconds during initialisation as an initial roll and pitch value does not have to be computed. In high vibration environments **Not level** may not work and so the xNAV can only start if the vehicle is level and the **Level** option has been specified.

Vibration

There are three options available to describe the level of vibration the system will be exposed to. In most cases **Normal**, will work correctly. If the xNAV is installed using vibration mounts allowing some movement independent of the GNSS antennas, **High** or **Very high** settings should be considered. Select the appropriate option from the drop-down list.

GNSS weighting

The xNAV can place different emphasis on the GNSS receiver's measurements. The default setting is **Medium**, placing equal weighting on the GNSS receivers and inertial sensors. Selecting **High** from the drop-down list will cause the xNAV to believe the GNSS receivers more and selecting **Low** will make the xNAV rely more on the inertial sensors.

In urban environments it is better to believe the inertial sensors more whereas in open sky the GNSS receiver should be believed more.

Heading lock

When stationary for extended periods of time, the heading of single antenna systems can drift. The heading lock option solves this by locking the xNAV's heading to a fixed value while the system is stationary. Using the dual antenna system will also keep the heading stable in which case heading lock is not necessary.

Heading lock cannot be used with host vehicles that can turn on the spot (i.e. without longitudinal velocity). Note that simply turning the steering wheel while stationary is often enough to change the heading on most road vehicles.

Select an option from the drop-down list. Table 12 gives a description of each heading lock option.

Table 12. NAVconfig heading lock options

Heading lock	Description
Disabled	Disables heading lock. Should be used if the vehicle can turn on the spot.
Normal	Best for most applications. Assumes that the heading of the vehicle does not change by more than 2° while the vehicle is stationary. The heading accuracy recovers quickly when the vehicle moves.
Tight	Assumes that the heading of the vehicle does not change by more than 0.5° while the vehicle is stationary. The recovery is fast if the heading of the vehicle does not change but will be slow if the vehicle turns before it moves.
Very tight	Assumes that the heading of the vehicle does not change by more than 0.3° while the vehicle is stationary. The recovery is fast if the heading of the vehicle does not change but will be slow if the vehicle turns before it moves. This option can cause problems during the warm-up period if the vehicle remains stationary for a long time and then drives suddenly.

SBAS

When operating in a region with a satellite-based augmentation service (SBAS), enabling this option will improve the GNSS performance compared with standard positioning service (SPS). Services currently supported are Europe (EGNOS), North America (WAAS), Japan (MSAS), India (GAGAN), and Russia (SDCM).

Initialisation speed

If static initialisation has not been enabled, the xNAV will need to be initialised by moving forwards in a straight line. When the vehicle exceeds the initialisation speed the roll and pitch measurements are assumed to be zero (with a large error), and the heading is approximated to the vehicle's course over ground.

The default speed of 5 m/s is suitable for most applications. It can be changed by selecting a predefined option from the drop-down list or by typing in a custom value.

Displace output

The xNAV can displace or move its outputs to another location in the vehicle. This simulates the xNAV being mounted at the new location. This function displaces all of the outputs (position, velocity, acceleration) to this new measurement point. In high vibration environments, any displacement should be kept to a minimum.

Click the [...] button to open the properties window, click the checkbox and enter the offsets to the new location in the vehicle. The offsets are measured from the xNAV in the vehicle co-ordinate frame. Select the directions from the drop-down lists. The images will change to help visualise the displaced measurement point of the xNAV.

Odometer input

In land-based survey applications, the xNAV's accuracy can be maintained for longer periods during GNSS blackouts if an independent wheel speed odometer is fed into the system.

To configure an odometer input, click the [...] button to open the properties window, shown in Figur. Ensure the checkbox is clicked, since if this option is disabled the xNAV will ignore corrections from the odometer even if one is connected.

It is essential to use the Wheel configuration feature (page 22) at the same time as an odometer input. As with the wheel configuration, an odometer input can only be used on land vehicles. It must not be used on a steered wheel. The odometer should be on a wheel that is measuring the forward direction of the vehicle. For best results, a front-wheel-drive vehicle should be used with the odometer on a rear wheel. The odometer pulses from driven wheels are less accurate.

The distances from the xNAV to the measurement point of the odometer in the vehicle co-ordinate frame should be input. The directions can be selected from the drop-down lists. If the odometer is from a prop shaft then the distance should be measured half way between the two wheels. The illustrations in the window will change depending on the settings you choose, to help visualise the position of the xNAV in relation to the odometer.

The pulses-per-metre should also be specified. A value that is accurate to 10% is sufficient unless the figure is known more accurately. The xNAV will improve this scaling factor itself when GNSS is available.

The xNAV also supports quadrature inputs. The **Directional odometer** checkbox should be selected to enable this feature.

Figure 15. NAVconfig odometer input properties window
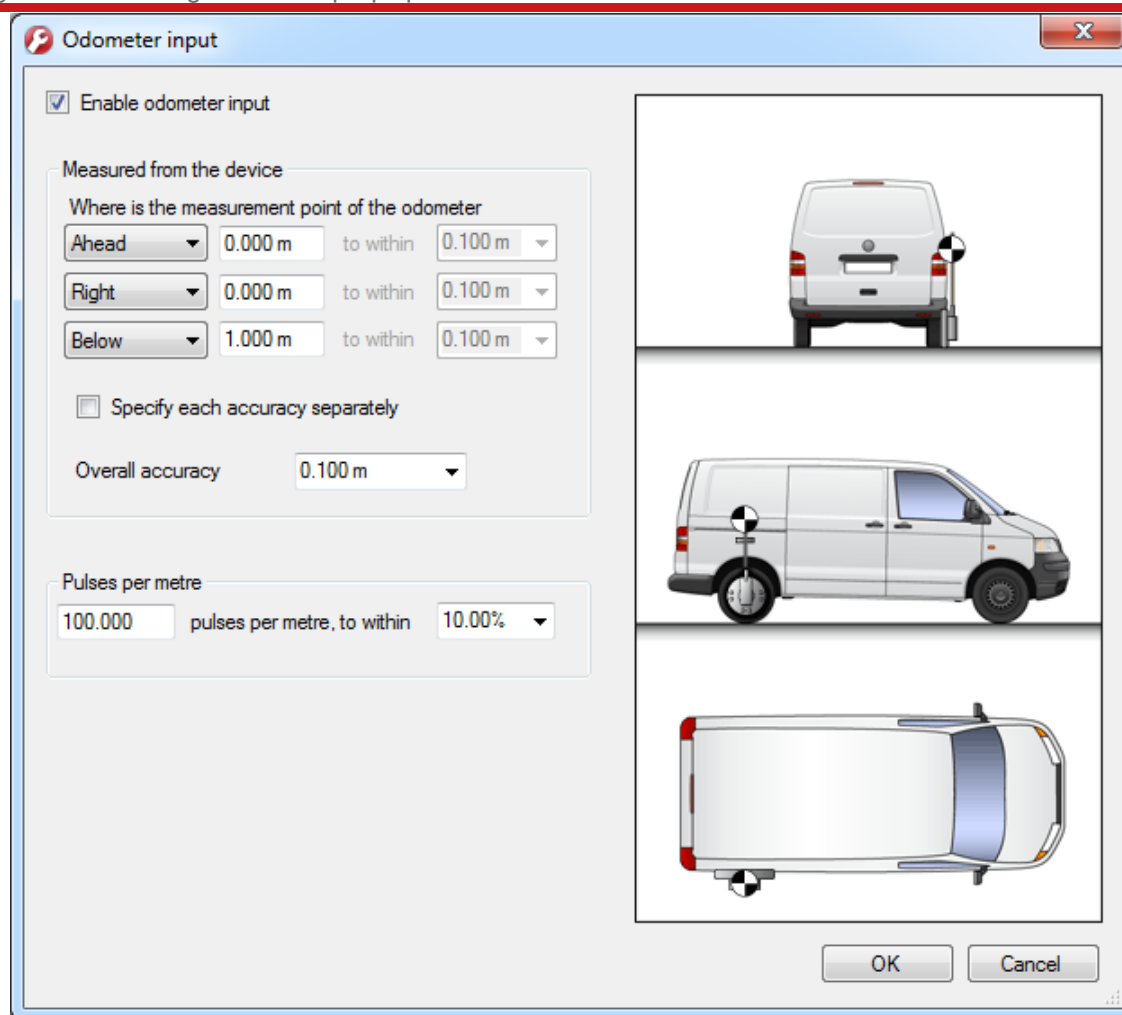
Trigger 1 and Trigger 2 (xNAV5**)

The xNAV5** models have two triggers that can be configured as either input triggers, output triggers, or an IMU sync pulse.
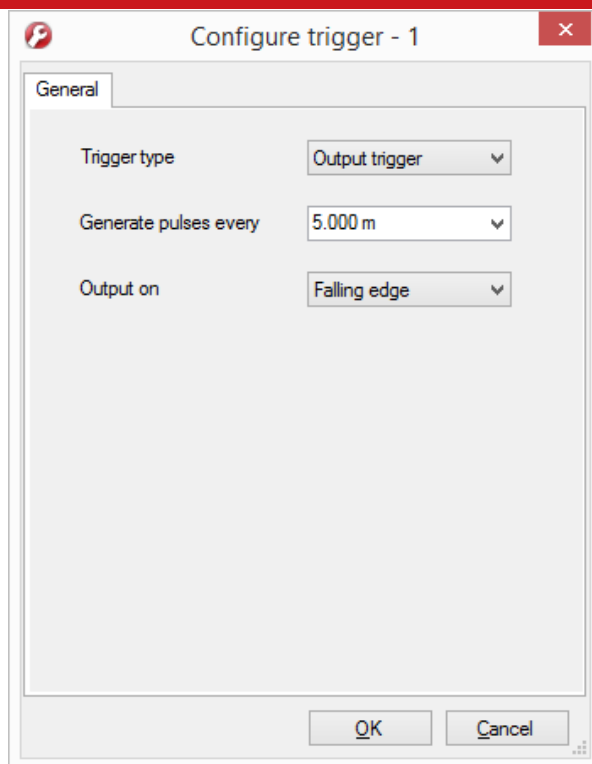
To enable a trigger, click the ⊡ button to open the properties window, shown in Figure 16. Select the trigger type from the drop-down list.

Figure 16. NAVconfig trigger properties window

Input: Accepts a trigger input from an external device, such as a camera shutter, to generate a data point with all measurements at the exact timestamp of the trigger. The event input has a pull-up resistor so it can be used with a switch or as a CMOS input. The input sees less than 0.6 V as low and more than 2.6 V as high. The input range should be kept between 0 V and 5 V.

Output: Generates a pulse based on distance. Select the distance interval to generate the pulses on from the drop-down list, or type in a value.

The output has 0.8 V or less for a low and 2.4 V or more for a high. The pulse width is 1 ms. By selecting **Rising edge** or **Falling edge** from the drop-down box the trigger can be configured as a low or high, as illustrated in Figure 17.

Figure 17. Output trigger settings
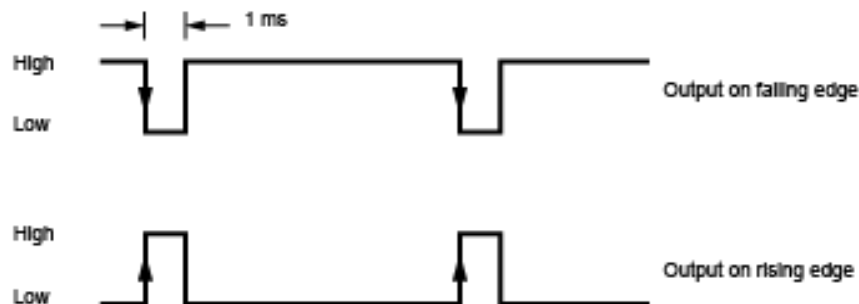
IMU sync: Generates an output pulse at the same frequency as the data rate of the system, synchronised to the IMU sample time. The output has a duty cycle of approximately 50% and the falling edge is synchronised to the sample file of the data from the IMU.

*Serial input (xNAV5**)*

The transmit and receive functions on the xNAV5**s' serial port can be configured separately. The serial input can be used to either receive differential corrections or to receive commands.

To configure the serial port input, click the [...] button to open the serial input properties window, shown in Figure 18.

Figure 18. NAVconfig serial input properties window

Select the input type from the drop-down list. The settings will then appear for customisation. If configuring the input for differential corrections, the **Correction type** drop-down list will appear as an extra option. The xNAV products can accept RTCMV3 format corrections.

The other options can be customised to fit the type of base station being used. The default options are compatible with the OxTS RT-Base and GPS-Base.
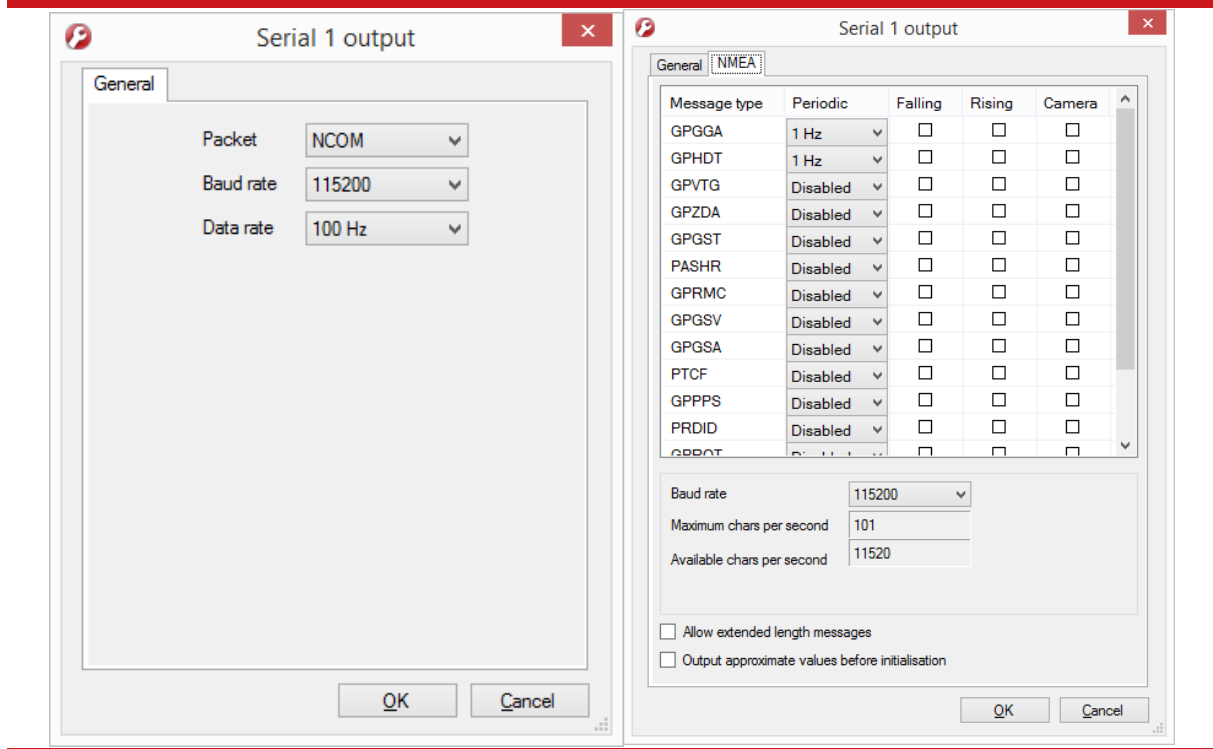
Serial 1 output

When using the serial port output, it can be configured for different message types. Click the […] button to open the properties window, shown in Figure 4.

Select the message type to output from the **Packet** drop-down list and select the output baud rate and data rate. Table 13 gives details of the different messages.

If the NMEA packet type is selected, the **NMEA** tab will appear in the properties window (see Figure 4). In this tab the NMEA messages to output on the serial port are selected by choosing the data rate for each message type from the drop-down lists and clicking the checkbox for when to generate the message.

Note: The xNAV2**s do not calculate measurements in real-time so cannot output any measurements over Ethernet or serial. However, there are two NMEA messages that can be configured to be output over serial: GPGGA and GPZDA. These are the GPS Fix Data and Date & Time sentences, respectively, and are limited to 4 Hz.

NMEA messages can be generated by falling or rising voltages on the event input trigger. Check the falling or rising edge checkbox to compute the message when the event occurs. The xNAV5**s can also generate NMEA messages from pulses on the output trigger. These messages use interpolation to compute the values at the exact time of the event but may be output on the serial port up to 30 ms late and out of order compared to the normal messages. To enable these messages check the appropriate checkbox.

Table 13. Serial output options

Option	Description
Disabled	The serial output is disabled. This option can be used to reduce the computational load and ensure that the Kalman filter runs quicker.
NCOM	Normal output of the xNAV. NCOM data is transmitted at up to 125 Hz over serial. The format is described in the NCOM Description Manual. Software drivers exist for decoding the NCOM data.
IPAQ	NCOM output at a reduced rate. The baud rate of the serial port is set to 19200 and the update rate is 25 Hz. It is used because the IPAQ cannot manage to receive the data reliably above 25 Hz.
IPAQ+	NCOM output at a reduced rate and polled. Windows Mobile 5 on IPAQs crashes if the xNAV is sending data when the IPAQ is turned on. Using IPAQ+ the IPAQ will poll the xNAV; the xNAV will not send data while the IPAQ is off, preventing the turn-on crash of the IPAQ.
NMEA	The NMEA outputs conform to the National Marine Electronics Association Standard (NMEA 0183 version 3.01). The NMEA sentences available are GPGGA, GPHDT, GPVTG, GPZDA, GPGST, PASHR, GPRMC, GPGSV, GPGSA, PTCF, GPPPS, PRDID, GPROT, GPGGK, and GPUTC. The NMEA 0183 description manual gives details of the fields output in the NMEA sentences.
Javad I+RTK	A special set of messages output in GREIS format to be used with Javad receivers. For assistance, please contact OxTS support.
MCOM	Used for marine applications. Identical to NCOM output but with the addition of heave measurements.
TSS1	TSS1 format outputting acceleration, heave, roll and pitch.
TSSHHRP	TSSHHRP format.
EM3000	Suitable for use with Simrad EM3000 multibeam sounders.
EM1000	Suitable for use with Simrad EM1000 multibeam sounders.

Note that it is easy to overload the serial port if there are too many events. The software computes the number of characters that will be output each second and displays this at the bottom of the window. A serial port data overflow warning message will appear if the data rate is too high for the selected baud rate; to fix this it is necessary to lower the data rate of the selected NMEA sentences or increase the baud rate.

Selecting **Allow extended length messages** enables the full GGA and RMC messages to be output, which are longer than the NMEA specification allows. Please see the NMEA 0183 Description manual for more details.

Selecting **Output approximate values before initialisation** forces output of the raw GNSS measurements before the xNAV is initialised. Currently just the position is output and this is the position of the antenna, not the inertial measurement unit. Note that there will be a jump (from the antenna to the inertial measurement unit) when initialisation occurs.

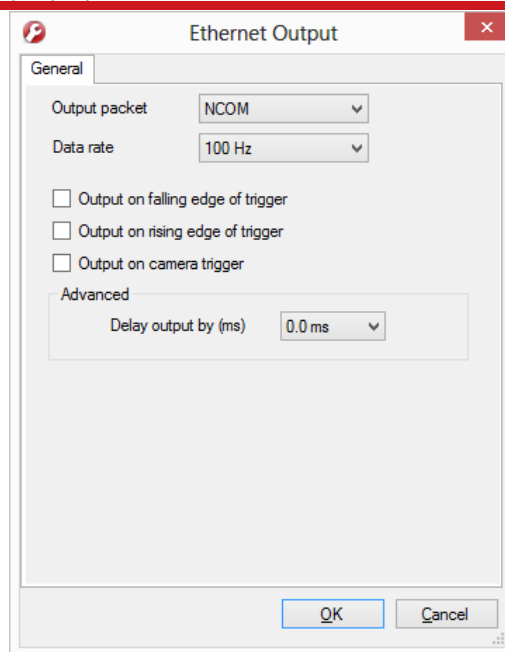## Ethernet output (xNAV5**)

Ethernet is the default setting to output measurements. It can be configured for different data rates and to output extra data packets based on triggers. Click the [...] button to open the properties window, shown in Figure 5.

Figure 5. NAVconfig Ethernet output properties window

The Ethernet output can either output NCOM or MCOM, or be disabled by using the **Output Packet** drop-down list. When NCOM or MCOM is selected, the **Data rate** can be selected by using the drop-down list.

If a trigger has been configured as an event input, click the **Output on falling edge of trigger** or **Output on rising edge of trigger** checkboxes to choose when the extra data packet is generated. If a trigger has been configured as an output trigger, click the **Output on camera trigger** to generate extra data packets based on the output trigger settings configured earlier.

These packets are interpolated to the time when the event occurred and may be output up to 30 ms late and out of order compared to the normal messages. It is essential to enable these options in order to see trigger information in NCOM, or if the events have a rate higher than 1 Hz otherwise the output cannot communicate all of the events and some will be lost.

The **Delay output** option should not be used with the xNAV.

Output smoothing

When the Kalman filter in the xNAV determines that there is some error to correct, this error is applied smoothly rather than as a jump. The output smoothing controls how fast the correction is applied to the outputs.

Click the [...] button to open the properties window and click the checkbox to enable output smoothing. The smoothing of the position, velocity and orientation corrections can be controlled

independently. The **Smoothing** parameters define the maximum amount of correction applied per second. The **Time limit** forces a correction if the correction will take more than the specified time.

Care should be taken not to make the smoothing too small. If these parameters are too small then the xNAV will not be able to make suitable corrections to the outputs and it will not work correctly.

Note: this function is designed to improve the data in real-time. Since the xNAV2**s are post-process only, this option should only be used when using the "simulated" post-processing option. When processing with the forwards-backwards "combined" option, output smoothing should not be used as it may give unexpected results. There is an option in RT Post-process for "Advanced smoothing" that is designed to work with combined processing.

GNSS control

The GNSS control option contains advanced options that control how the GNSS information is managed in the xNAV. Click the ⟦...⟧ three leading dots button to open the properties window. The **GNSS algorithm** tab (Figure(a)) can be used to select the algorithm used for blending the GNSS and the inertial data in the Kalman filter. The **Recovery** tab (Figure(b)) can be used to decide how to begin using GNSS measurements if they have been rejected or ignored for a period of time.

Use OxTS gx/ix raw data processing algorithm enables gx/ix™ mode

The gx/ix processing uses the raw data from the GNSS and custom algorithms to compute position and velocity tailored to the needs of the Kalman filter. It also improves performance in poor GNSS environments using single satellite aiding technology and tightly coupled GNSS and inertial measurements. In environments where signal lock may be difficult to maintain (e.g. urban canyons), gx/ix mode is recommended to achieve the highest accuracy.

Currently, not all GNSS modes are compatible with gx/ix. Table 14 details the current compatibilities of gx/ix mode.

Table 14. GNSS compatibility with gx/ix

GNSS mode	Real-time	Post-process
SPS	✔	✔
SBAS	x	x
DGPS	✔	✔
RTK	With gx/ix RTK upgrade	x
PPK	x	With gx/ix RTK upgrade
GLONASS	✔	✔

Use GNSS receiver's calculations option

The Use GNSS receiver's calculations option turns off gx/ix mode and uses the receiver's default algorithms for calculating a GNSS solution.

Figure 21. NAVconfig GNSS control properties window

(a)   (b)
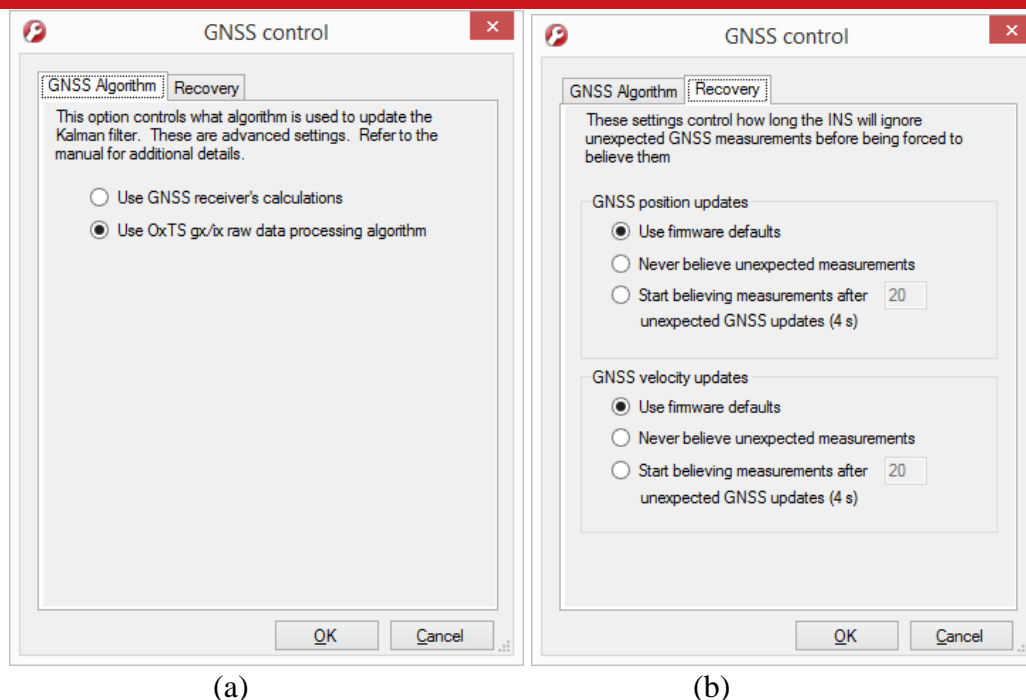
The **Recovery** tab controls how the xNAV will accept or reject GNSS measurements. The GNSS control determines how many updates the xNAV should ignore before forcing the GNSS to be accepted. Both the velocity and the position can be controlled separately.

In the default state the xNAV will reject up to 20 GNSS measurements before it forces the GNSS to be accepted. However, in high multipath environments or when wheel speed measurements are used, it may be desirable to reject more GNSS measurements. Select the **Start believing measurements after** option and enter the number of GNSS measurements to reject before the system starts believing it again.

The xNAV GNSS receivers update both position and velocity at a rate of 5 Hz. Therefore to ignore updates for 60 s for example, the number to enter to start believing measurements again would be 300.

The gx/ix processing algorithm makes its own decisions about when to trust, and how to recover from GNSS errors, so **Use firmware defaults** should be selected when using gx/ix mode.
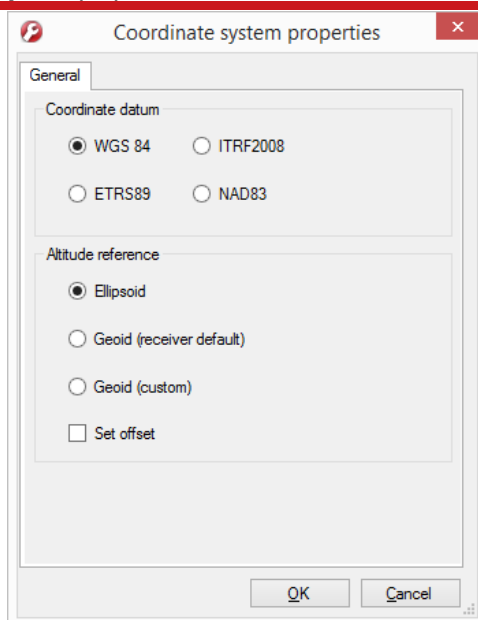
Coordinate system

The xNAV can output position relative to different coordinate frames. Click the [...] three leading dots button to open the properties window, shown in Figure 22.

Figure 22. NAVconfig coordinate system properties window

From the **Coordinate datum** section you can choose which reference datum to output latitude and longitude relative to. The default system and the standard for GPS is the WGS 84 datum.

Note: Currently outputs will only reference datums other than WGS 84 in post-processing. Real-time outputs will still be referenced to WGS 84 even if another option is selected.

The **Altitude reference** can be compared to either ellipsoidal or geoidal height. If **Ellipsoid** is selected, the altitude will be output with respect to the reference ellipsoid selected in the coordinate datum section. If **Geoid (receiver default)** is selected, the altitude will be relative to the geoid used in the GNSS receivers. A **Custom geoid** file can be used for local variations. To download supported geoid files, go to https://support.oxts.com/hc/en-us/articles/115005711989-Custom-geoid-files. The UGF file must be saved in C:\Users***username***\Documents\OXTS\Shared\Custom geoid files. Once the file is downloaded and saved in this location, it can be selected from the dropdown box.

A constant offset to the specified altitude reference can be applied by checking the **Set offset** box typing in a value into the cell

1PPS

A one-pulse-per-second signal from the primary GNSS receiver is output when a valid GNSS solution is found. The output is a low-voltage CMOS output where 0.8 V or less represents low and 2.4 V or more represents high. No more than 10 mA should be sourced from the output. The GNSS time crossing boundary can be configured to coincide with the rising or falling edge of the signal.

Output lock

The output of the xNAV will continue to change even when the vehicle is stationary. For some systems this leads to ambiguous results. The position and orientation can be "locked" by the xNAV automatically when the vehicle becomes stationary.

While the outputs are locked, the Kalman filter continues to run and accumulate errors. When the vehicle moves, the Kalman filter will quickly return to the new solution. The drift rate can be controlled using the **Output smoothing** option.

Advanced

Clicking the three leading dots [...] button opens the **Advanced settings** window. This can be used to set special commands for the xNAV. This should only be done with special instructions from OxTS.

Committing the configuration

NAVconfig is an off-line configuration tool, so configurations must be explicitly uploaded to the xNAV via Ethernet when finished. On the Commit page (Figure 6) enter the IP address of the xNAV that you want to configure or select it from the drop-down list. The drop-down box will list all of the systems that are connected to the computer's network so ensure to select the correct system if there are multiple listed. The list will not work if NAVdisplay or other software is using the xNAV UDP port unless the OxTS UDP server is running.

Click **Commit** to save the configuration to the xNAV. This will automatically reset the xNAV so the changes take effect. It will be necessary to initialise and warm-up the system again after the changes have been applied.

Figure 6. NAVconfig Commit page
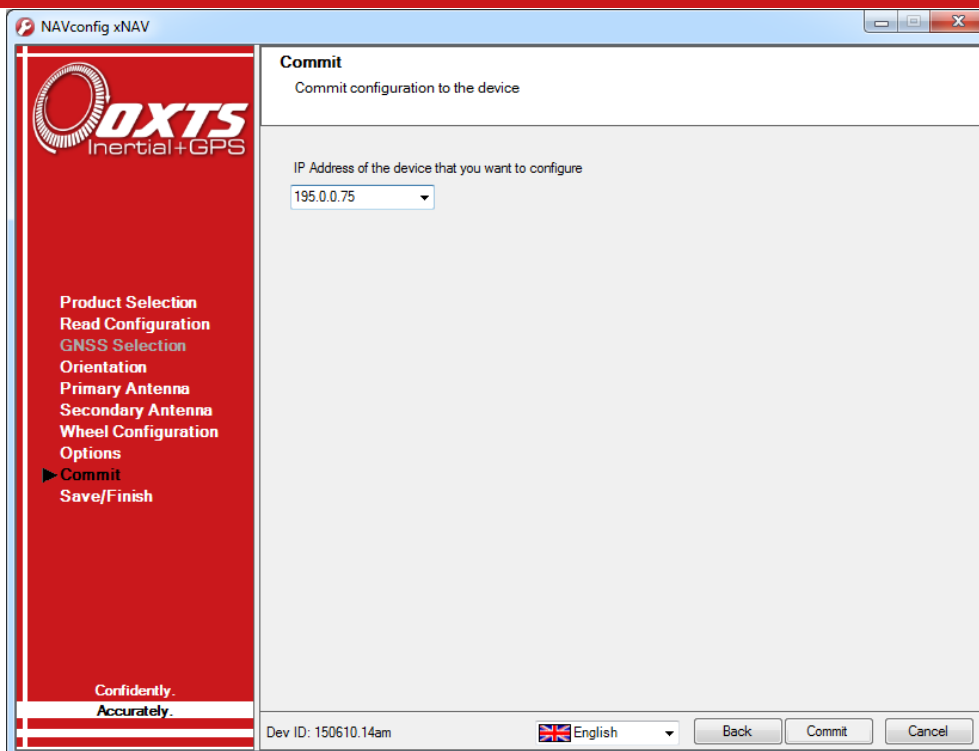
Saving the configuration and finishing

Before finishing it is possible to save a copy of the configuration in a folder on your computer. This can then be easily loaded back into the system if using the same configuration again. The Save/Finish page also lets you know if the settings have been committed successfully or not. Figure 24 shows the Save/Finish page.

Figure 7. NAVconfig Save/Finish page
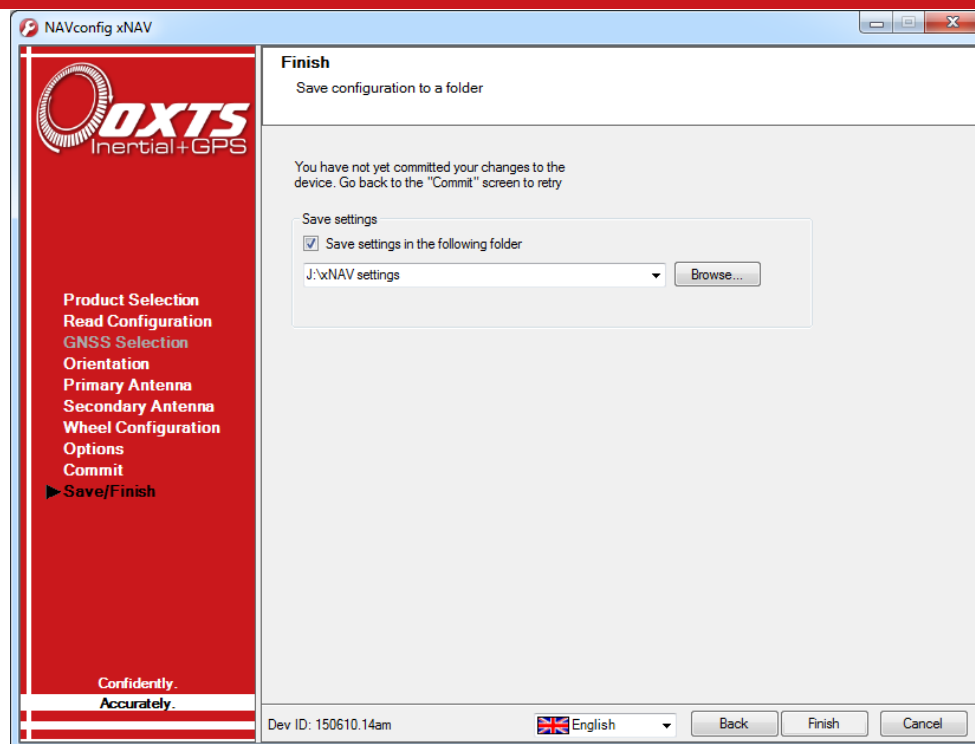
To save a copy of the configuration in a local folder check the **Save settings in the following folder** box and use **Browse** to select a folder. The configuration has a number of files associated with it so it is recommended to create a new folder. Click **Finish** to save the configuration to the selected folder and close NAVconfig.

Operating the xNAV

Initialisation and warm-up

For a short period after powering on, the xNAV will not conform to specification. The Kalman filter requires data in order to tighten its model of the system. This applies to both real-time accuracy and post-processed data.

When powering up the xNAV, the normal procedure should be to wait until both primary and secondary GNSS receivers achieve a position fix. If static initialisation has been enabled, the xNAV will then use the dual antenna system orientation to initialise heading. If not, once GNSS lock is achieved the vehicle should move forwards and in a straight line exceeding the initialisation speed set in NAVconfig. This will approximate the heading to course over ground. Roll and pitch are estimated over the first 40 s of motion.

At this point the xNAV is initialised, but will still benefit from a warm-up to improve its accuracy. To provide that information, it is necessary to excite the accelerometers and gyros in all axes. For land vehicles, this means driving figures of eight with some acceleration and braking. In the case of aerial vehicles, the system should be flown in a similar way, but with the addition of climbs and dives.

This warm-up process should take about five minutes. For xNAV5** models, NAVdisplay can be used to verify the system is working correctly. For xNAV2** models there are no real-time navigation outputs to check the system, so the data should be downloaded using the RT Post-process utility and processed to verify correct operation of the system. Once the system has warmed up it should be left with power applied. Turning off the xNAV will require the warm-up process to be repeated.

The process from initial power on to conducting the first test is summarised below:

1. Turn the system on.

2. Wait for the primary and secondary GNSS receivers to achieve fix.

3. Move forwards in a straight line, exceeding the initialisation speed.

4. Move for about three to five minutes, exciting the accelerometers and gyros in all axes.

5. Check the measurements in real-time or download the data and verify correct operation.

6. Conduct tests.

Downloading data

Once measurements have been collected with the xNAV the data is downloaded to a PC using RT Post-process. A full explanation of RT Post-process is given in the RT Post-process manual. It should be noted this manual was written before the xNAV existed and only talks about the RT systems. RTs work just like the xNAV but are larger and output real-time data. Otherwise the download and post-processing of data is the same.

## Improve the configuration with 'Get improved settings'

During the warm-up period, the system tries to improve some of the configuration parameters that were originally specified in NAVconfig. In particular, it tries to improve the GNSS antenna position, orientation of the dual antennas, yaw orientation of the xNAV in the vehicle and the wheel speed values if used.

The **Get improved settings** button is located on the **Orientation** page of NAVconfig. The button provides a way of importing these improved settings directly into NAVconfig, by reading them from a correctly warmed-up system or a forward processed NCOM file. The new and improved parameters can then be uploaded to the xNAV and used during subsequent data collection or post-processing applications.

This feature should not be used if there is a risk the xNAV will rotate in the vehicle or that the GNSS antennas can move - even by a few millimetres. It is possible to select which parameters are updated during Step 2 of the Get settings from xNAV window shown in Figure 25.

Figure 25. Get settings windows
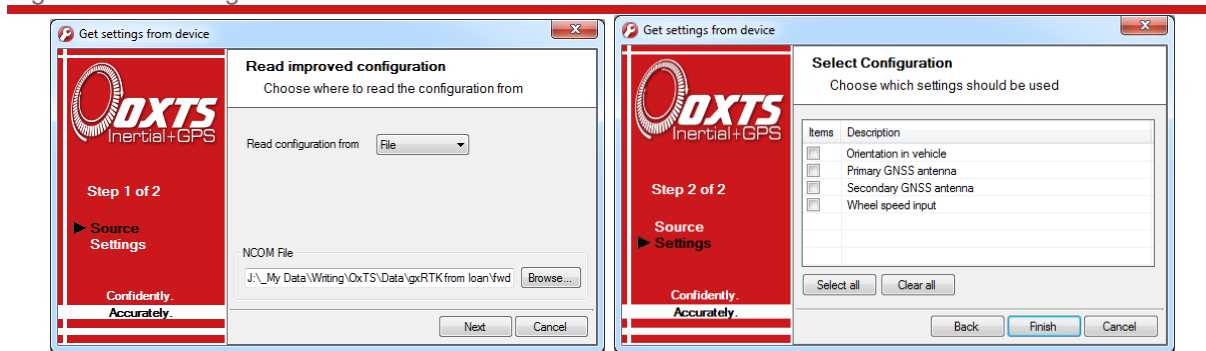
Click the drop-down list and choose which source to read the configuration from. The two options are:

- **Read configuration from file**. If an NCOM file has been saved to disk, or processed using the post-process utility then this file can be read and the settings extracted from it. Use this setting if you have a forward processed NCOM file. Click **Browse** and select the NCOM file you wish to read the configuration from. Do not use an NCOM file that has been combined from forward and backwards processing of the inertial data.

- **Read configuration from Ethernet (xNAV5** only)**. This will get the information that the xNAV is currently using and apply it next time the system starts. Use this setting if the xNAV is running, has initialised and has warmed up. Select the correct IP address of the xNAV to read the configuration from in the drop-down list.

  Note: the list will not function correctly if NAVdisplay or other software is using the xNAV UDP port unless the OxTS UDP Server is running.

Once the source has been selected, click **Next** and the software will find which settings can be obtained from the source. Settings that cannot be obtained will be shown in grey; this may be because the xNAV is not calculating these values at present. Select the settings you want to be updated and uncheck the ones that you do not want to update. Click **Finish** to transfer these settings to the configuration wizard.

If **Orientation in vehicle** is selected, the improvement to orientation should only be applied if the change in the orientation is small (less than 5°). If the change in orientation is large then it is likely that the original configuration was wrong or has not been loaded into NAVconfig. You are very likely to get poor results if the orientation is changed by a large amount.

Use with survey hardware

For using your xNAV INS device with a range of different surveying devices we have online support manuals. This is by no means exhaustive, the xNAV is compatible with almost any LiDAR or camera when it is configured correctly, and the correct interfaces are created between the devices.

Table 15: Hardware integration manuals for surveying devices

Manual	Description
Hesai LiDAR	Hesai hardware integration guide https://support.oxts.com/hc/en-us/articles/360017030840
Ouster LiDAR	Ouster hardware integration guide https://support.oxts.com/hc/en-us/articles/360017072719
Phase One Camera	Phase One Camera User Guide https://support.oxts.com/hc/en-us/articles/360000099345-Phase-One-Camera-User-Guide
Velodyne LiDAR	Hardware integration with Velodyne LiDAR https://support.oxts.com/hc/en-us/articles/360017123620
Z&F Profiler	Hardware integration with Z&F 9012 Profiler https://support.oxts.com/hc/en-us/articles/360002379180-Hardware-integration-with-Z-F-9012-Profiler
PTP	Procedure for configuring PTP for a time synchronisation method over ethernet https://support.oxts.com/hc/en-us/articles/360016515759-PTP-Quick-Start-Guide-Beta-

For information on setting up a configuration for your INS to work with survey devices you can follow the guides above and the NAVconfig support guide.

Many devices will require to receive NMEA messages and a time synchronisation. For the xNAV, time synchronisation can be done using PPS or using PTP. See the manual at the hyperlink above to configure your INS to use PTP. PTP messages are sent over Ethernet whereas PPS will require a suitable cable connection to be made. NMEA messages can be configured to be sent over serial or over Ethernet using NAVconfig. For the serial connection, there must again be a suitable cable connection made.

Using NAVconfig you can also configure input and output triggers and a displaced output if you want the navigation data to be representative of the survey device instead of the INS.

Data logging

A Feature Code can be purchased to allow your xNAV device to log Ethernet traffic directly onto the unit. This allows you to bypass the need to monitor and record your files in real time. Files can be retrieved from the device in the same way as RD files via FTP interfacing.

When LiDAR data is logged in this way it is recorded as .lcom which is identical to a .pcap except without Ethernet headers. LCOM and PCAP files work identically in OxTS Georeferencer.

Please note that data logging does not work for all LiDAR. Data rates from LiDAR devices can be very large which can be overbearing for the CPU of the xNAV650. For Velodyne LiDAR usage, a 16 laser LiDAR will log comfortably onto the xNAV but a 32 laser LiDAR will not log correctly onto the xNAV. 3 MB/s is the given specification for data recording reliably.

This setting can be enabled or disabled in the LiDAR Scanner tab of the Hardware Setup in NAVconfig. Select the Velodyne VLP-16 as your scanner type (regardless of your device) and then select 'Log data' and 'Log telemetry'.

PPS and NMEA

Many survey devices require to receive PPS synchronisation and NMEA data. This can be easily configured using NAVconfig. The hardware setup will also have to be made to support this via a suitable cable. Furthermore, ensure that the PPS requirements for the device are the same as the INS output. If you require TTL input, for example, you will need an adapter between the two devices.

In NAVconfig PPS and NMEA can be set in the LiDAR Scanner tab of the Hardware Setup section. Choosing Velodyne VLP-16 (regardless of your device) will allow you to choose NMEA settings. Depending on the cabling setup you have used you are able to send NMEA messages over either Ethernet or serial. For example, when using a PTP setup you will want NMEA and PTP messages to both be sent over Ethernet to the device.

There are further PPS options in the PPS/Triggers section.

Figure 26: NAVconfig LiDAR Scanner tab
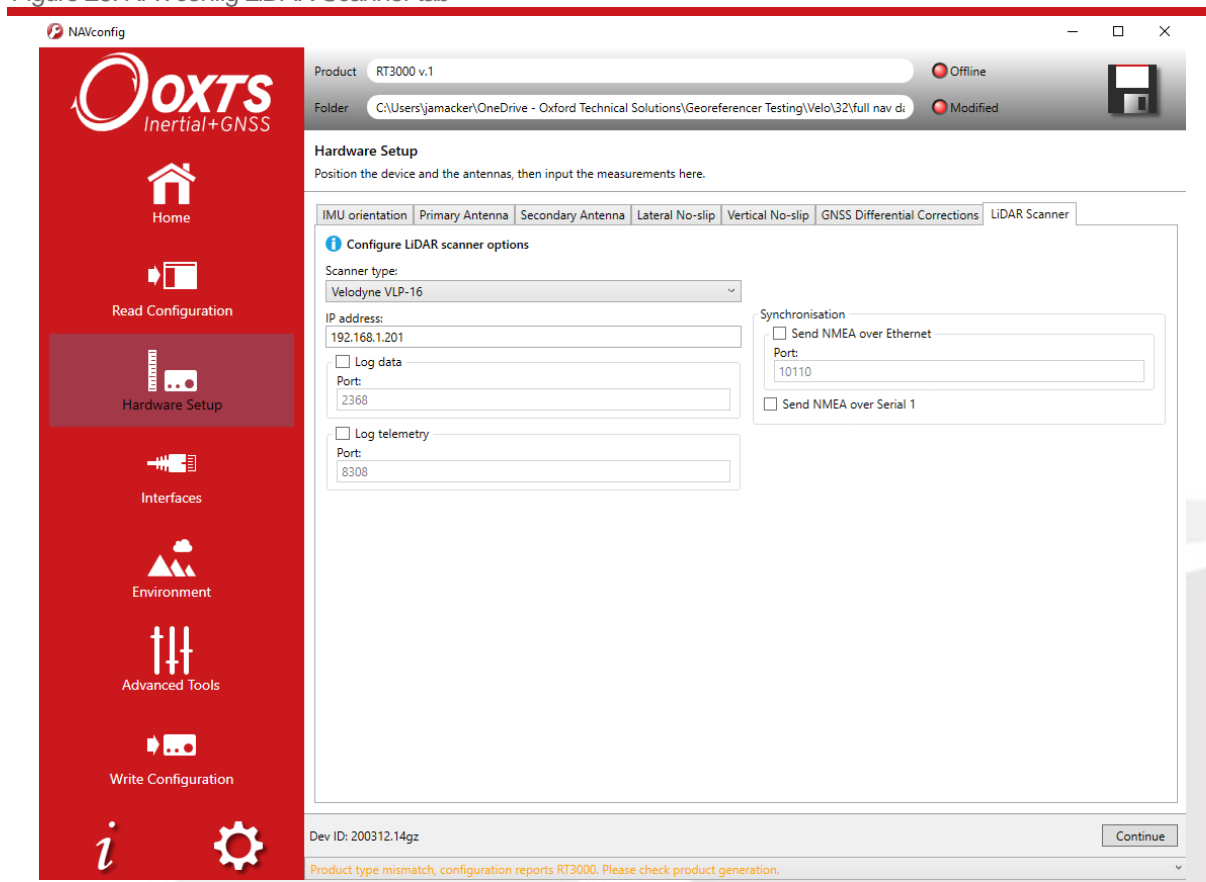
PPS/Triggers

NAVconfig allows users to easily configure trigger inputs for cameras within the PPS/Triggers tab of the Interfaces section. These are set on the right-hand side and can be input, output triggers or IMU sync triggers.

PPS signals can be set to have the active edge in the falling or rising edge in this tab also. Check your device's manual to determine which is required.

NCOM (navigation data) packets can be set to output on triggers in the Ethernet tab.

Figure 27: The PPS/Triggers tab in NAVconfig.
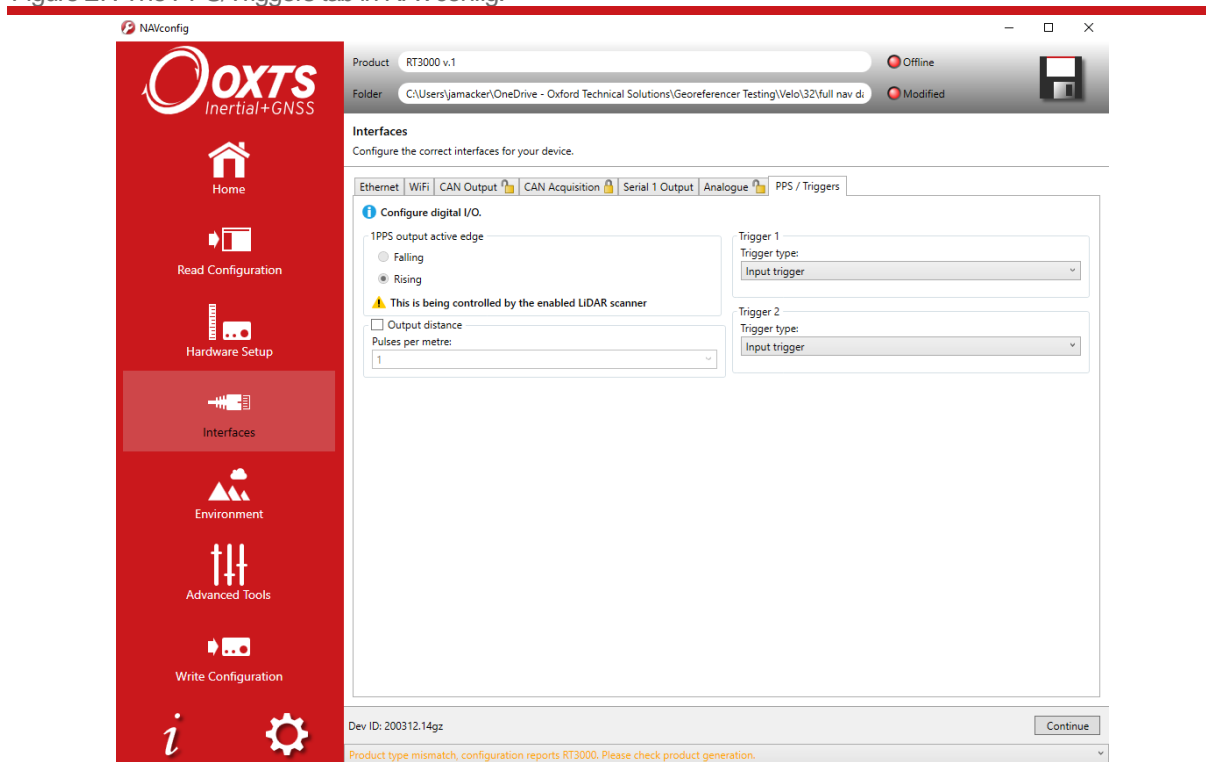
PTP

Currently (March 2021), there is no GUI way of configuring PTP settings but this will be implemented in a future release of NAVsuite.

Use the link above to access the PTP Quick Start Guide on our support site that has more details.

To use PTP on your xNAV650 device ensure that you have the PTP feature code purchased and enabled and do the following:

1. Upgrade the firmware of the OxTS INS.
2. Upload a ptpd.conf file and the leap-seconds.list file to the unit.
3. Ensure the PTP feature code is enabled.
4. Append -enable_ptp to mobile.cfg.
5. Reboot the unit.

For the PTP functionality to work, the unit must have the primary GNSS antenna connected and be tracking satellites. For optimum performance, the unit must also be initialised.

All of the other PTP settings are configured with the "ptpd.conf" file. All the options are documented (for example, https://manpages.debian.org/testing/ptpd/ptpd.conf.5.en.html), though some are not supported. See the support article for an example of this. To edit the configuration, edit the ptpd.conf file and then upload it again to the unit and reboot it.

PTP packets will be viewable in software such as Wireshark as PTPv2 protocol packets.

OxTS devices get their time solution from GNSS satellites which use very accurate atomic clocks. The time that OxTS devices receive from the satellites is the number of seconds since midnight on 5th January 1980. This is known as the GPS epoch and from this the device can calculate the current date and time. By default, when an OxTS device is used with PTP, it will be using the GPS epoch.

Not all devices expect timestamps to be in the GPS epoch. Here is a list of commonly used time modes:

Table 16: Epoch time configurations

GPS	Time in seconds since the GPS epoch (1980-01-01 00:00:00 UTC), same as NCOM.
Unix	Time in seconds since the Unix epoch (1970-01-01 00:00:00 UTC).
UTC	Time in seconds since the Unix epoch (1970-01-01 00:00:00 UTC), including leap seconds.
PTP	Time in seconds since the PTP epoch (1969-12-31 23:59:51 TAI), including leap seconds.

To get the correct date and time from a timestamp, it is important to know which epoch is being used.

If the PTP device being synchronised to the OxTS device does not use the GPS epoch, it is possible to configure the OxTS device to output PTP timestamps from a different epoch (this will not change the timestamps in the NCOM stream). This is done by adding the relevant advanced command in NAVconfig (Modify Configuration>Advanced>Commands):

Table 17 Time epoch advanced commands

GPS	-ptp_time_mode_gps
Unix	-ptp_time_mode_unix or -ptp_custom_offset_315964800
UTC	-ptp_time_mode_utc or -ptp_custom_offset_315964782
PTP	-ptp_time_mode_ptp or -ptp_custom_offset_315964819

Here you can see that the different time modes can be reached by adding different offsets to the GPS timestamps. Similarly, the -ptp_custom_offset_%d command can also be used to access time modes not listed above by finding the correct offset (which will be the number of seconds between the different epochs).

During internal testing of the PTP feature, a data was collected with a Hesai Pandar40P and an RT3000 v3. Time synchronisation was achieved using PTP. The RT3000 v3 was in GPS mode but the Hesai Pandar40P was expecting timestamps in UTC. The following command was required to generate an accurate pointcloud:

lidar_time_offset=315964785000000000

If the RT3000 v3 was instead in Unix time mode, the following command would be required:

lidar_time_offset=-18000000000

Finally, ensure that your survey device is correctly configured to anticipate PTP time synchronisation.

Cable modification

The standard user cable for the xNAV is shown in Drawing 14C0091x (page 50). This has been made to be ideal for modification to the user's selected purpose. Using the cable wiring diagram and the wiring guide shown at the end of this document you will be able to wire up a cable with a suitable connector to interface with whichever requirements you have. If you are creating your own cable you will need to ensure that the same micro-d connector is used and the pinouts are correctly configured.

OxTS does not guarantee the functionality of any modifications made to the user cable and is not responsible for any damage caused to the INS or other devices.

Specifications

Table 18. xNAV specification

Parameter	xNAV200 xNAV500	xNAV250 xNAV550
Positioning	GPS L1 GLONASS L1	GPS L1, L2 GLONASS L1, L2 BeiDou L1, L2 (option)*
Position accuracy (CEP)	2 m SPS 0.6 SBAS 0.5 m DGPS	1.6 m SPS 0.6 m SBAS 0.4 m DGPS 0.02 m RTK
Position drift after 60 s GNSS outage (RMS)	0.95 m	0.95 m
Velocity accuracy (RMS)	0.1 km/h	0.1 km/h
Roll/pitch	0.05° 1σ	0.05° 1σ
Heading (2 m antenna baseline)	0.15° 1σ	0.1° 1σ
Accelerometers – Bias stability – Linearity – Scale factor – Range	0.02 mg 1σ 0.05 % 0.01 % 1σ 30 g	0.02 mg 1σ 0.05 % 0.01 % 1σ 30 g
Gyros – Bias stability – Linearity – Scale factor – Range	3°/hr 0.05 % 0.05 % 300°/s	3°/hr 0.05 % 0.05 % 300°/s
Update rate	100 Hz 200/250 Hz (option)	100 Hz 200/250 Hz (option)
Power	10–31 V dc, 6.5 W	10–31 V dc, 9 W
Dimensions	132 × 77 × 36 mm	132 × 77 × 36 mm
Mass	0.365 kg	0.395 kg
Operating temperature	-40–70 °C	-40–70 °C
Specification temperature	-10–70 °C	-10–70 °C
Vibration	0.002 g^2/Hz, 5–500 Hz	0.002 g^2/Hz, 5–500 Hz
Shock survival	60 g	60 g
Environmental protection	IP65	IP65
Internal storage	32 GB eMMC	32 GB eMMC

Valid for open-sky conditions over ± 1 g range.

* BeiDou is not compatible with gxRTK. Triple GNSS constellation not recommended due to data bandwidth restrictions on GNSS receiver.
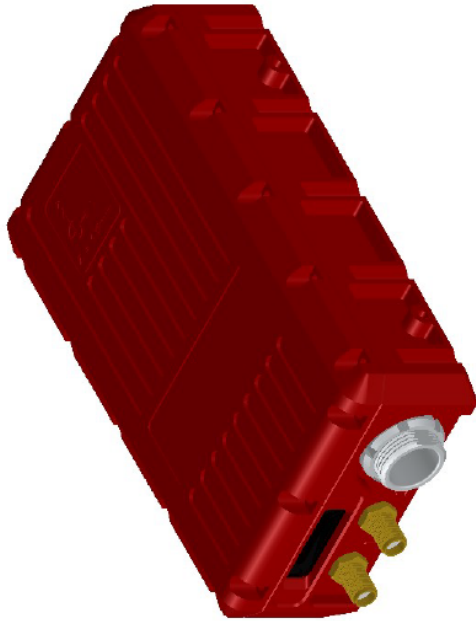
Revision history

Revision	Comments
130712	Initial version
131125	Updated to NAVsuite
140207	Added xNAV500
140606	More xNAV500 revisions. Updated NAVconfig
150106	Added xNAV550
150424	Added xNAV250. Added co-ordinate system configurations. Updated wheel config configurations
150701	Added IMU output rate and vehicle starts options. Updated for NAVsuite Spring 2015 release
160412	Added GLONASS option for xNAV200&500
180222	WEEE update
190124	Updated to reflect v3 xNAV product
190718	Updated specification table (Accelerometers)
191008	Updated xNAV drawings and specification table
200219	Removed user cable and antennas from "what's in the box"
210326	Added PTP Master, cable diagrams and surveying guide. Rebranded throughout

Drawing list

The following pages contain drawings that describe the components of the xNAV system. Note that the '*x*' following a drawing number is the revision code for the part. If you require a drawing, or different revision of a drawing, that is not here then contact OxTS.
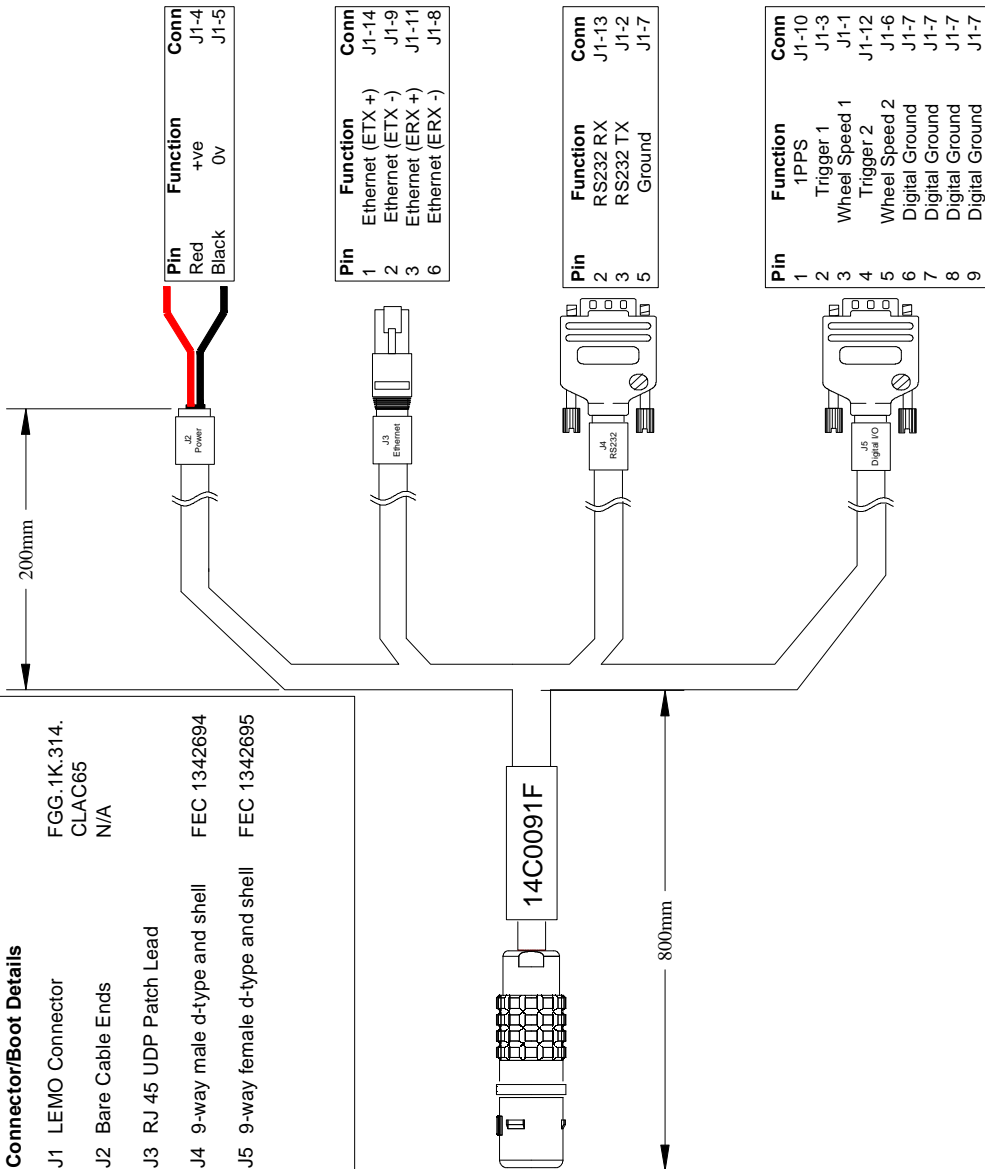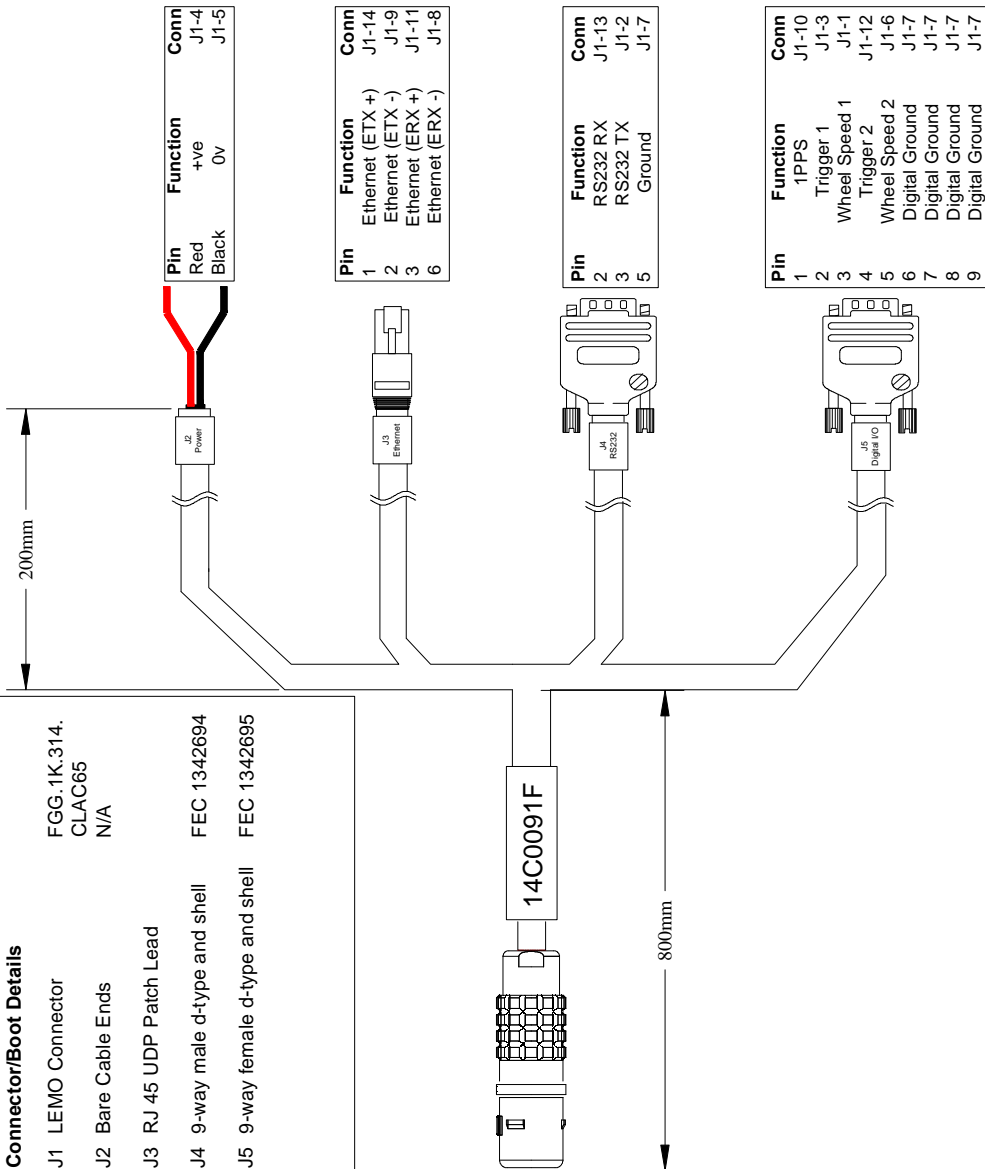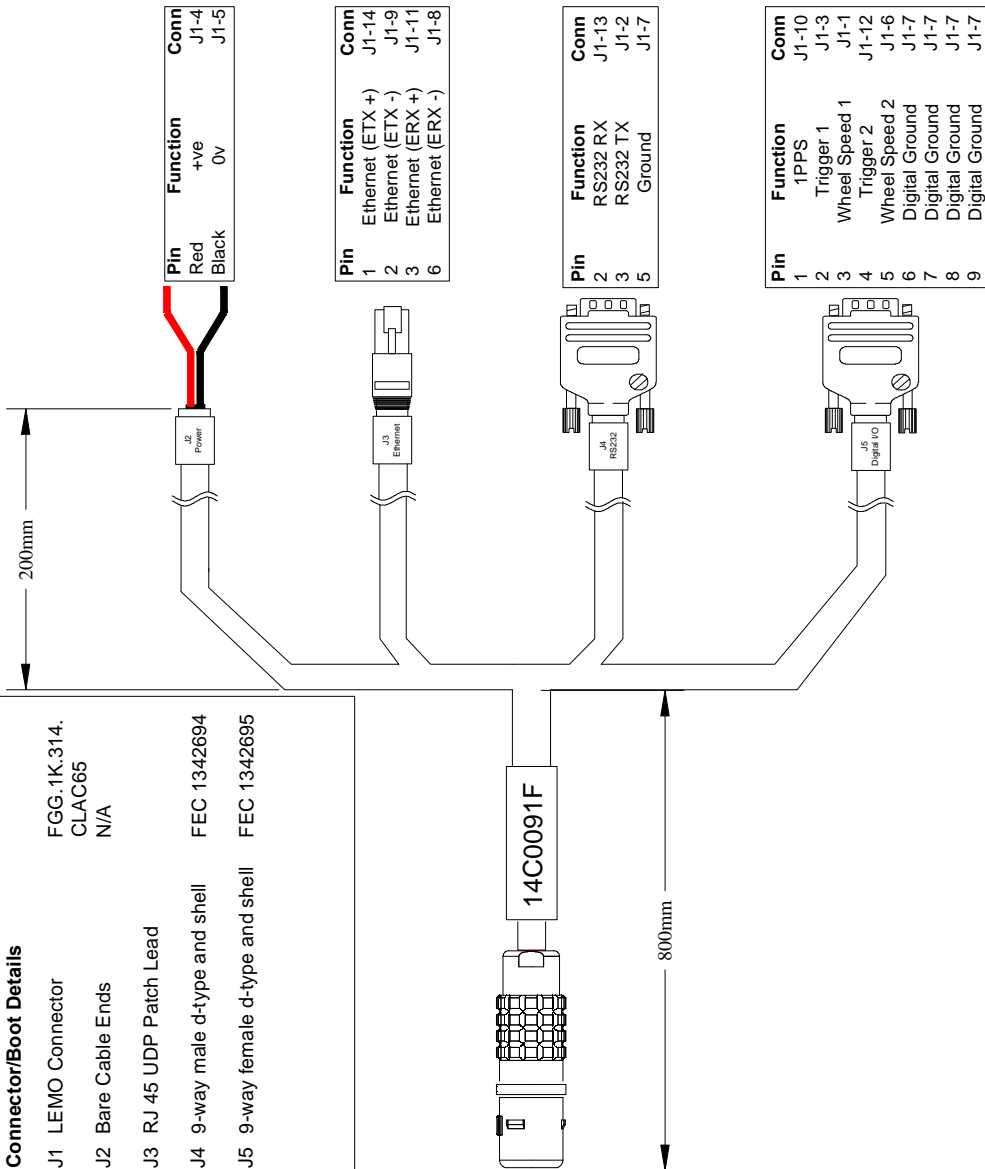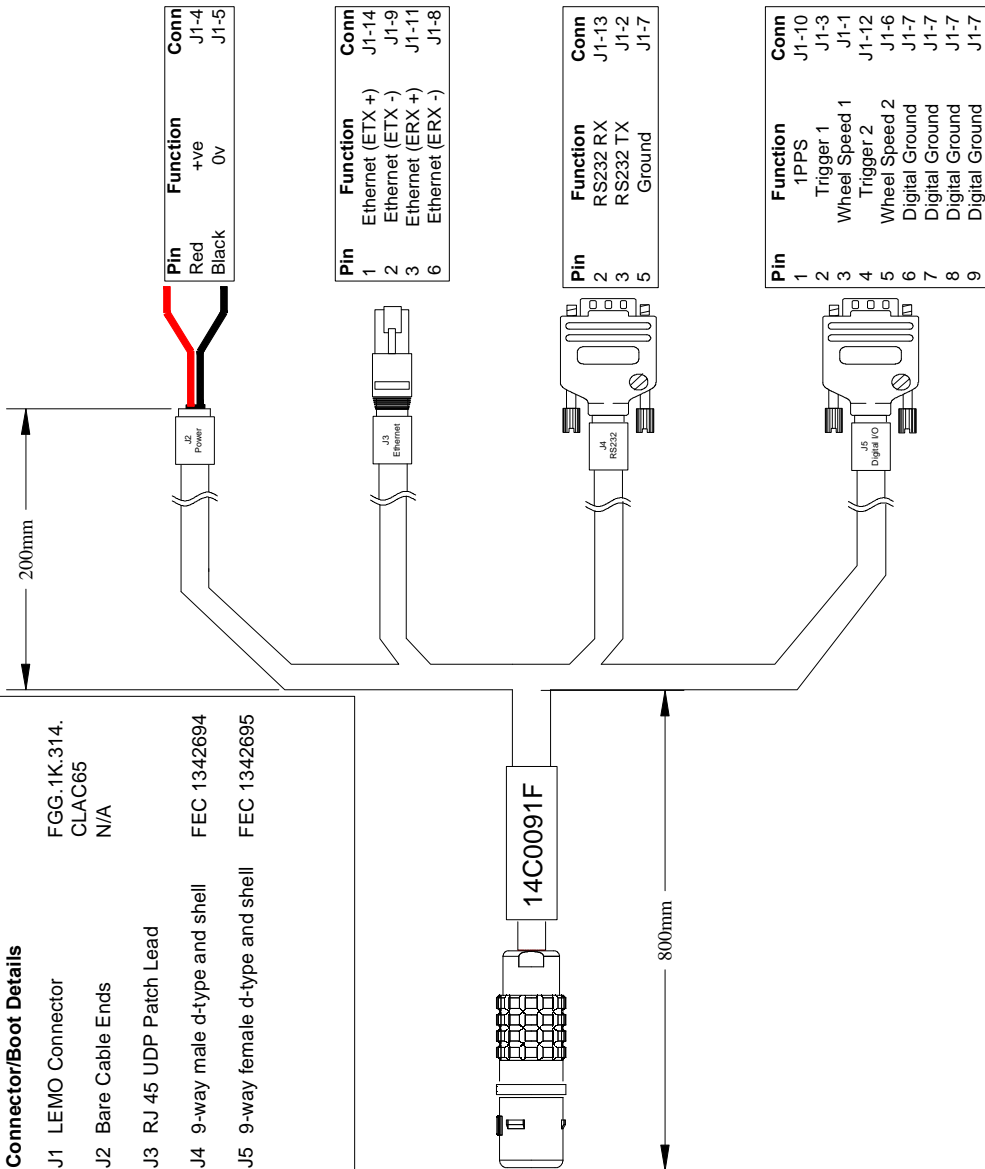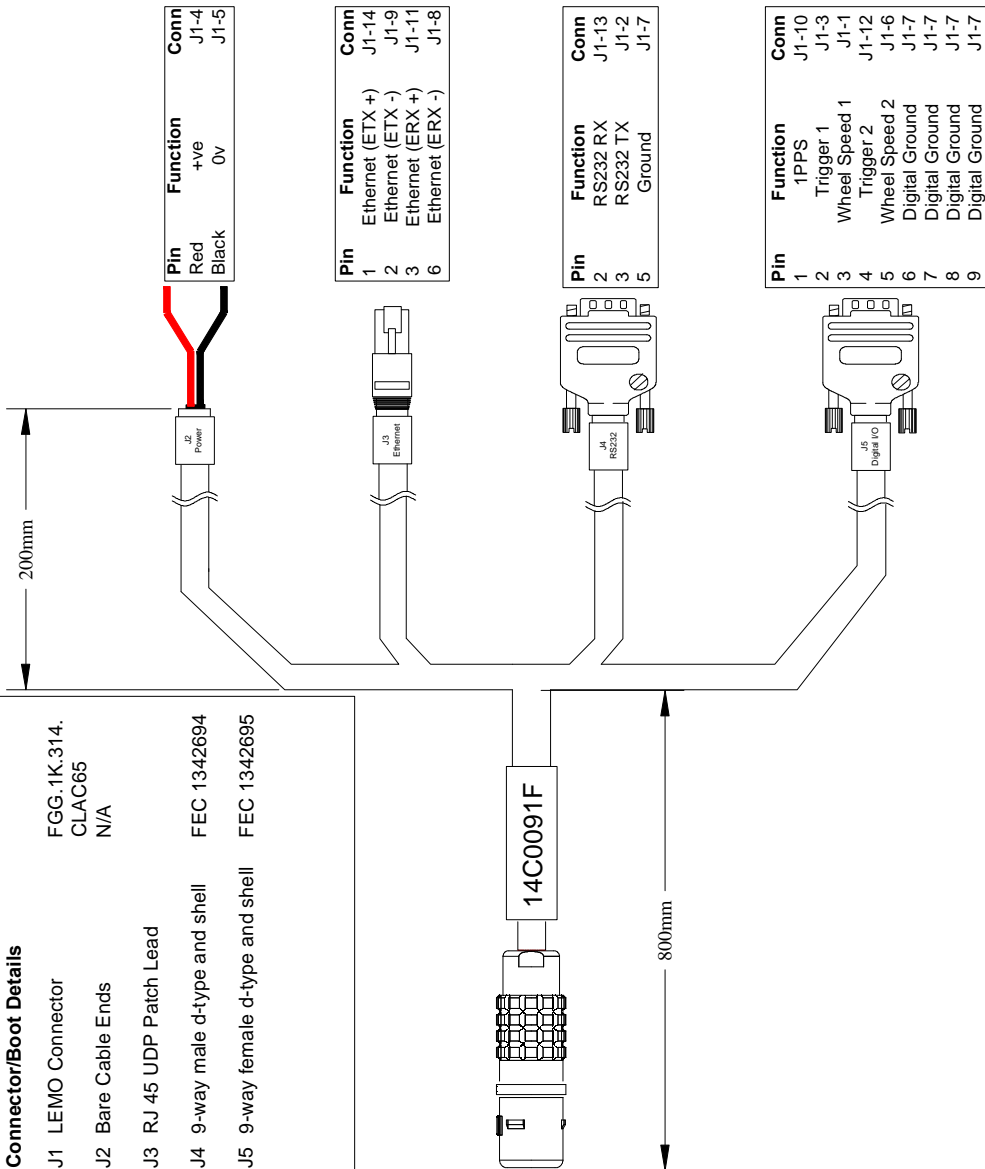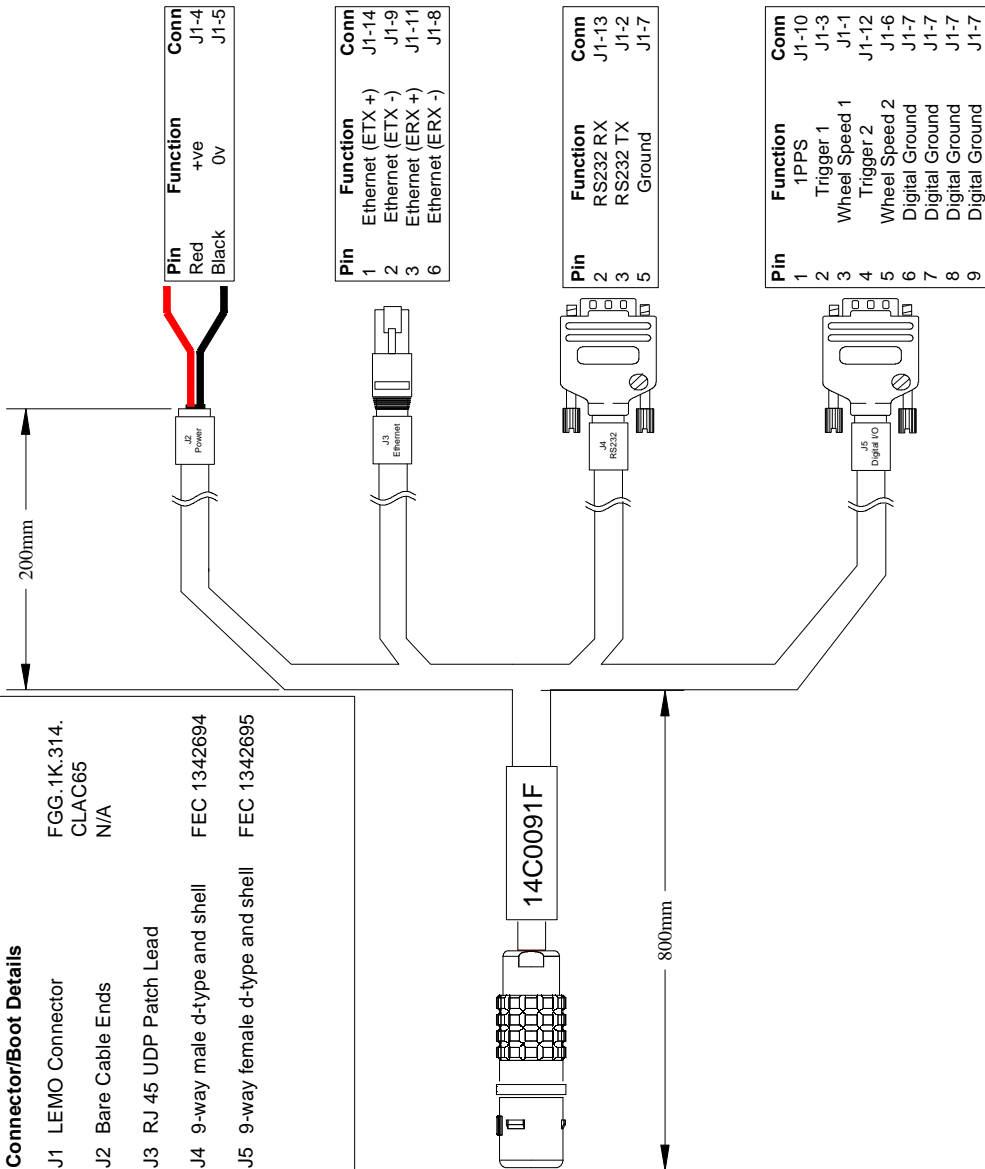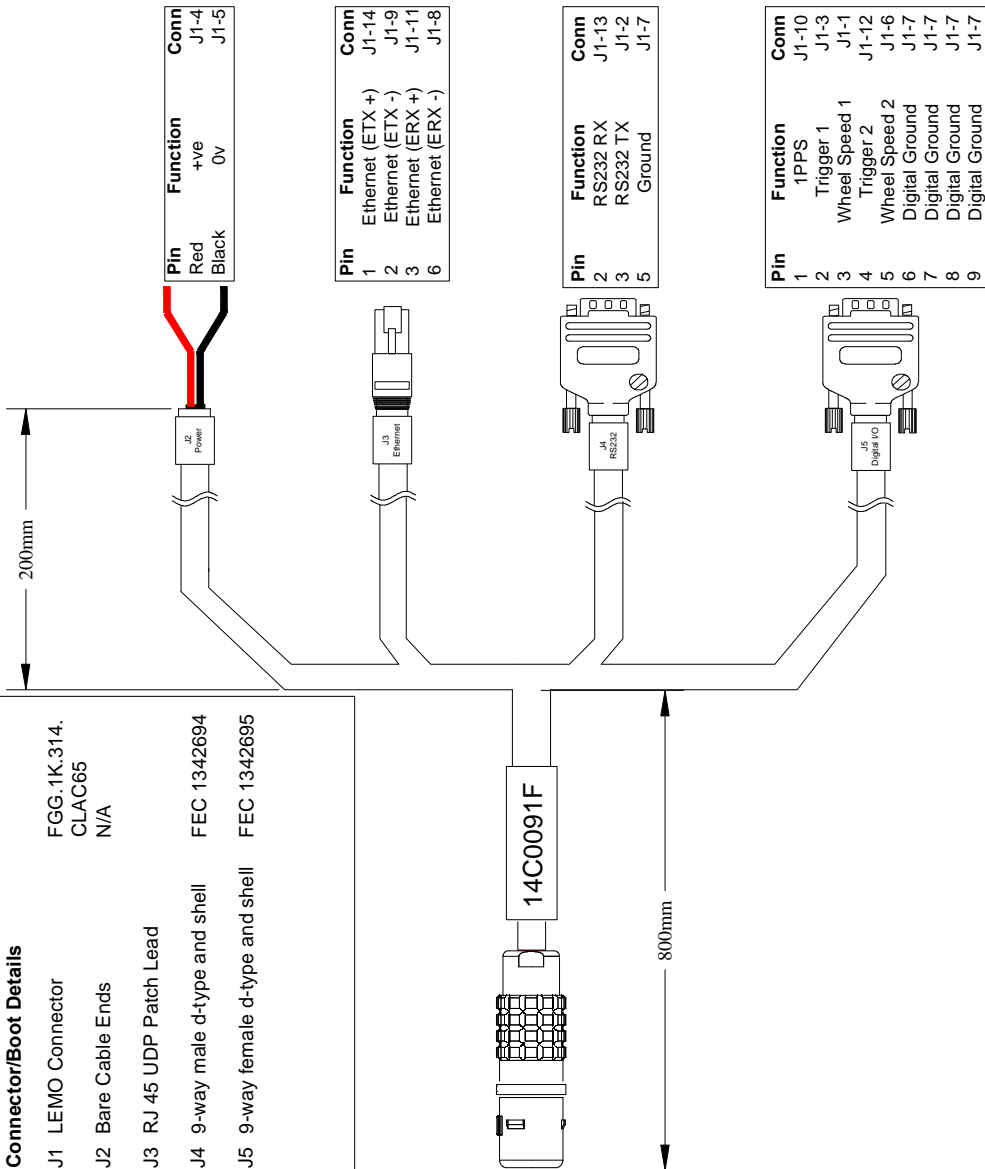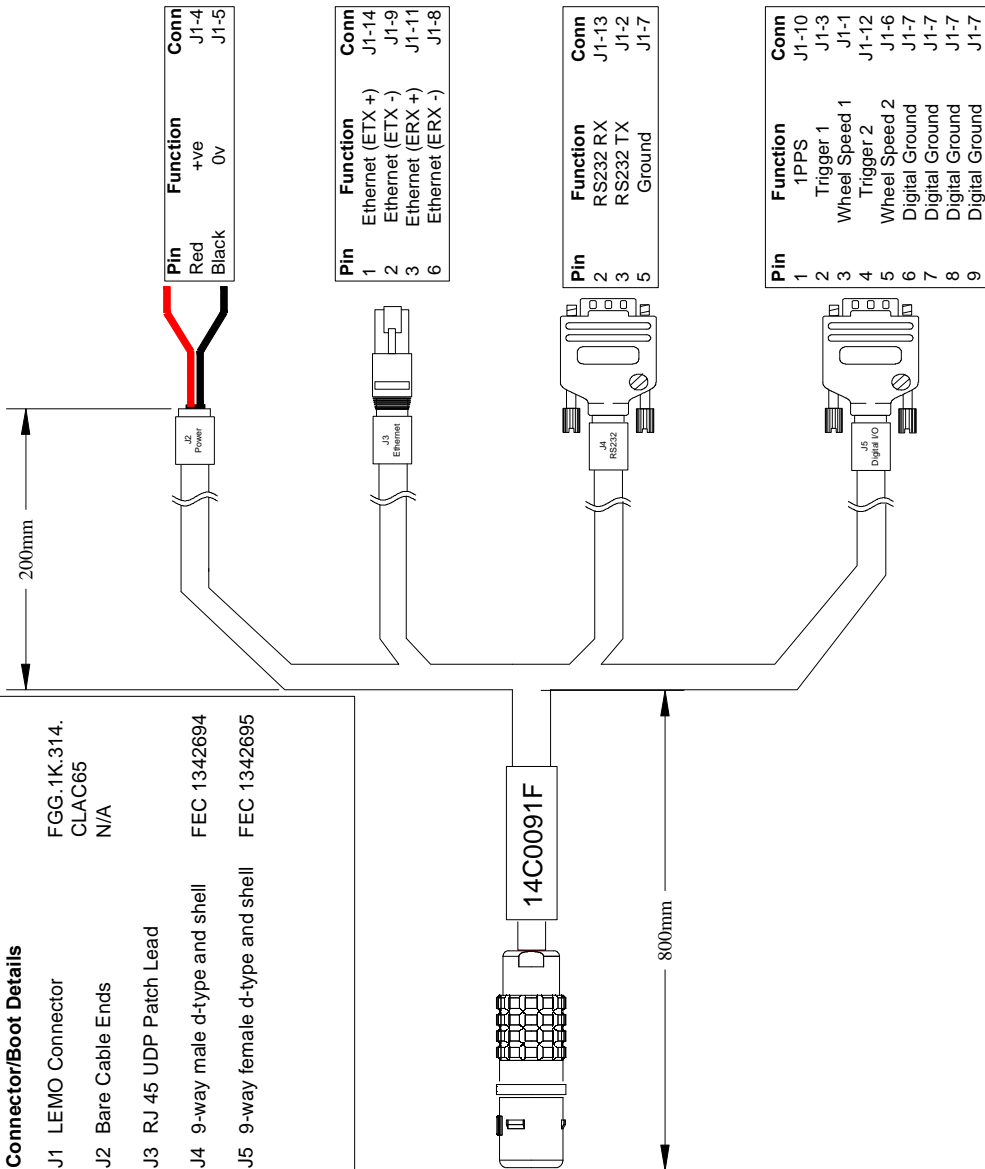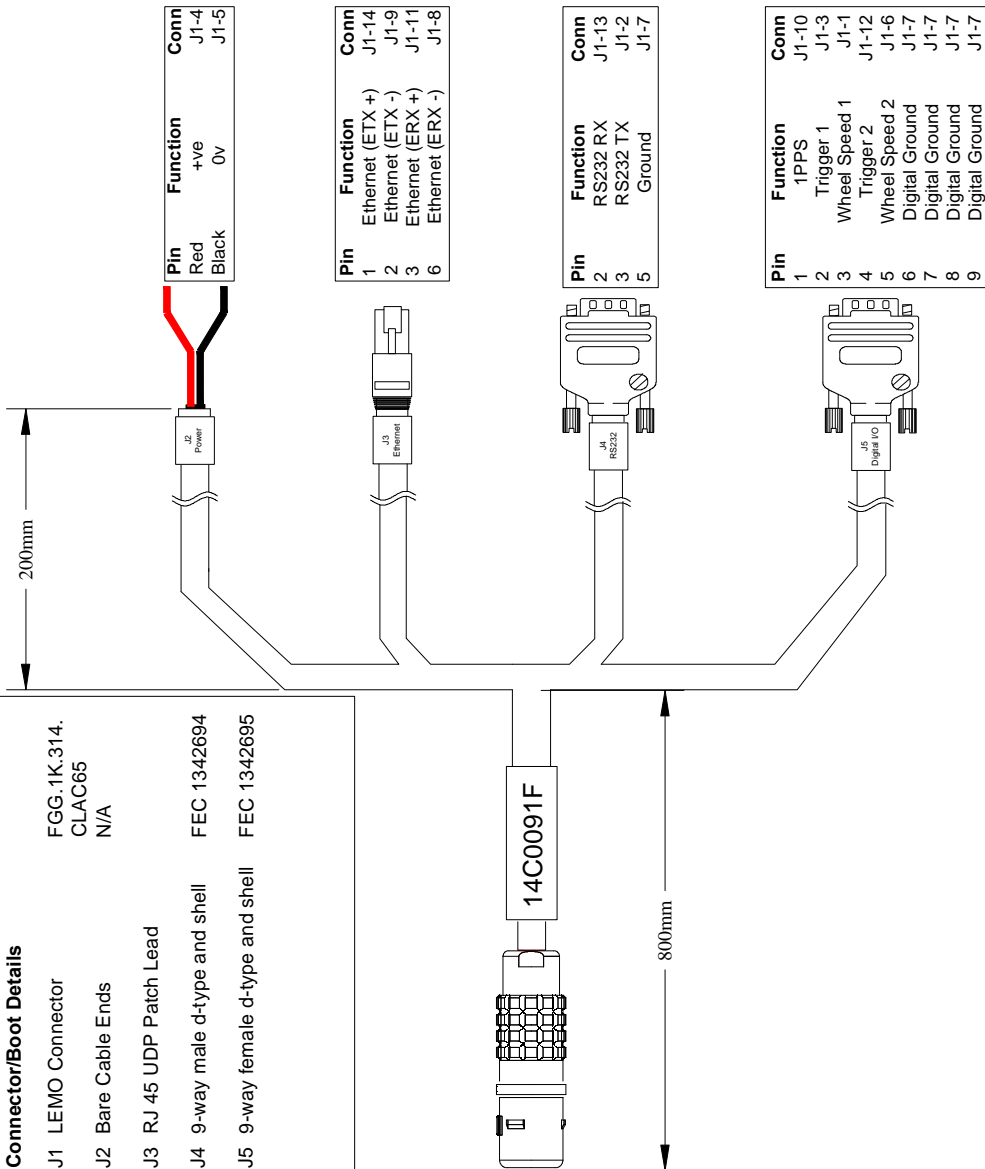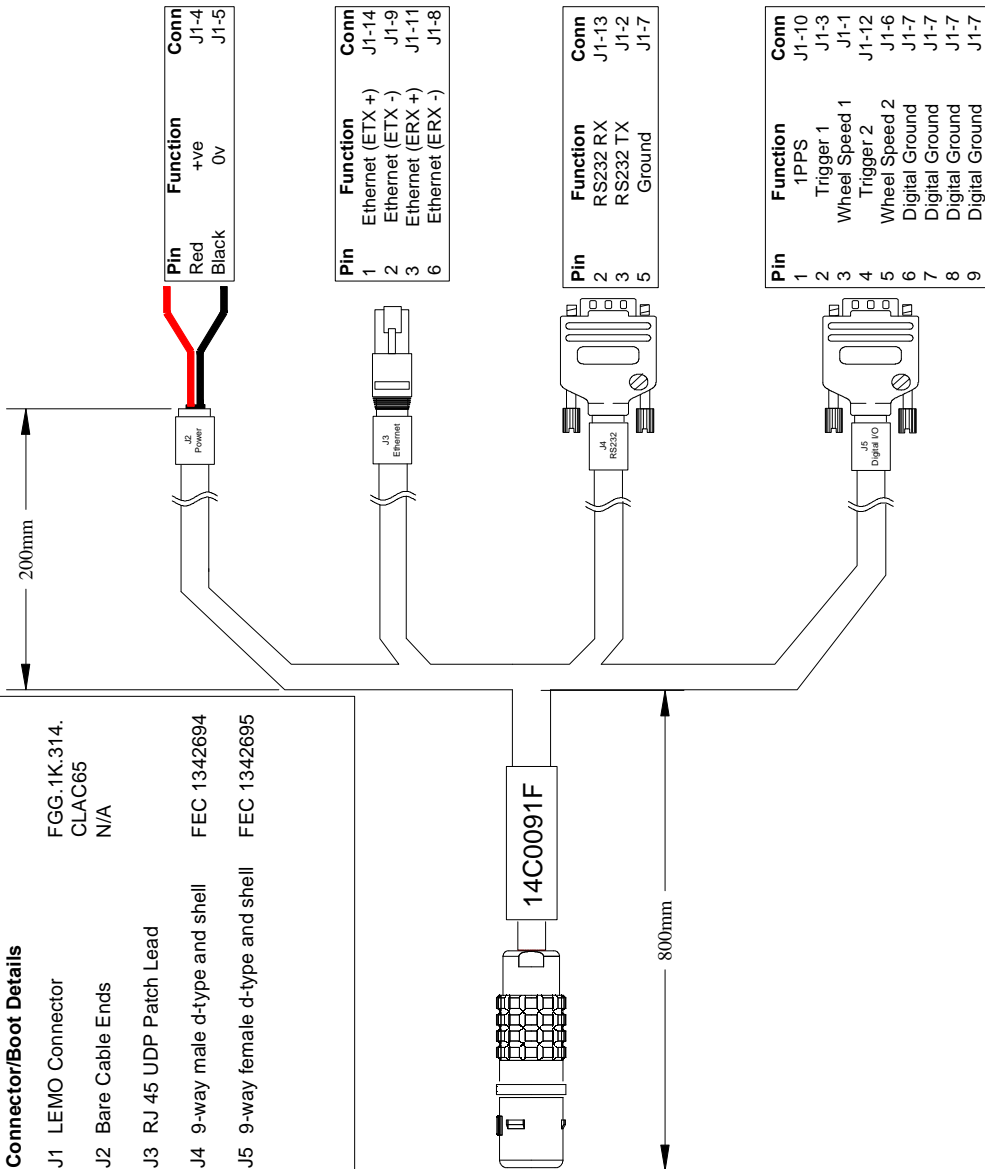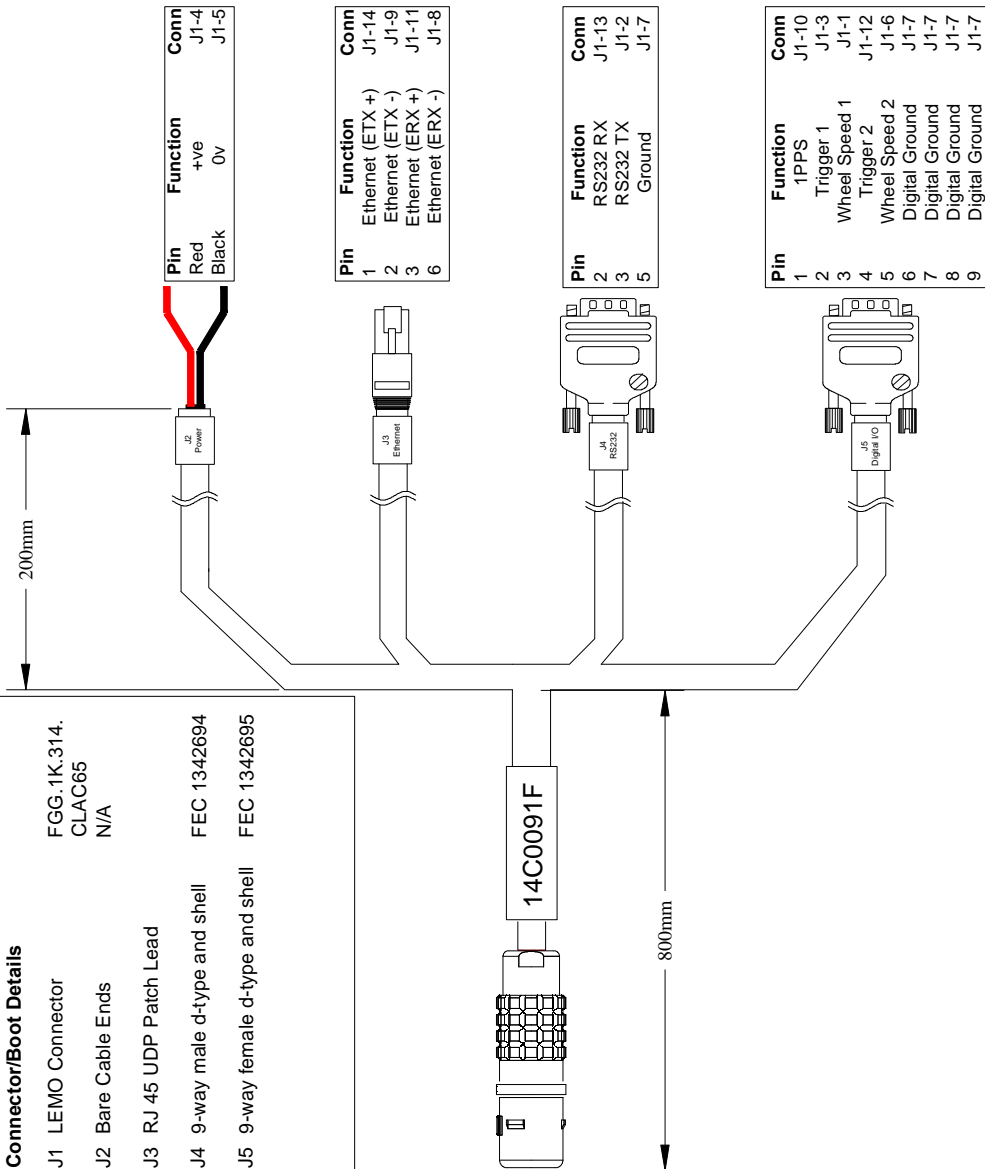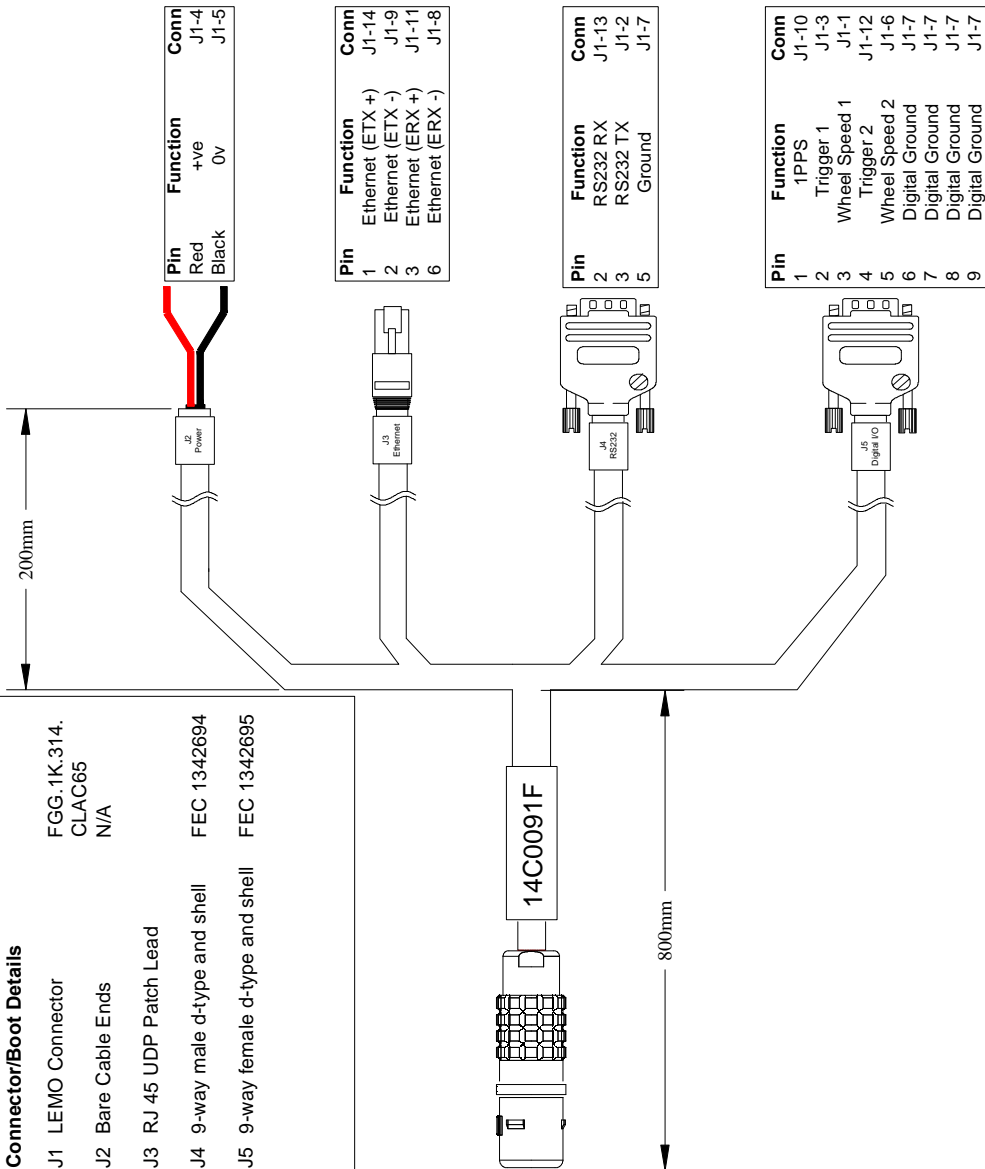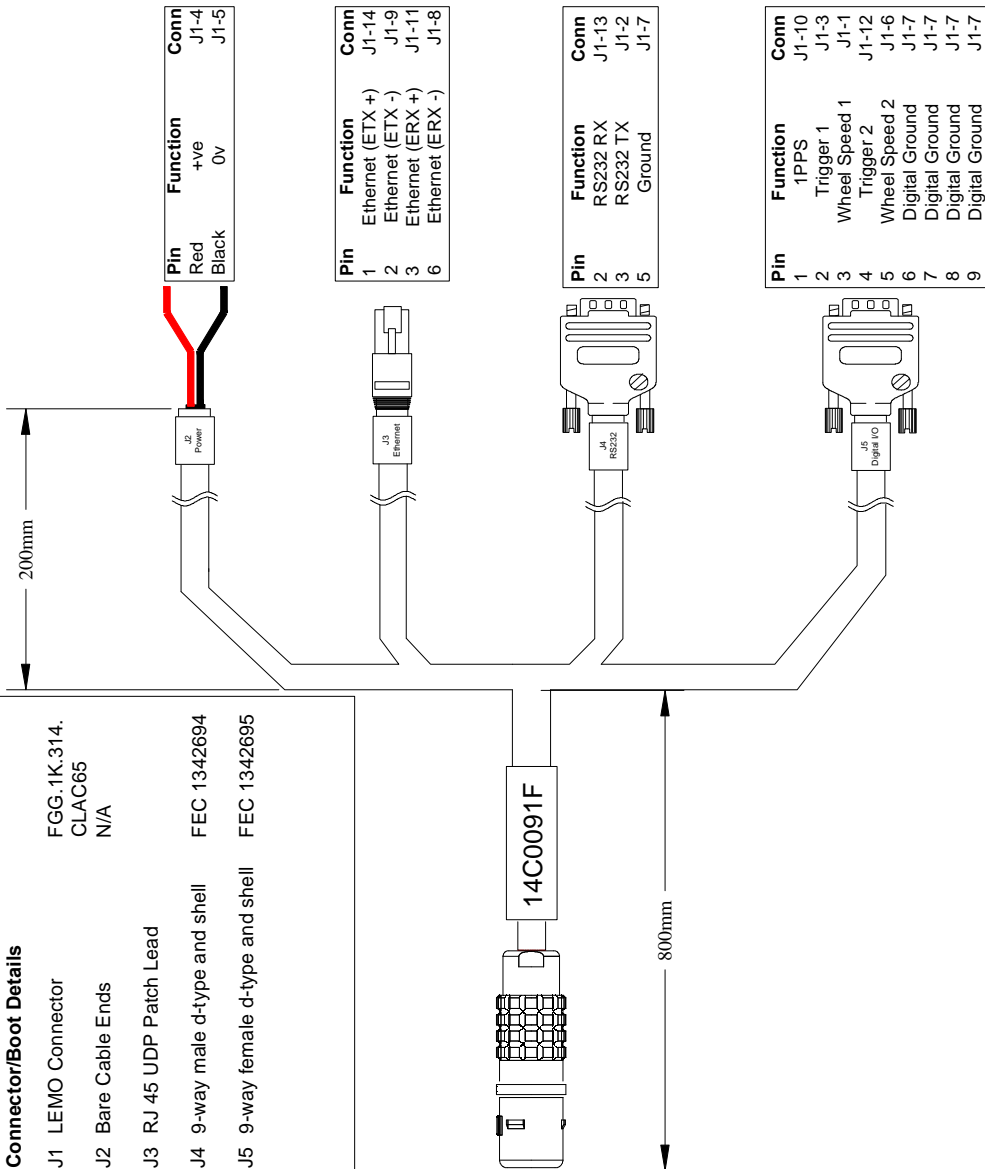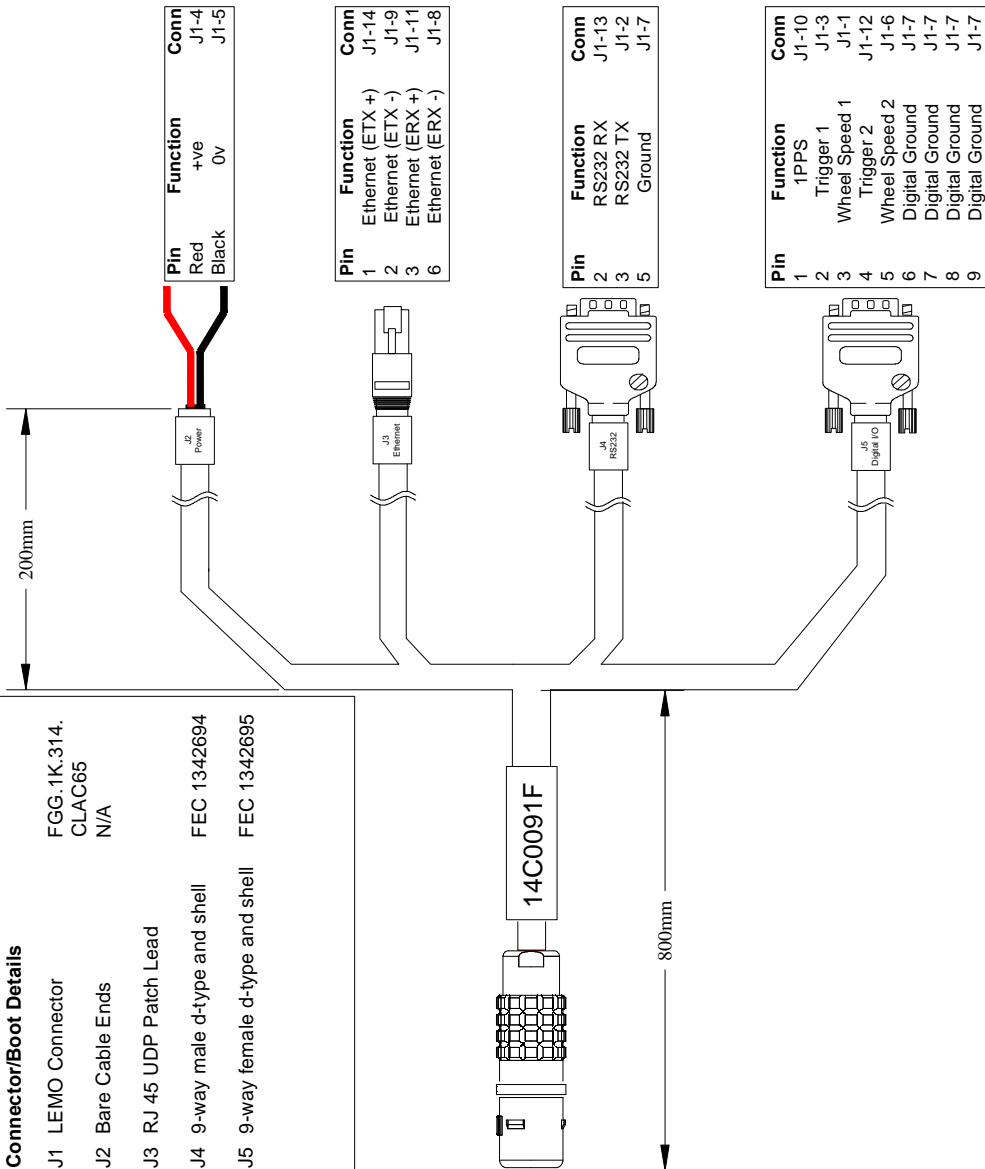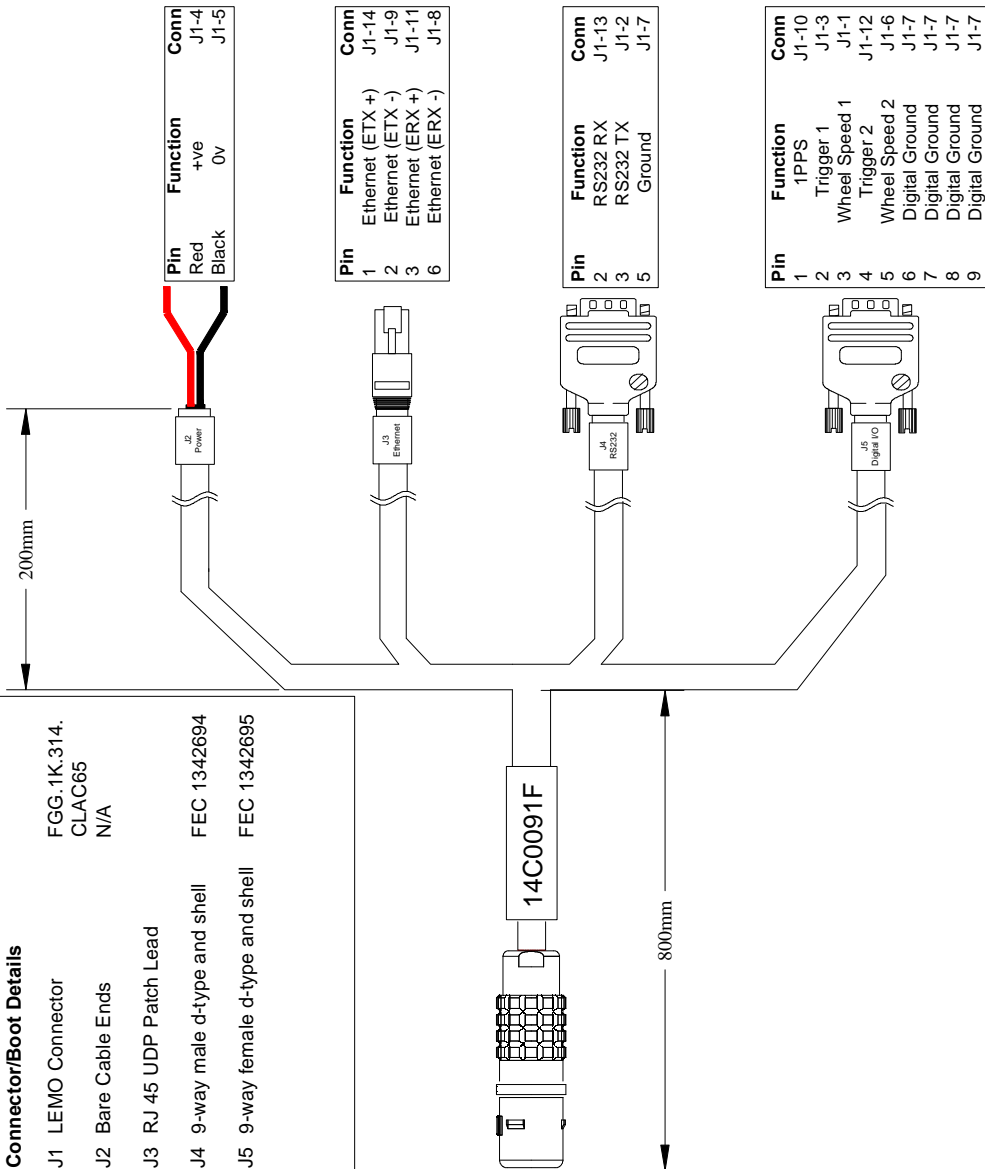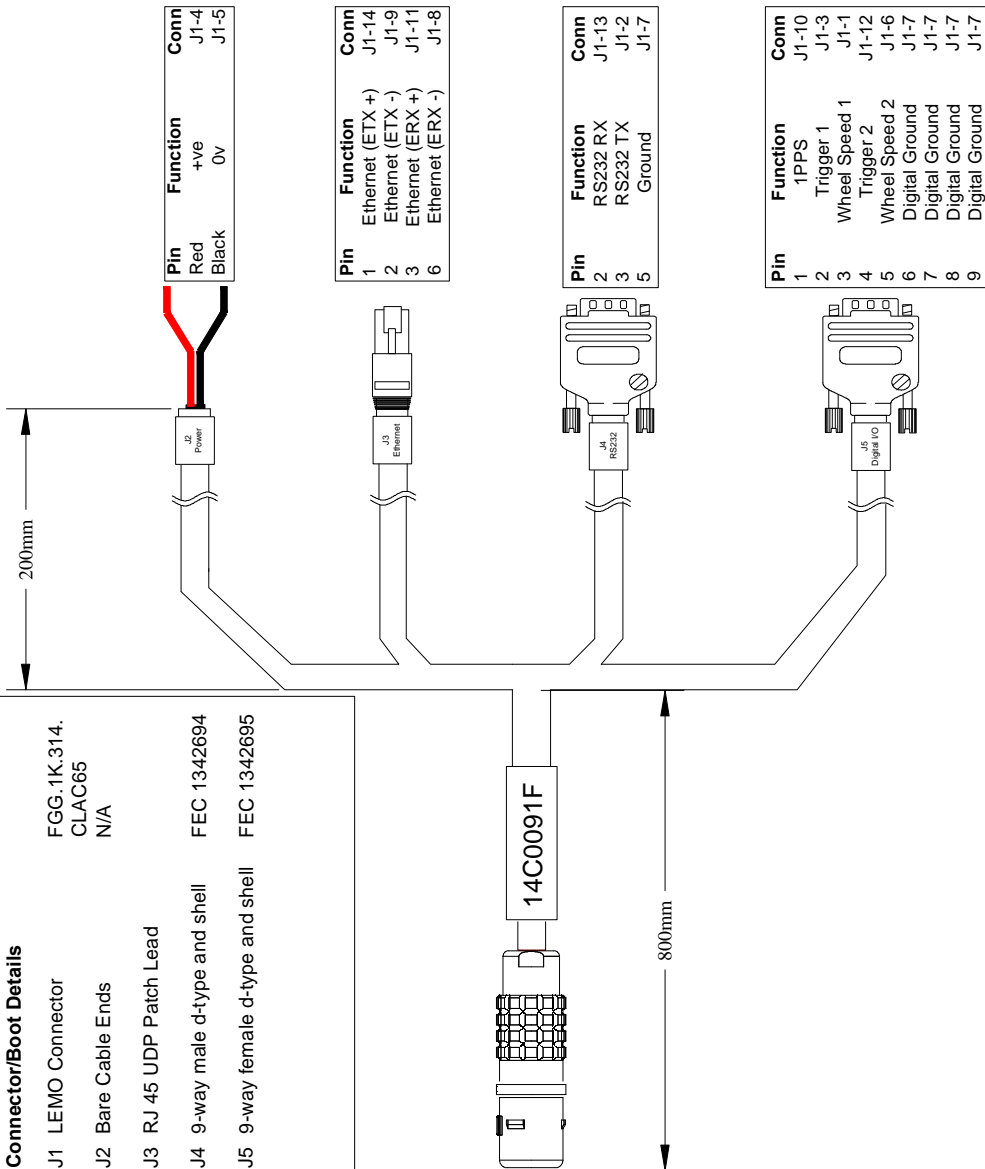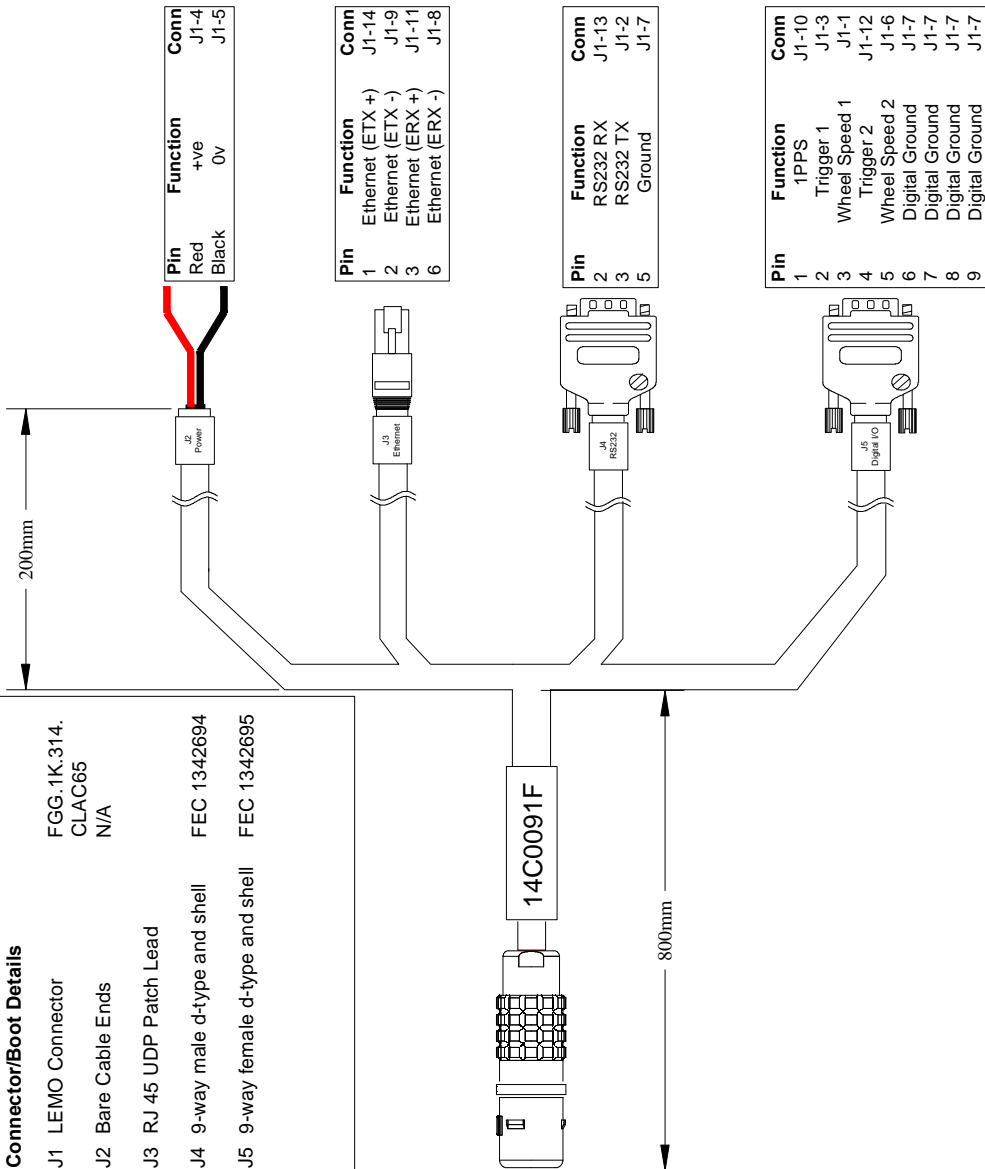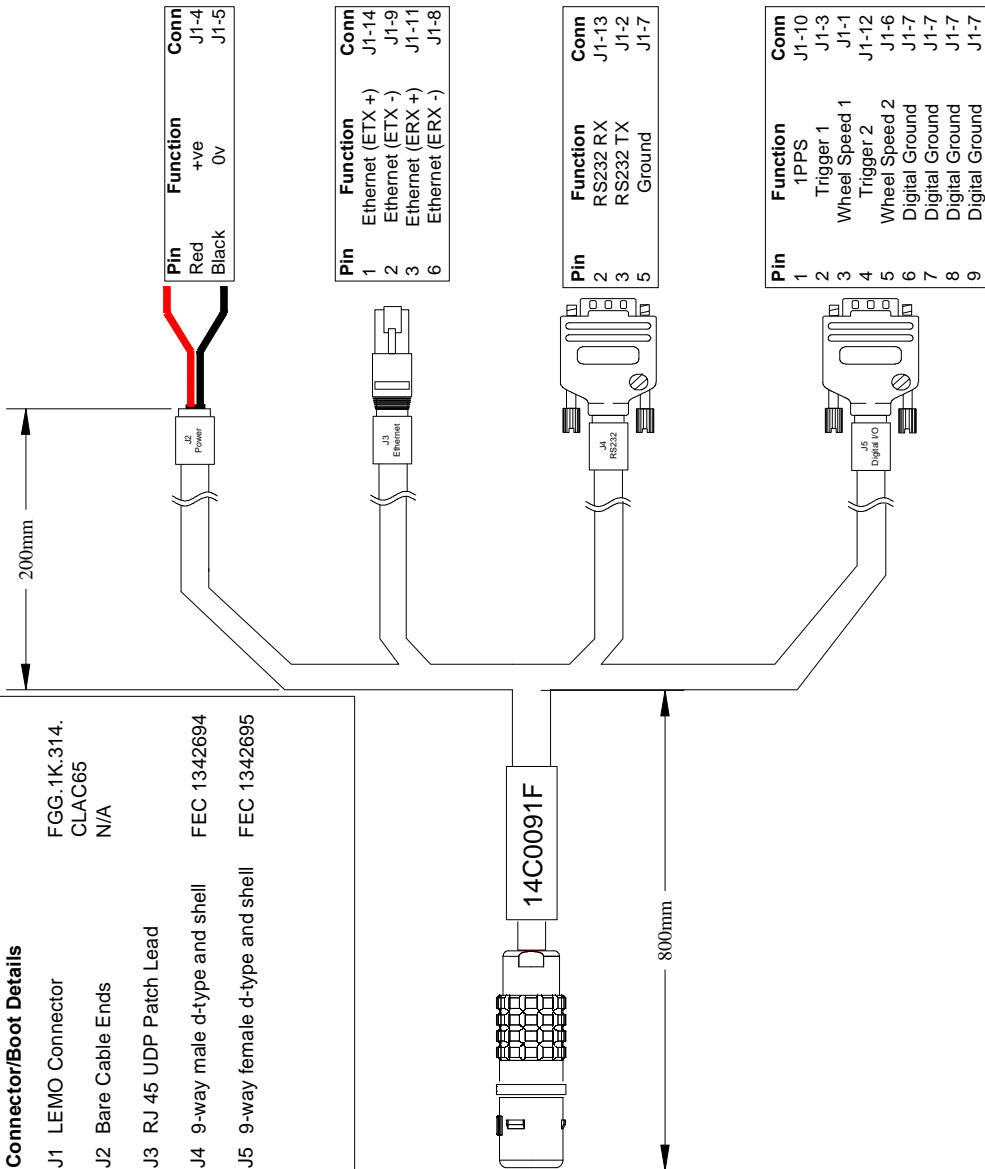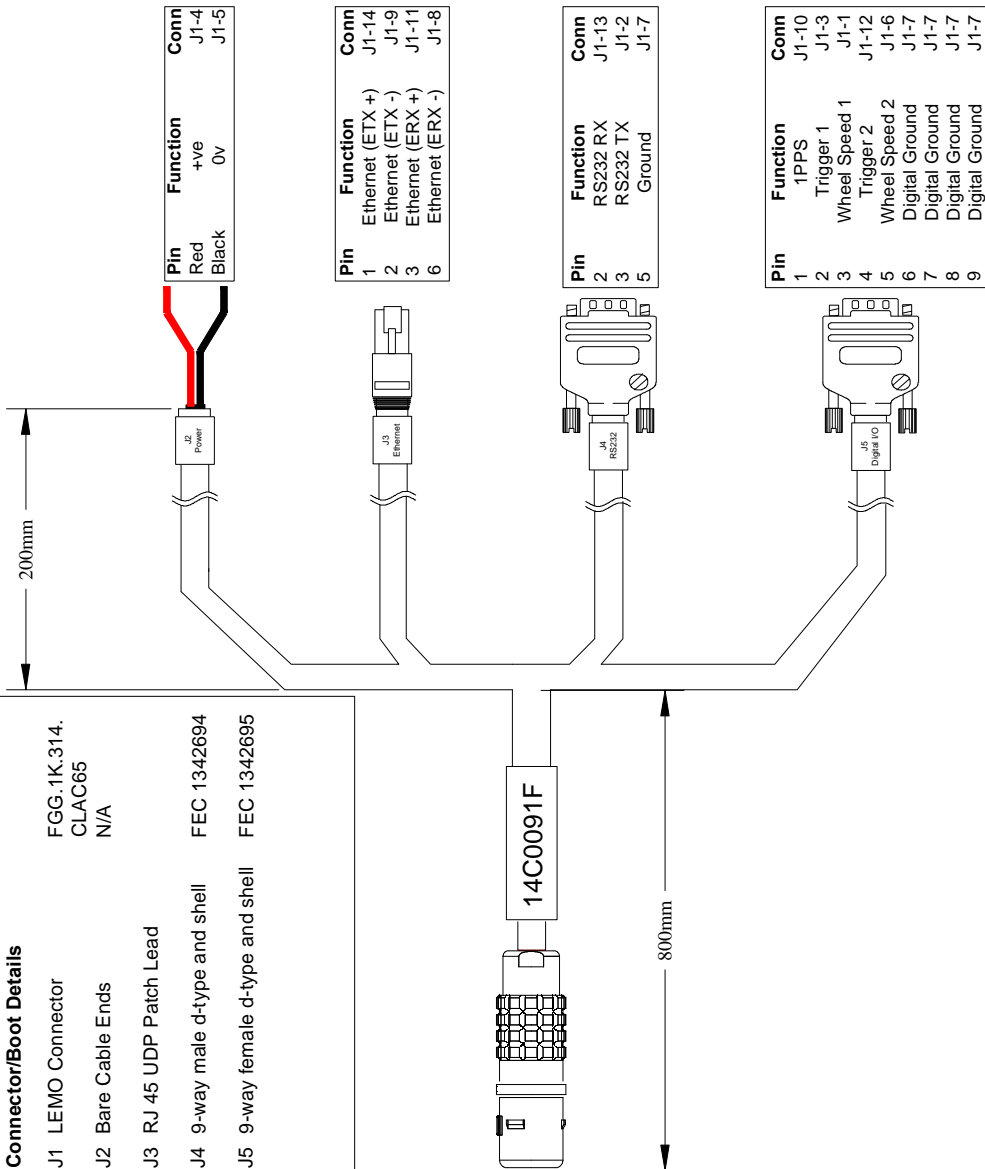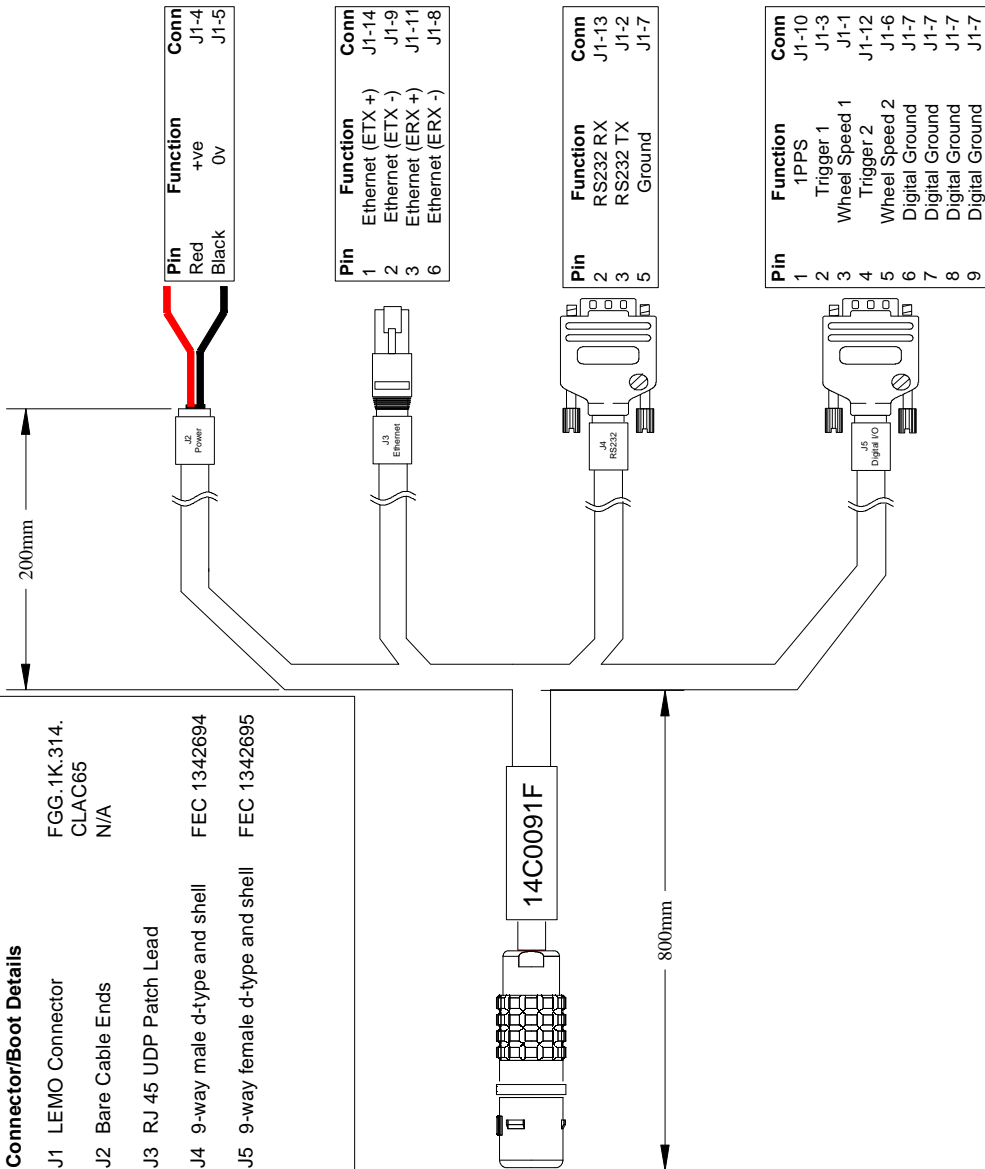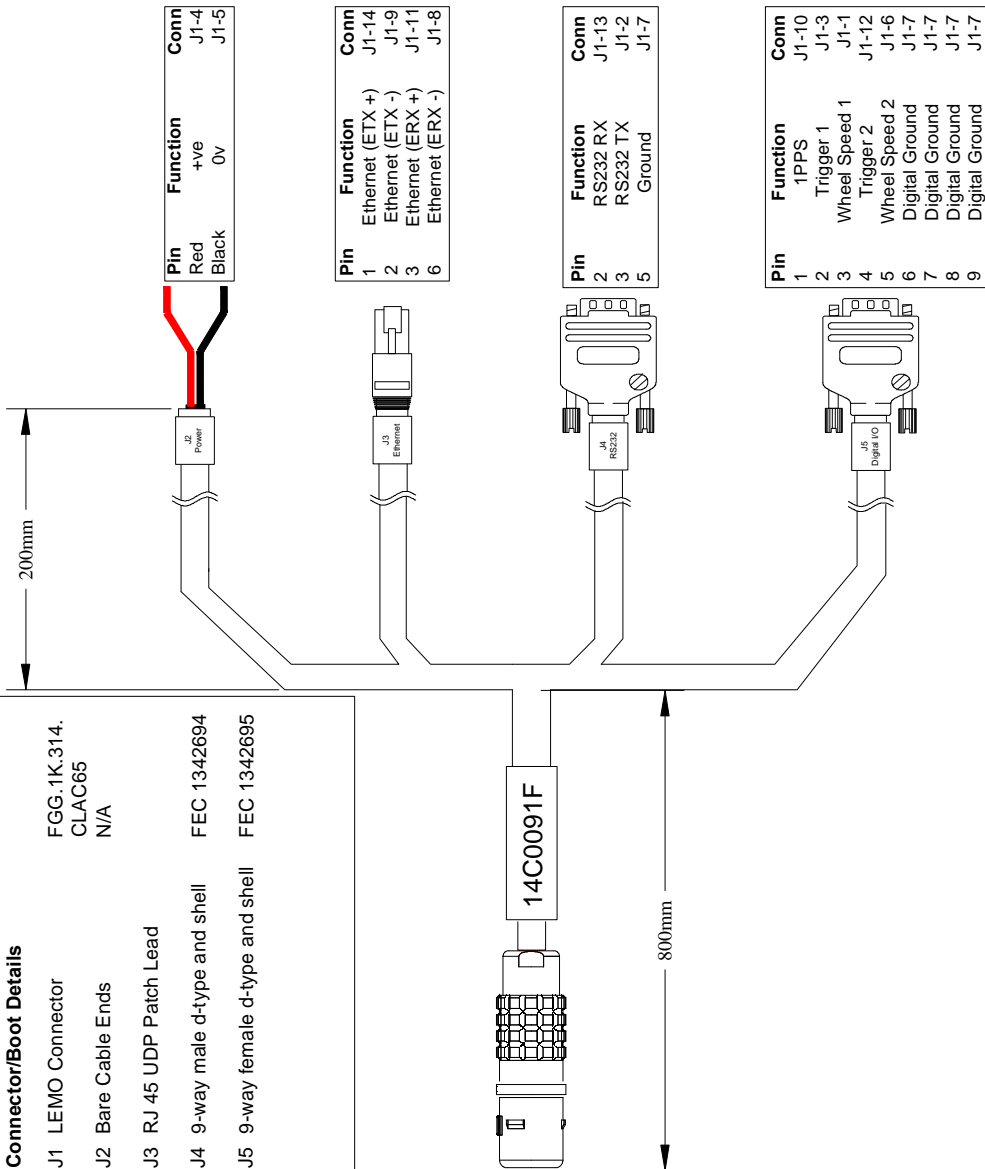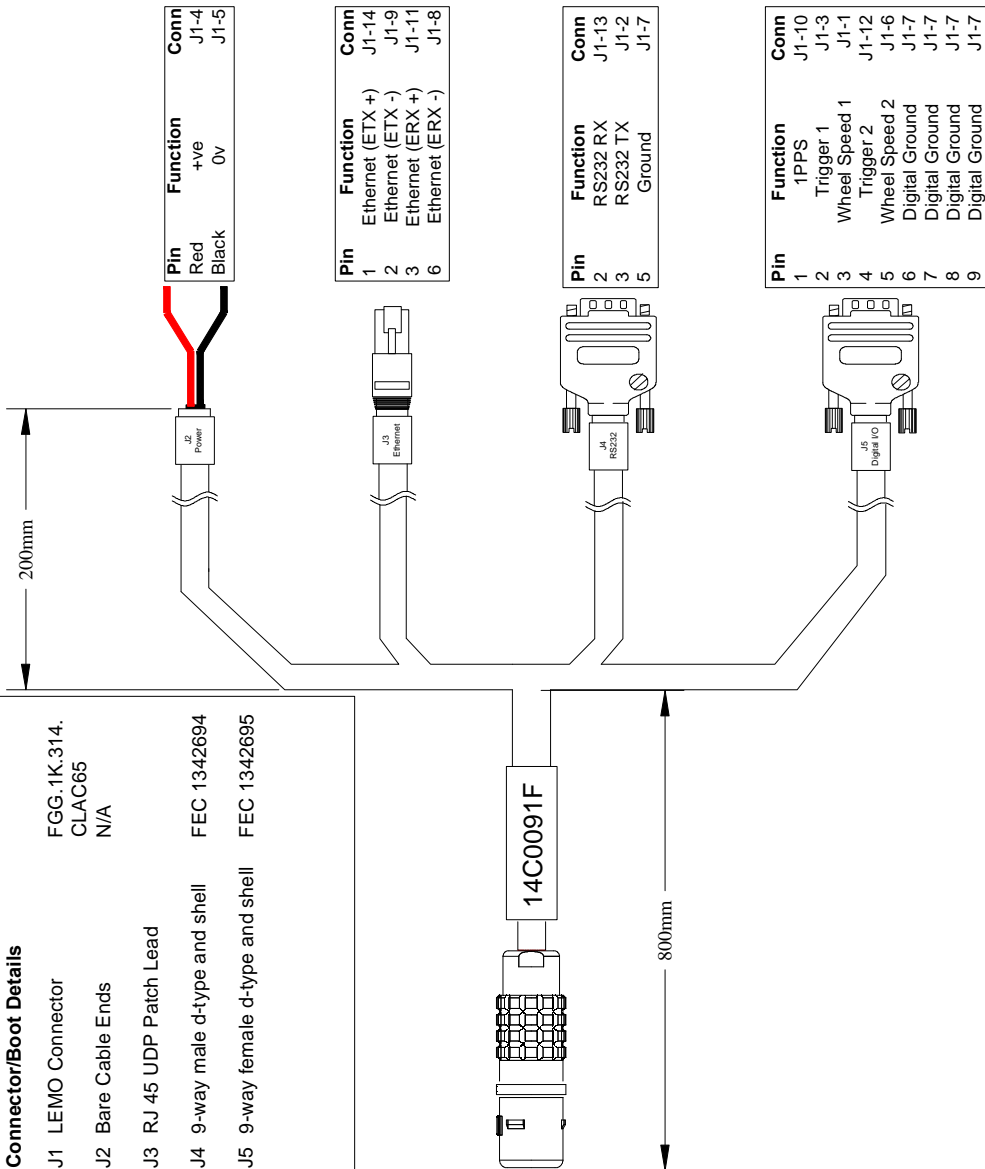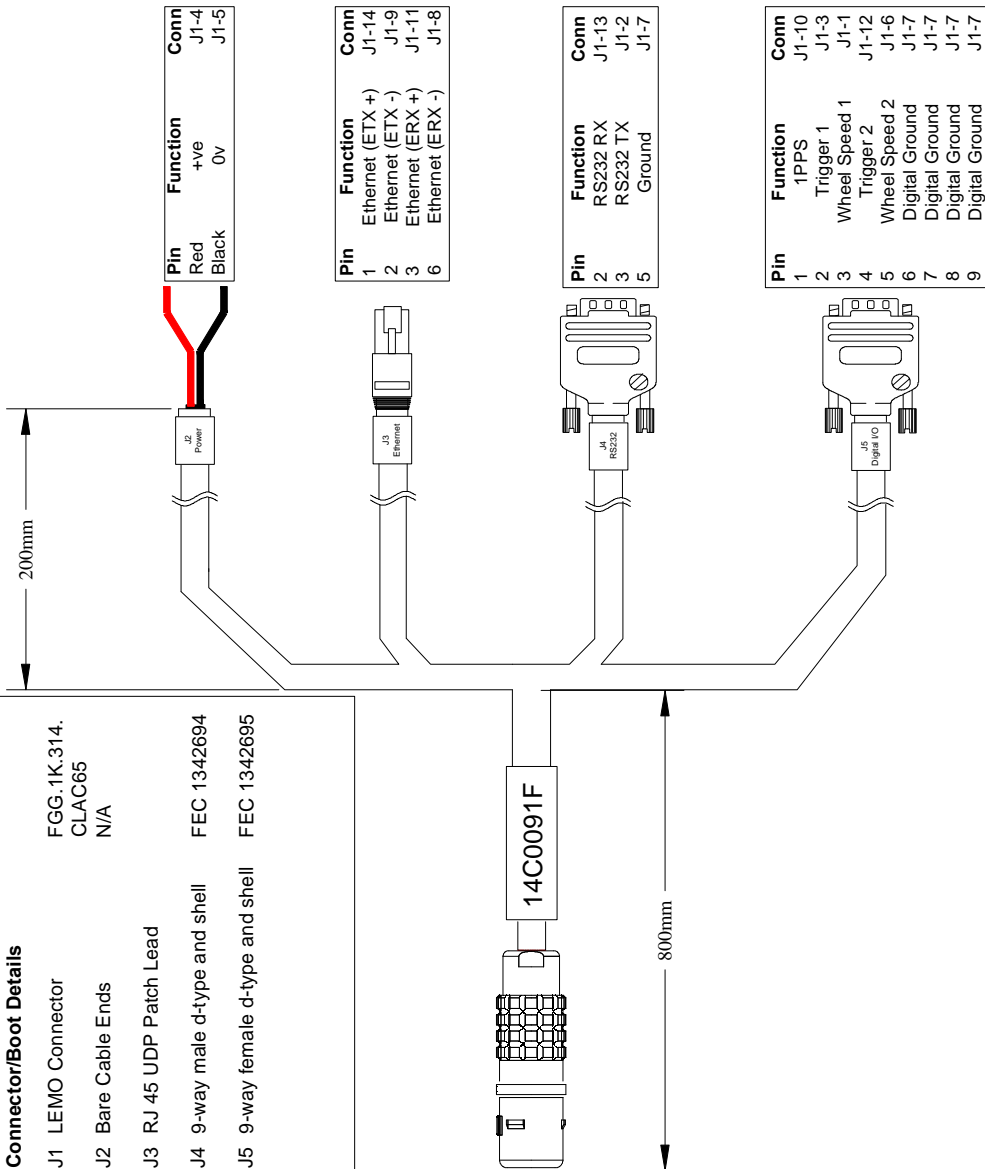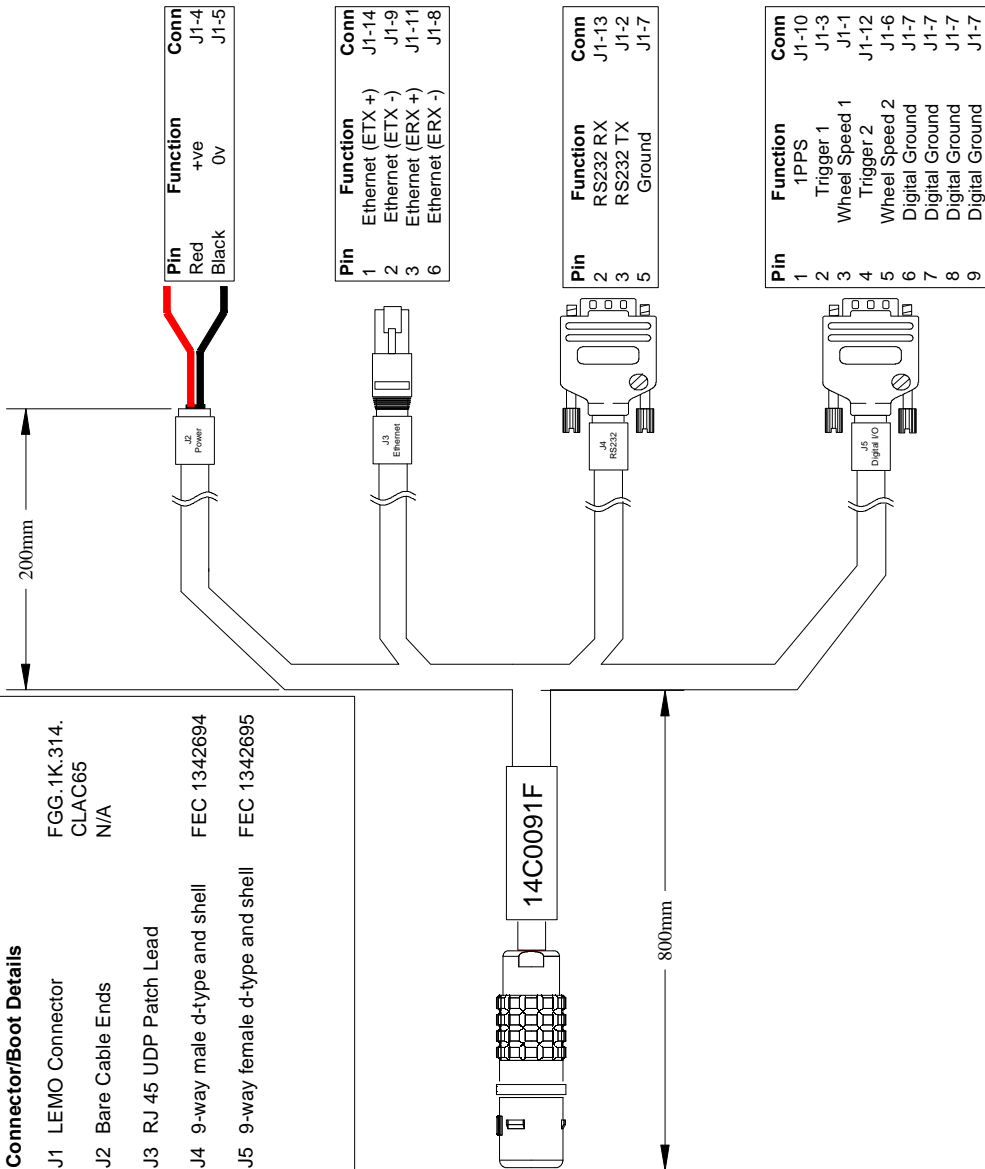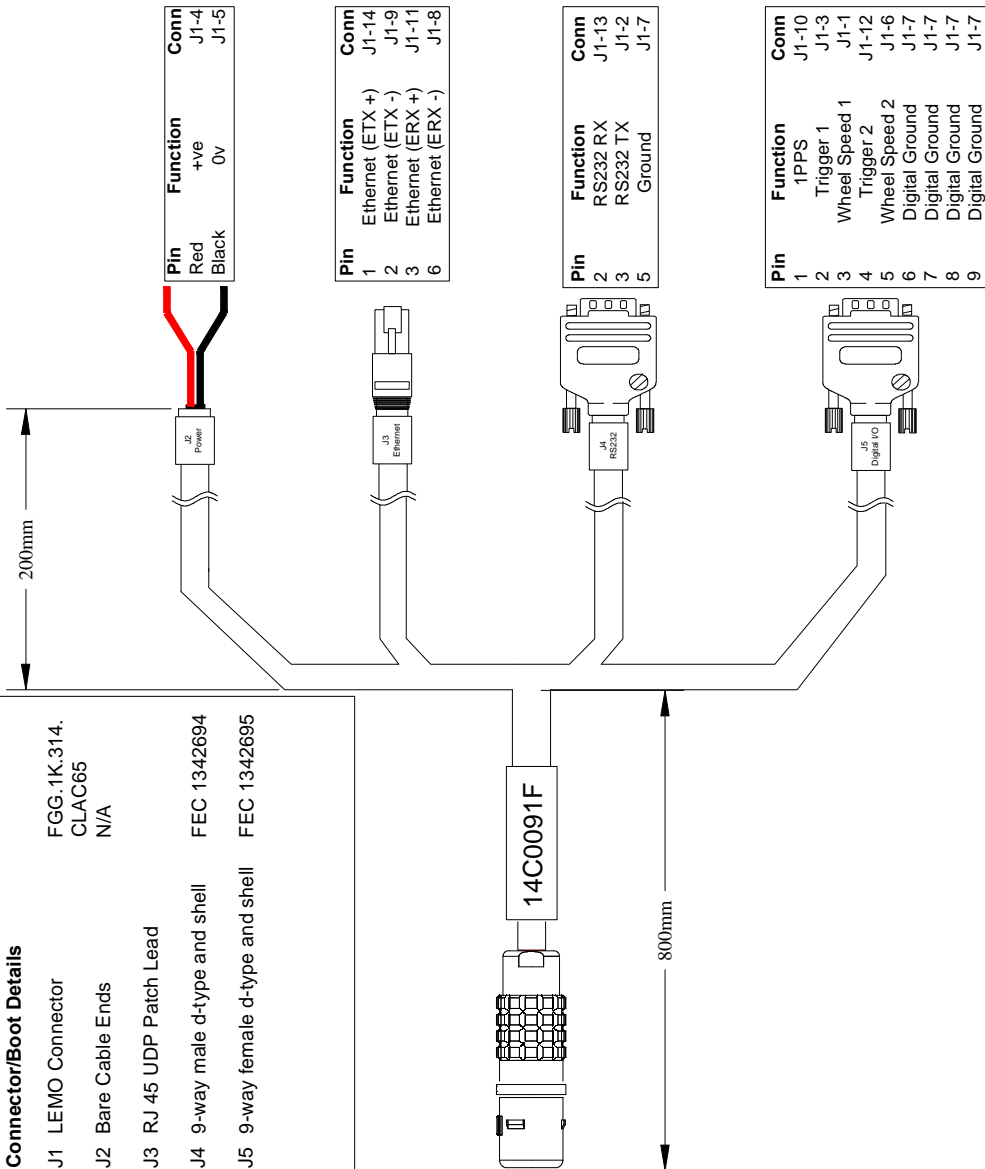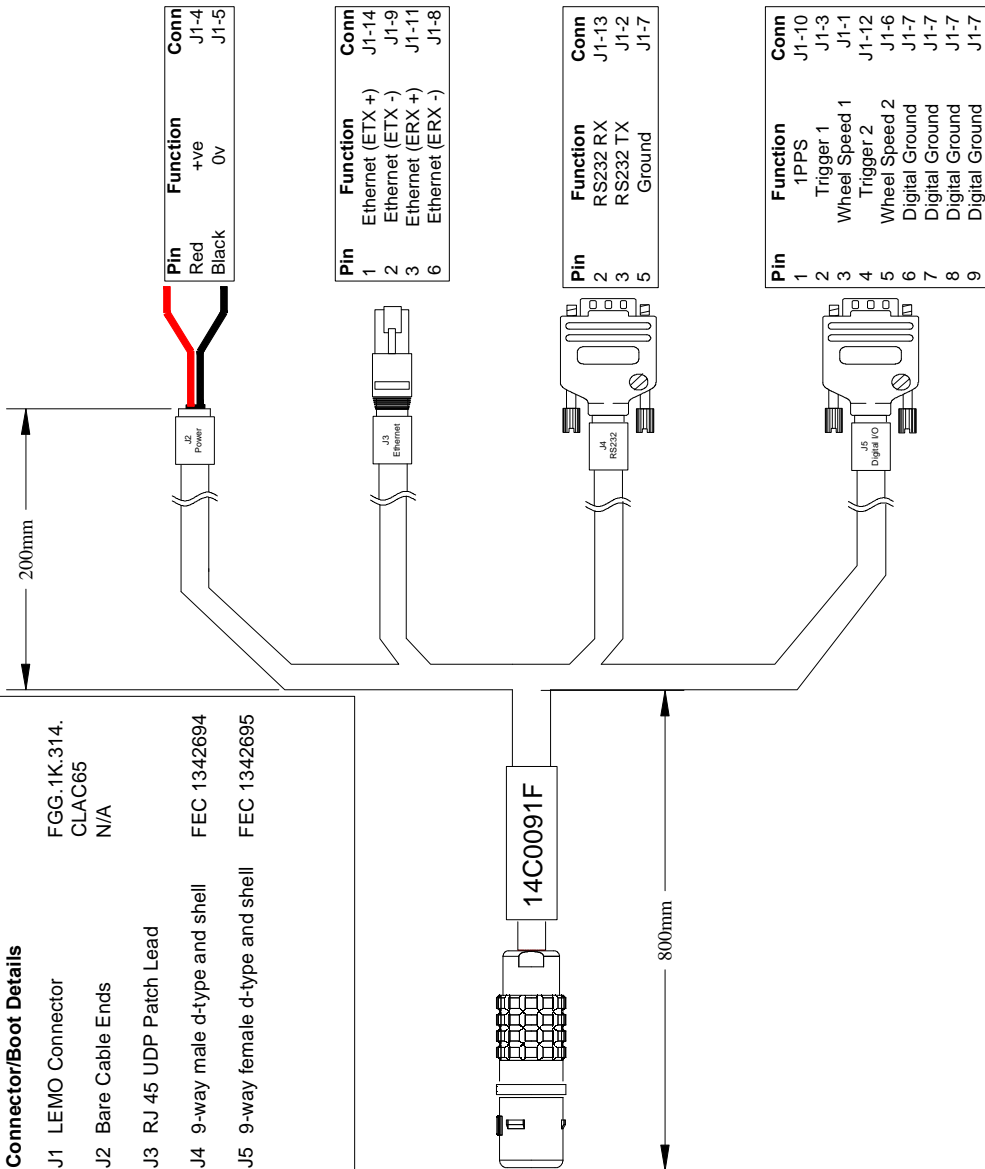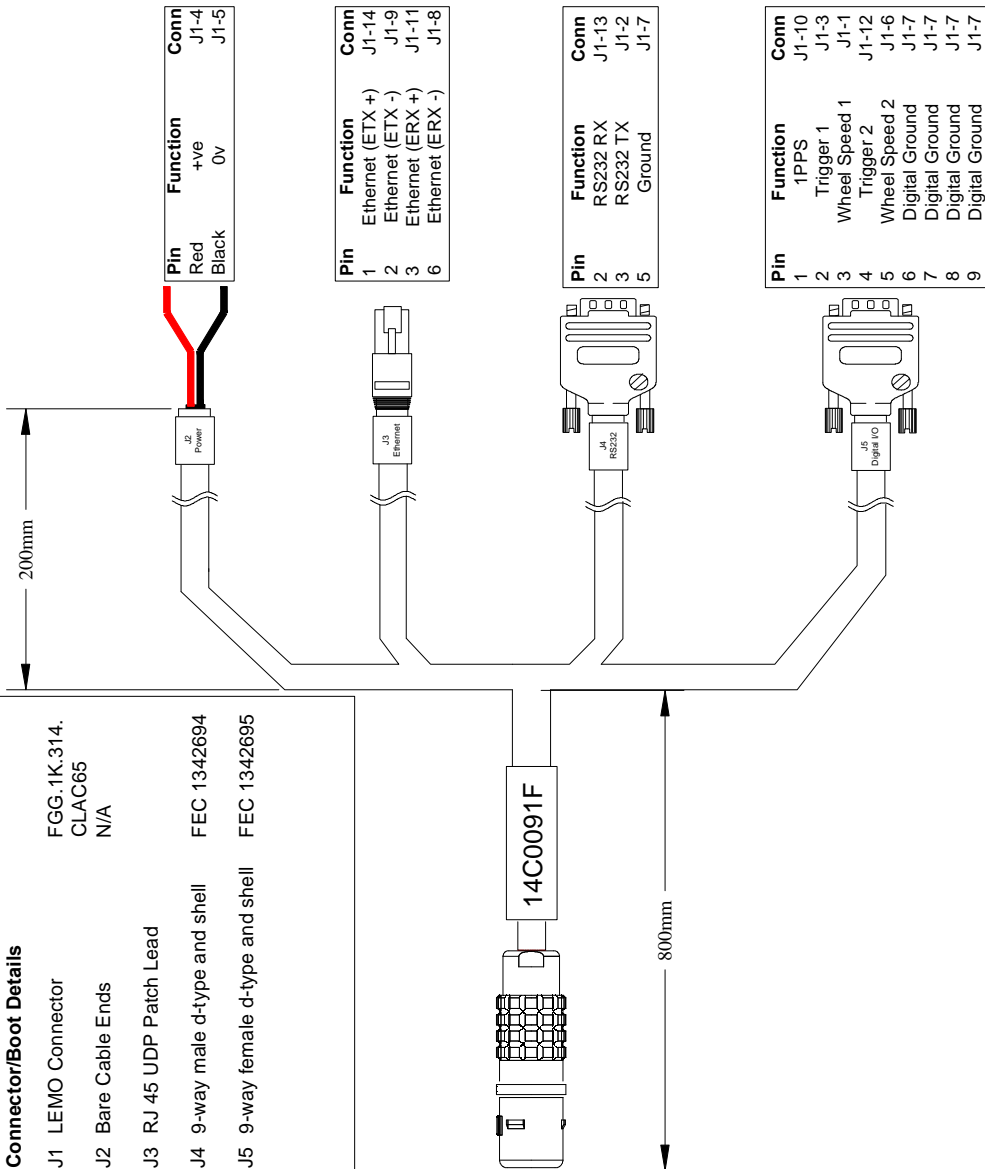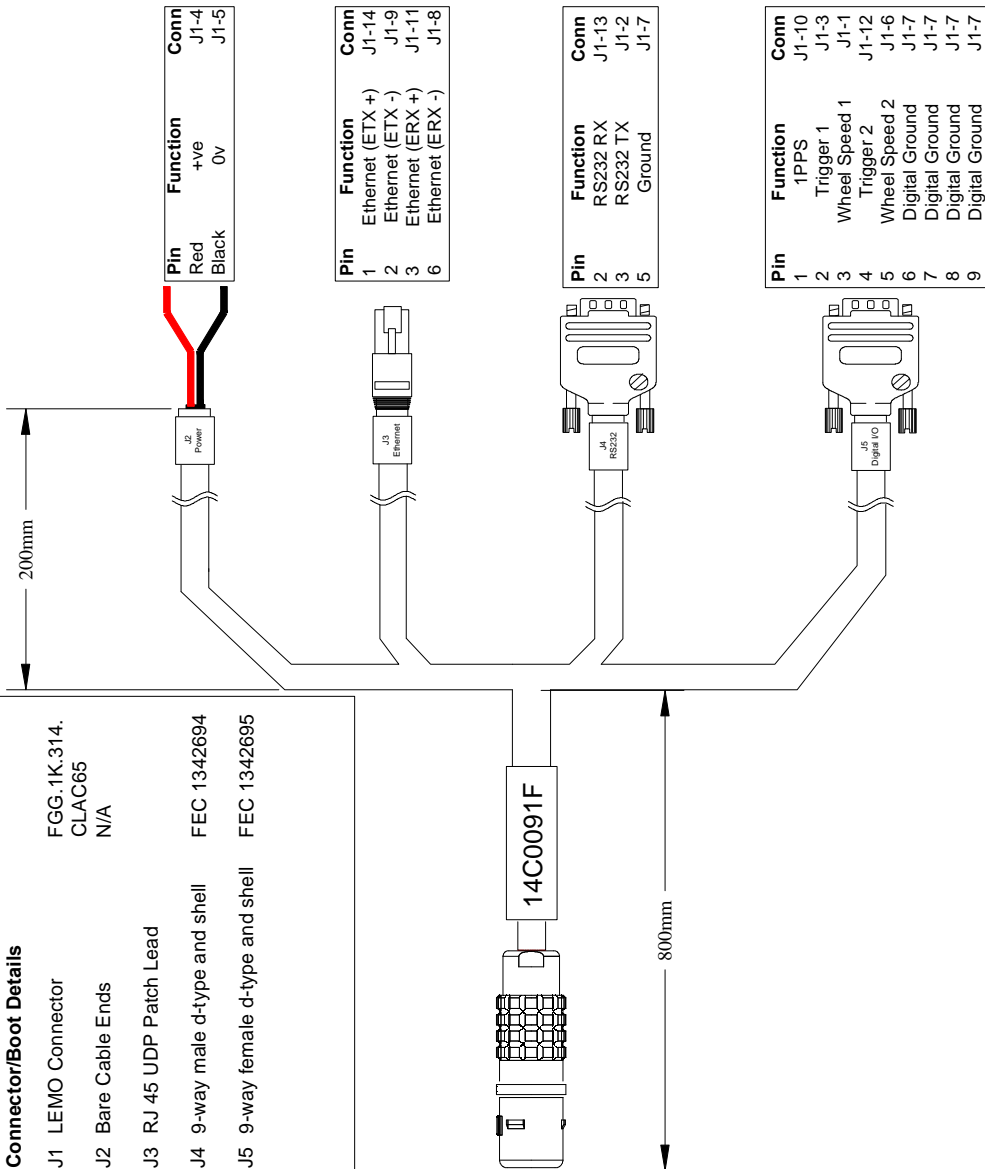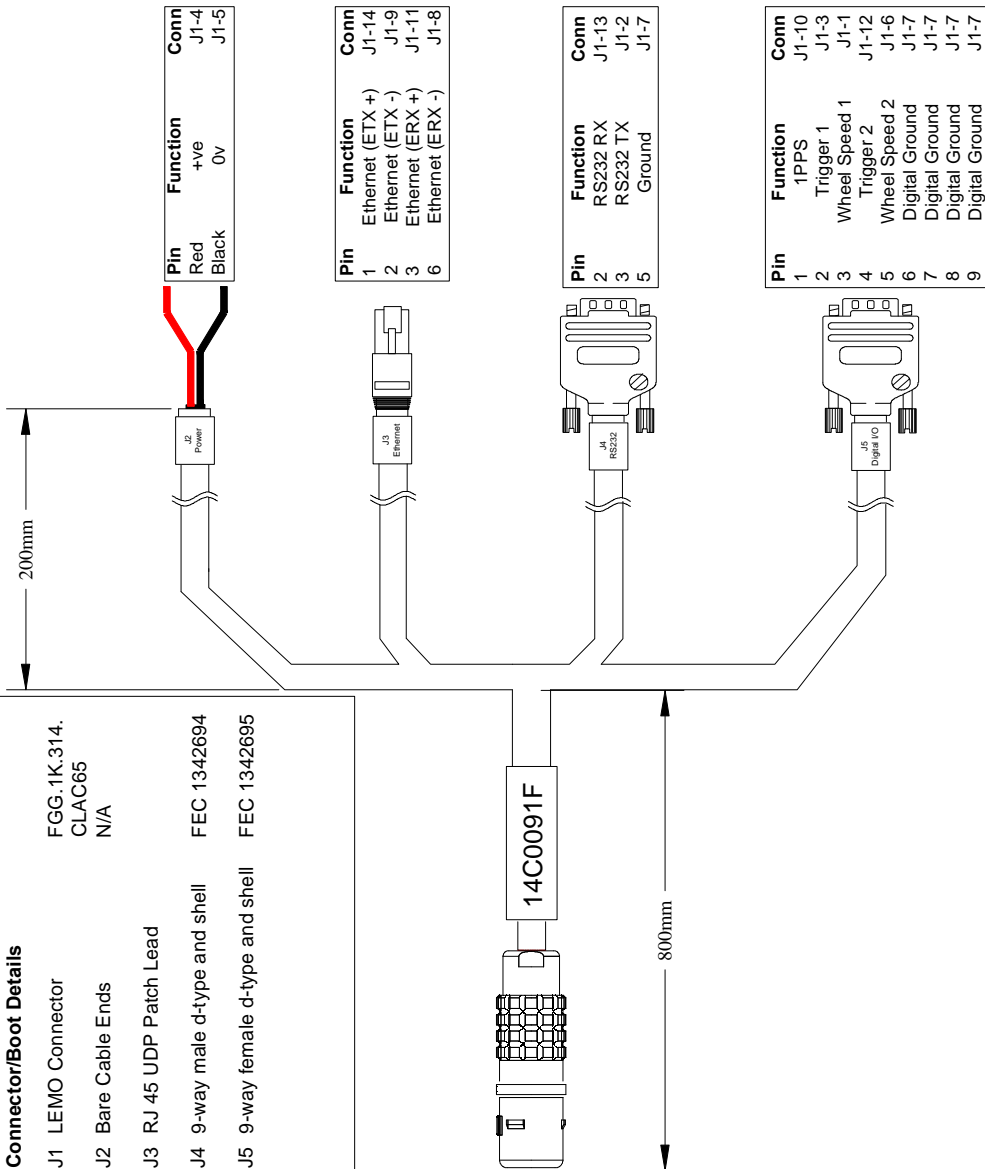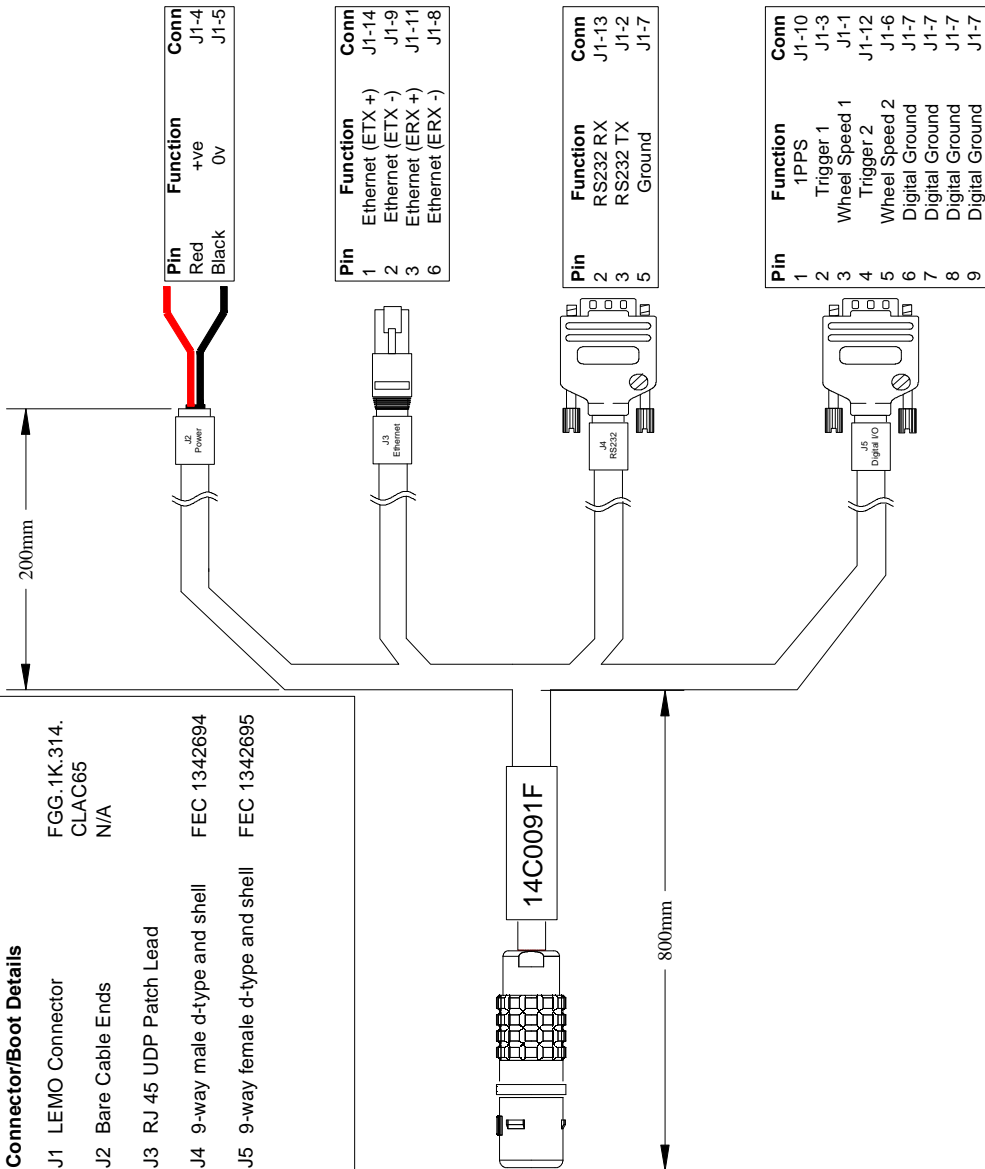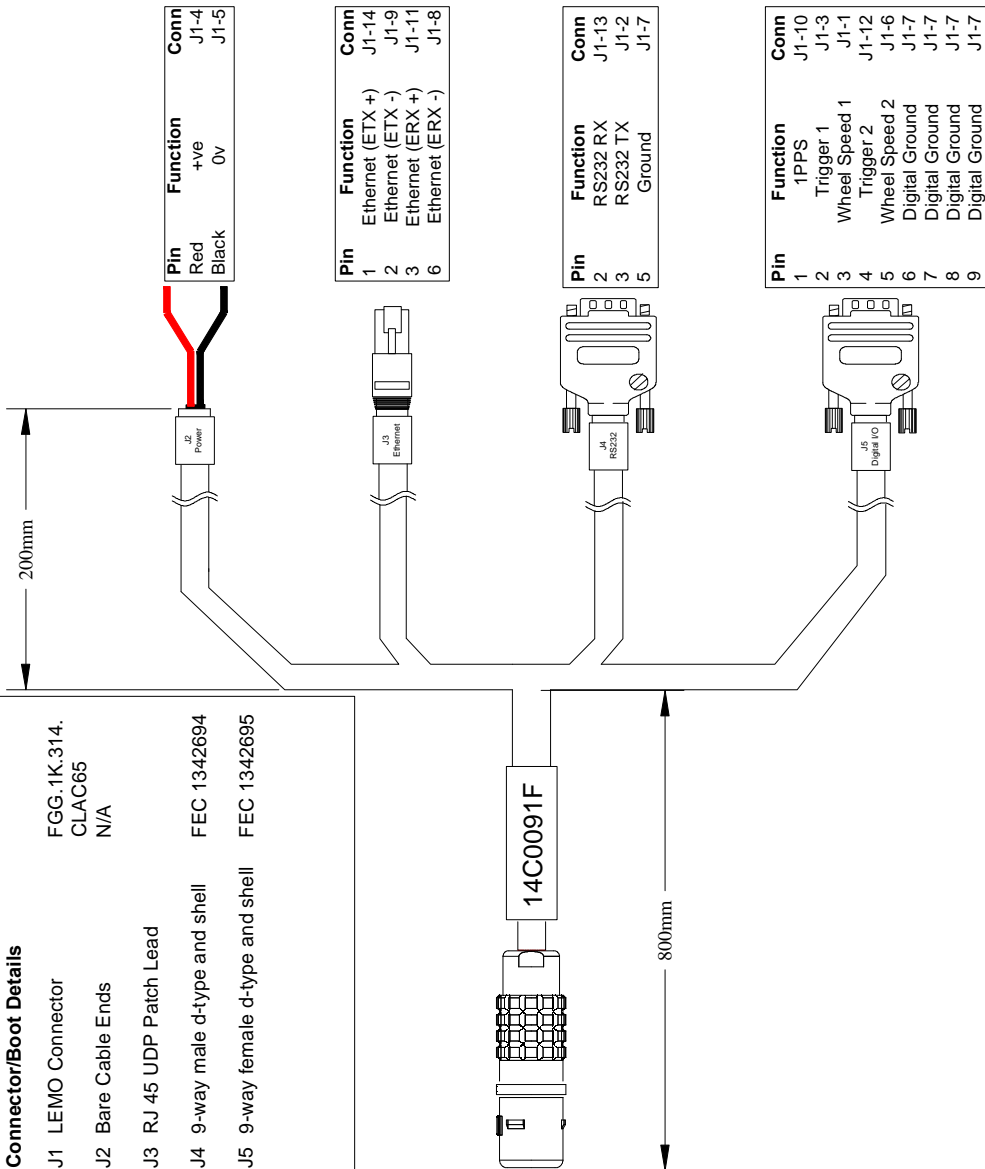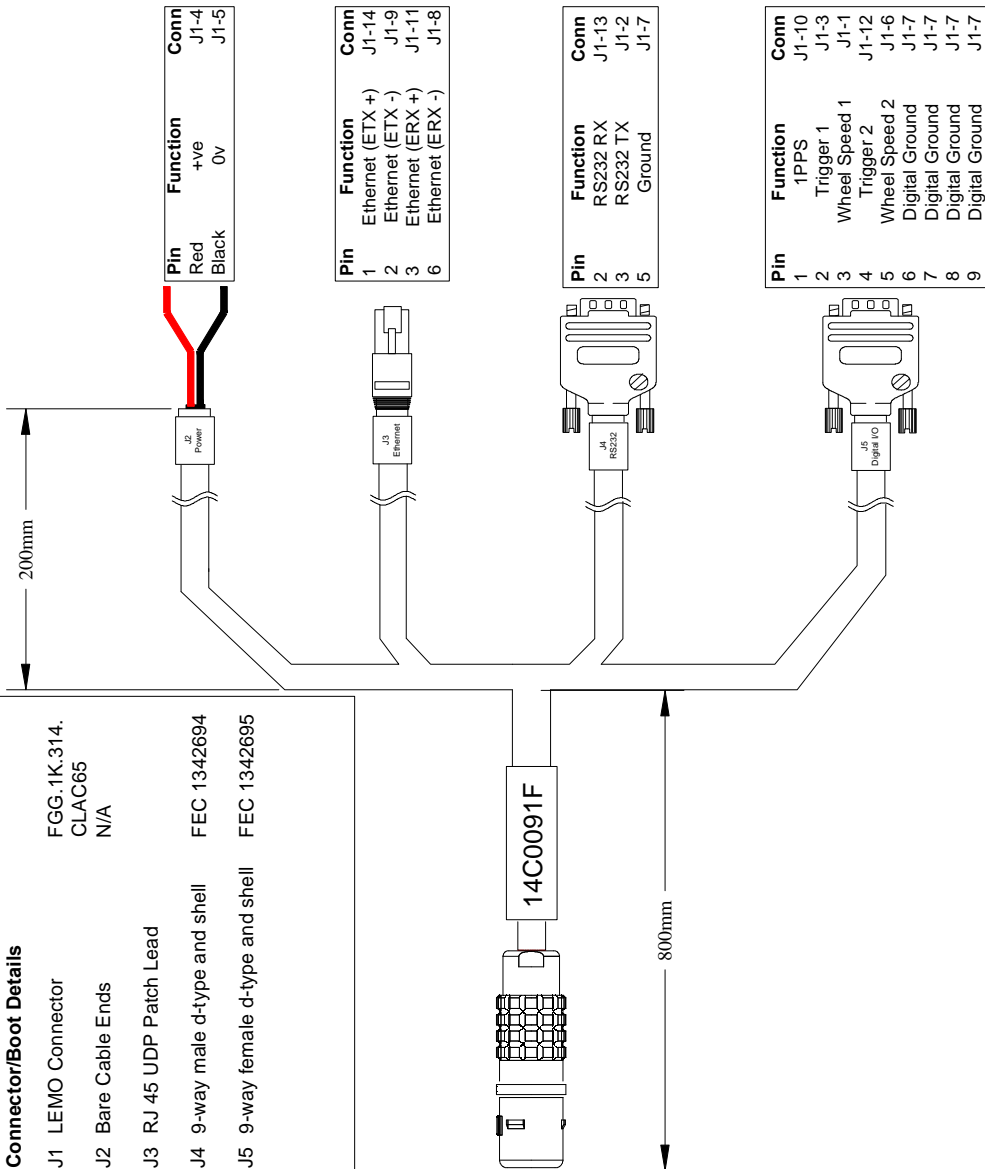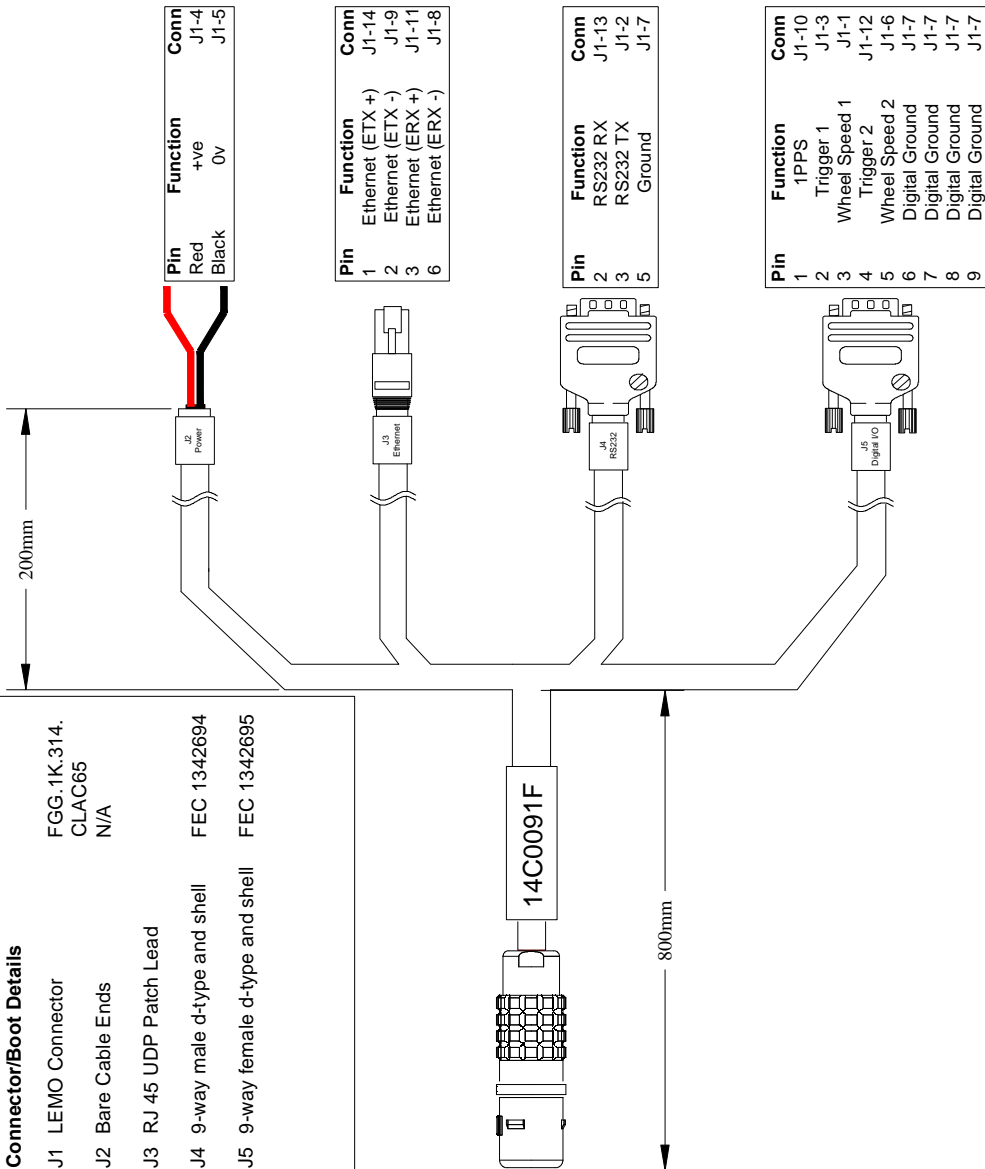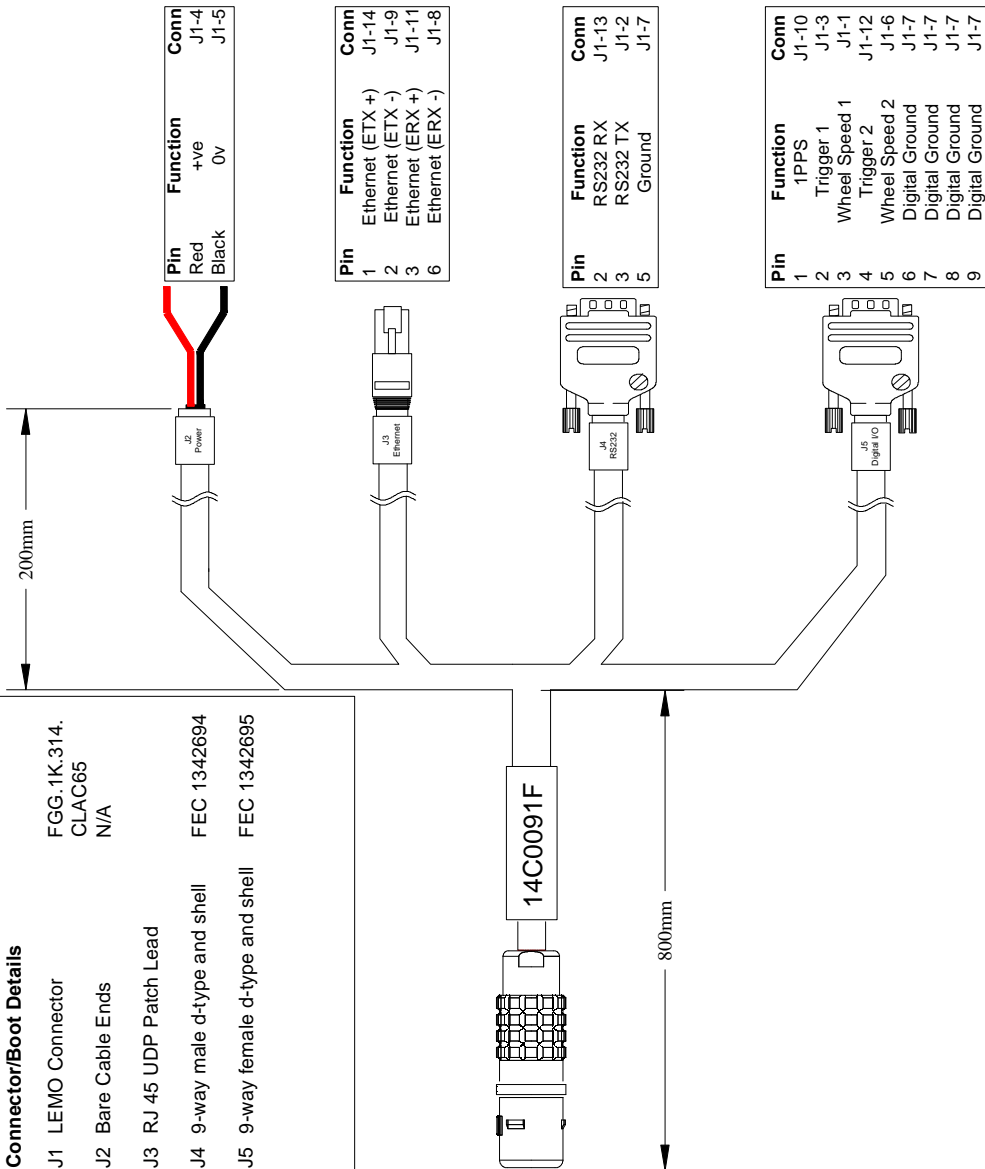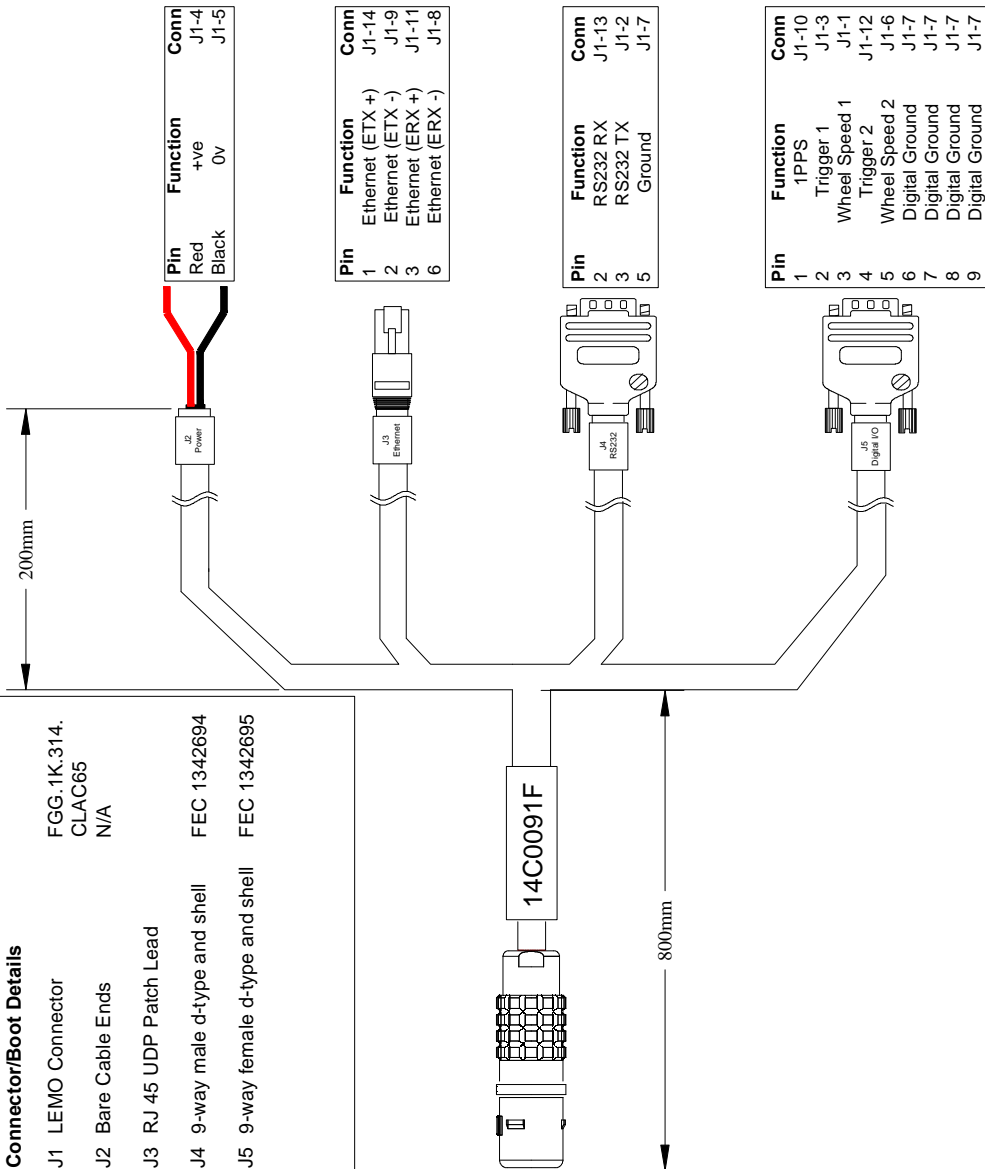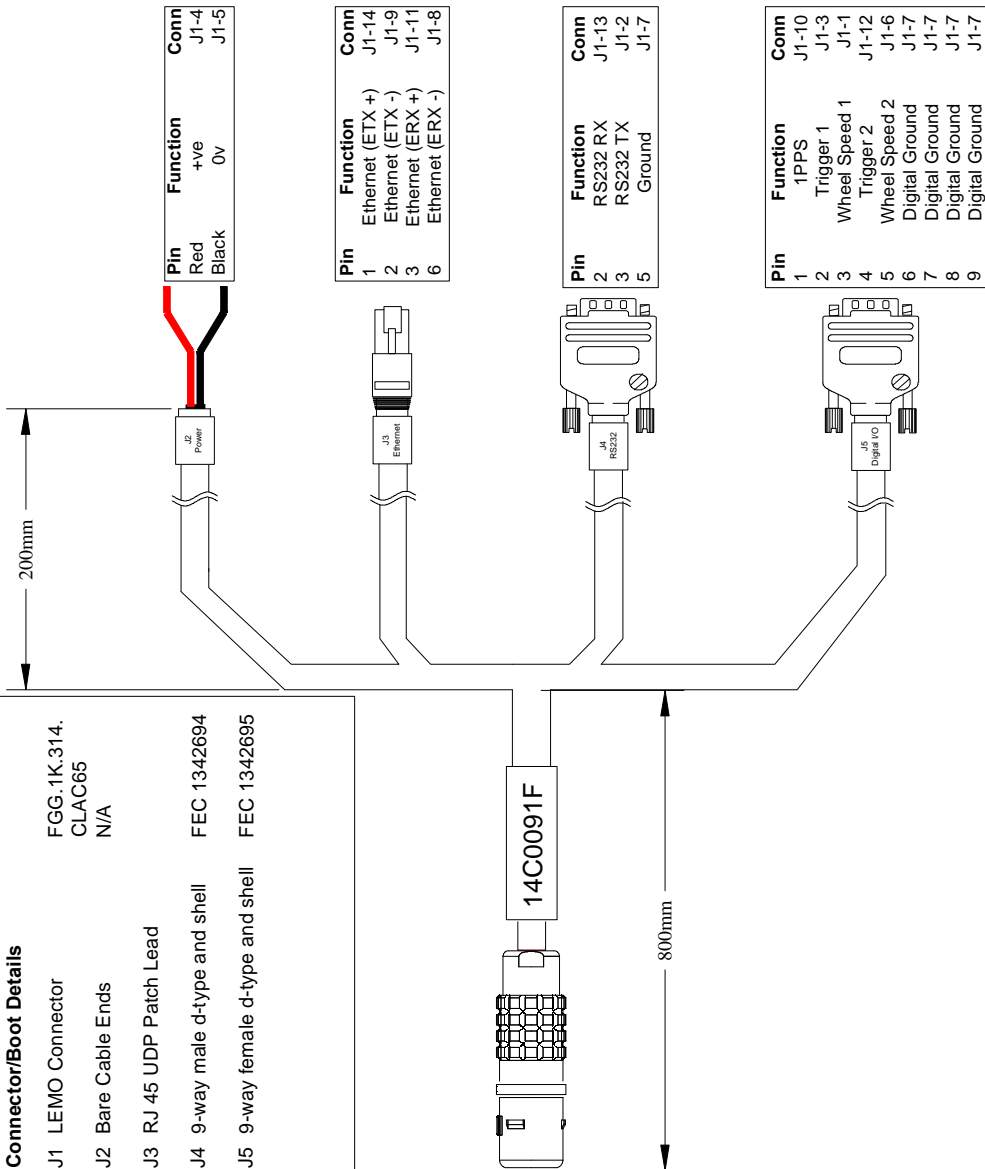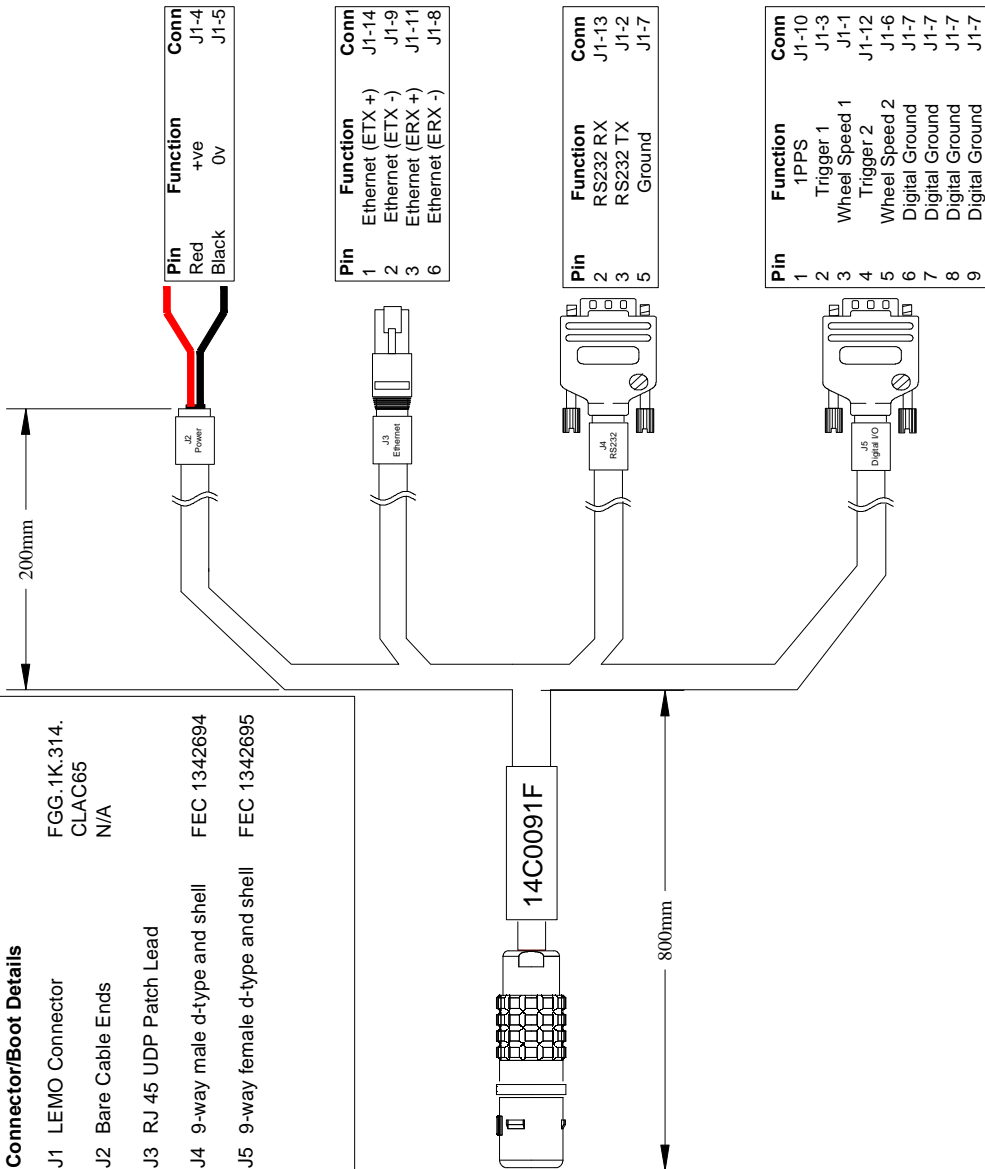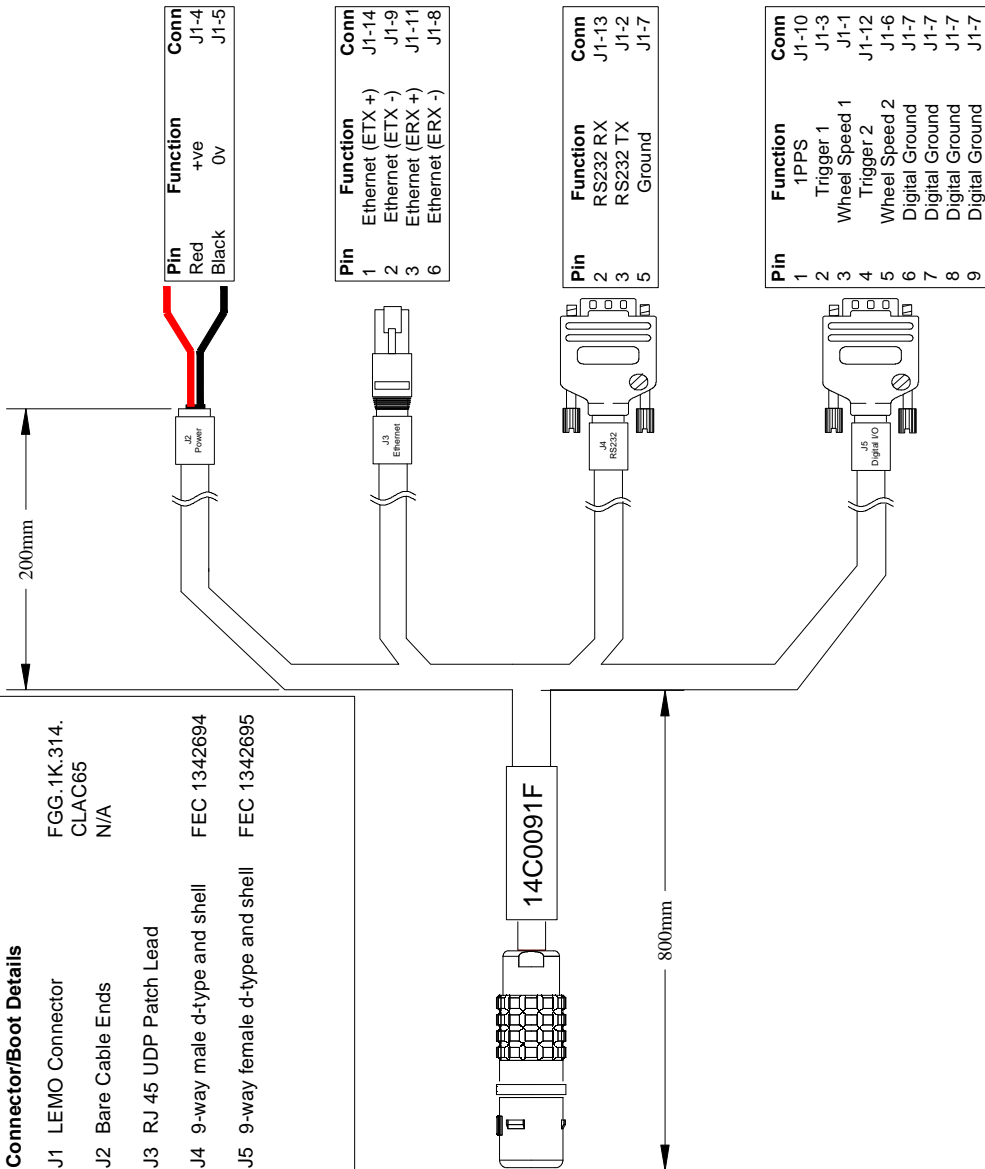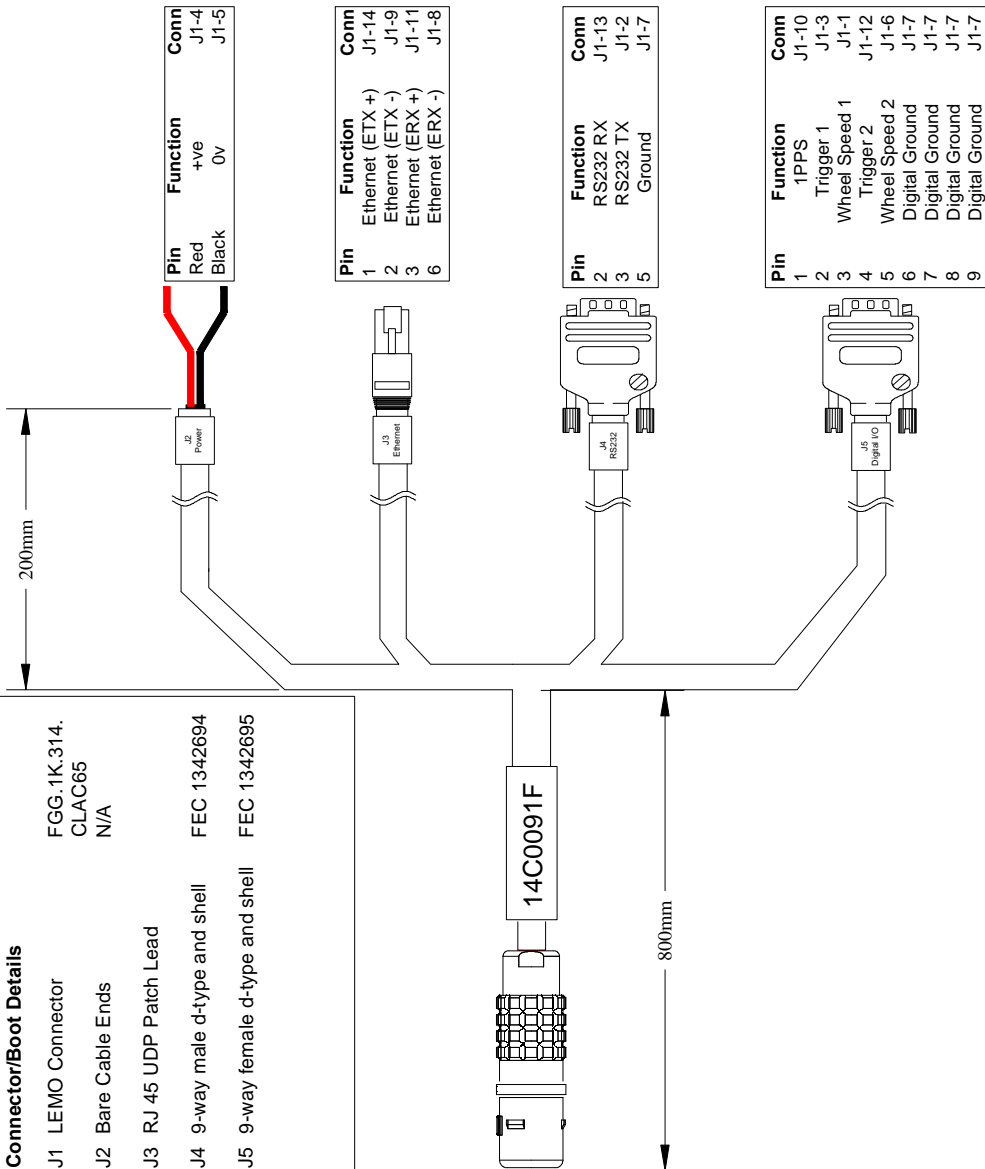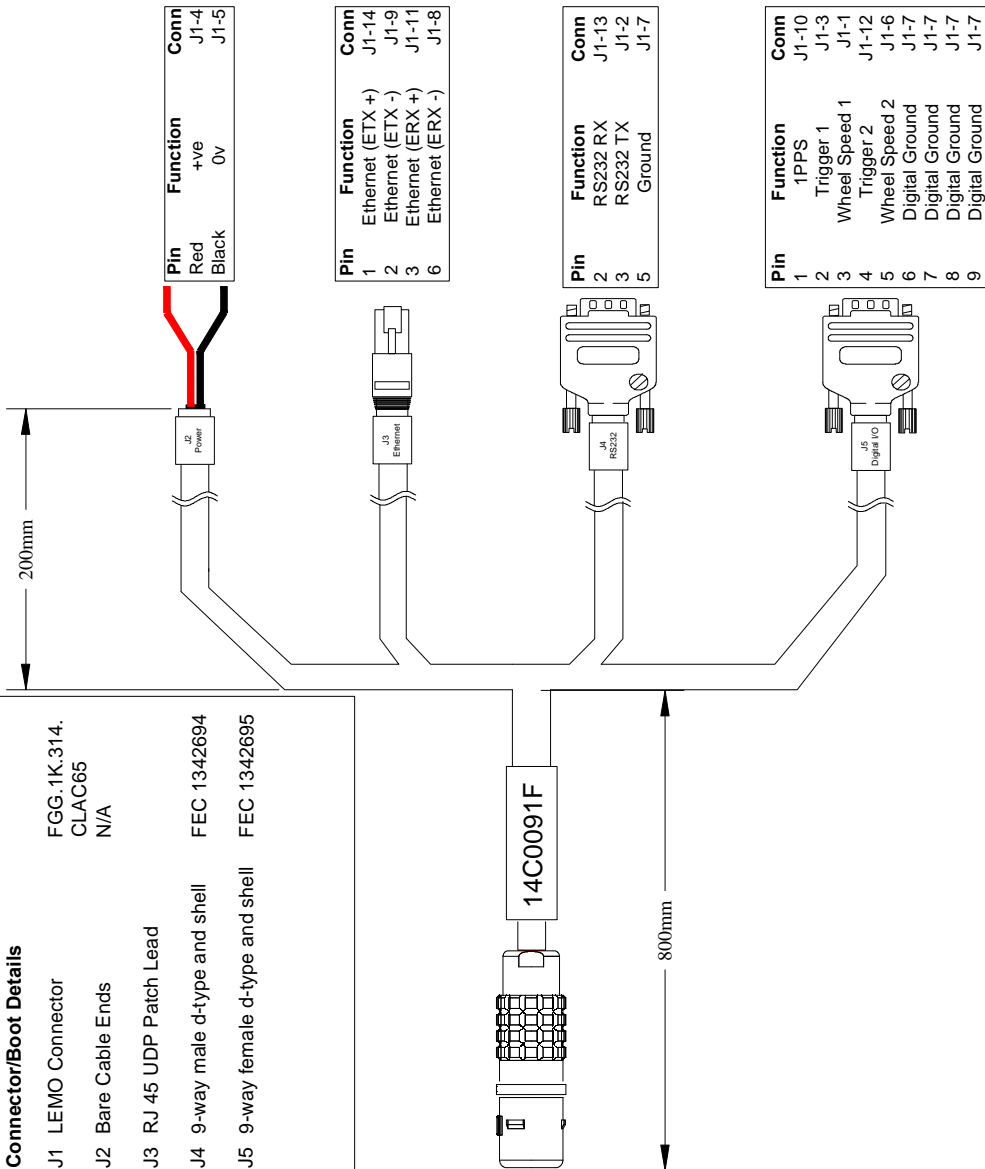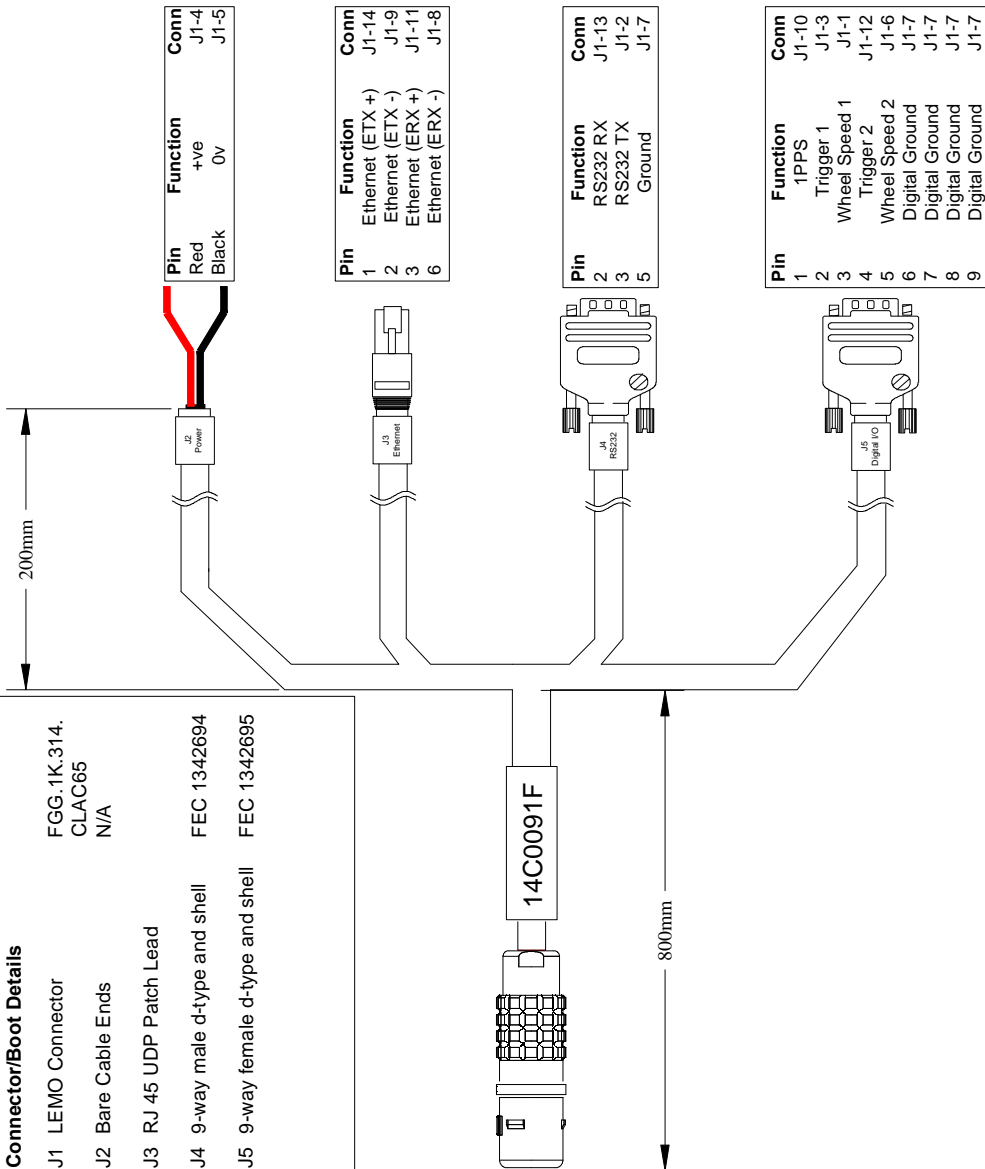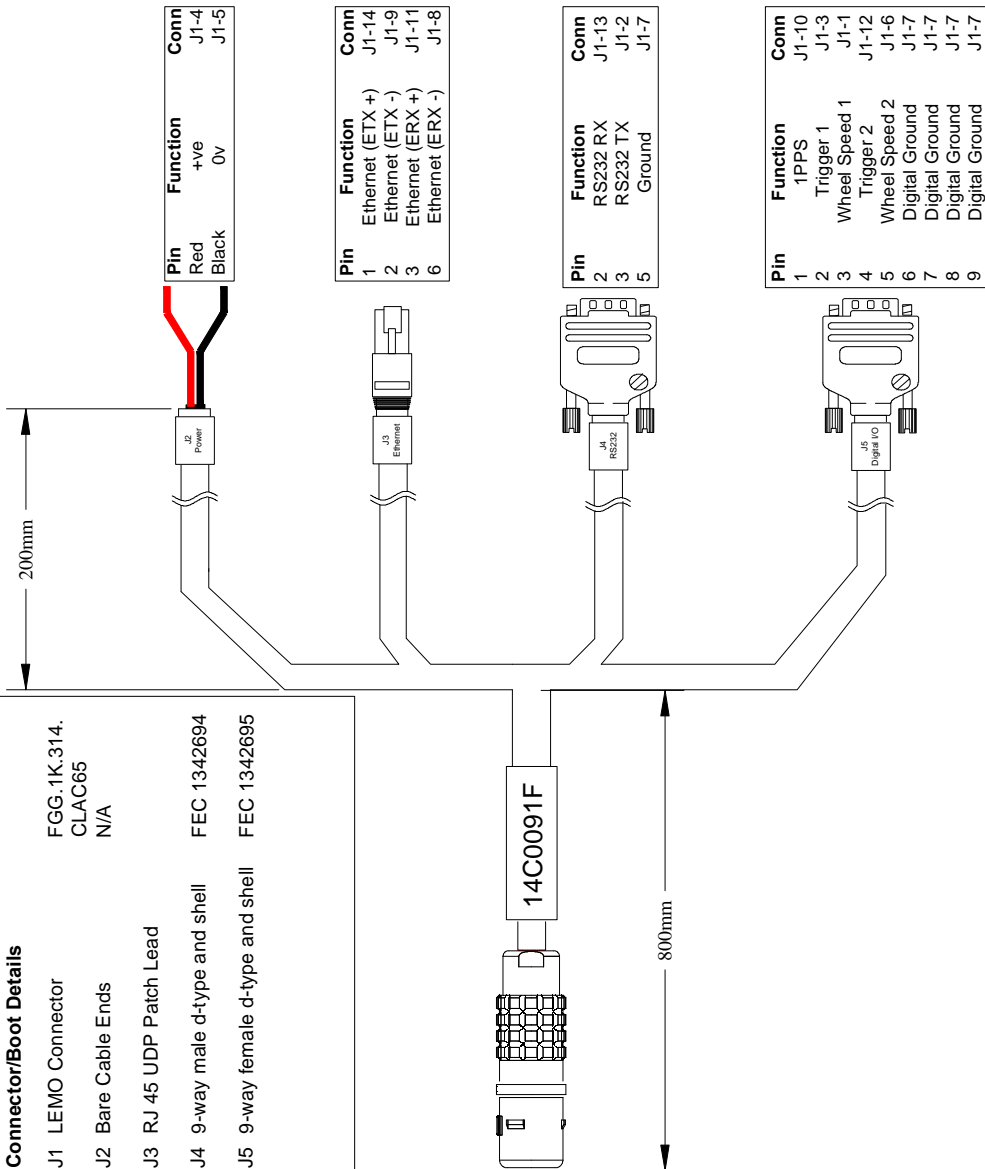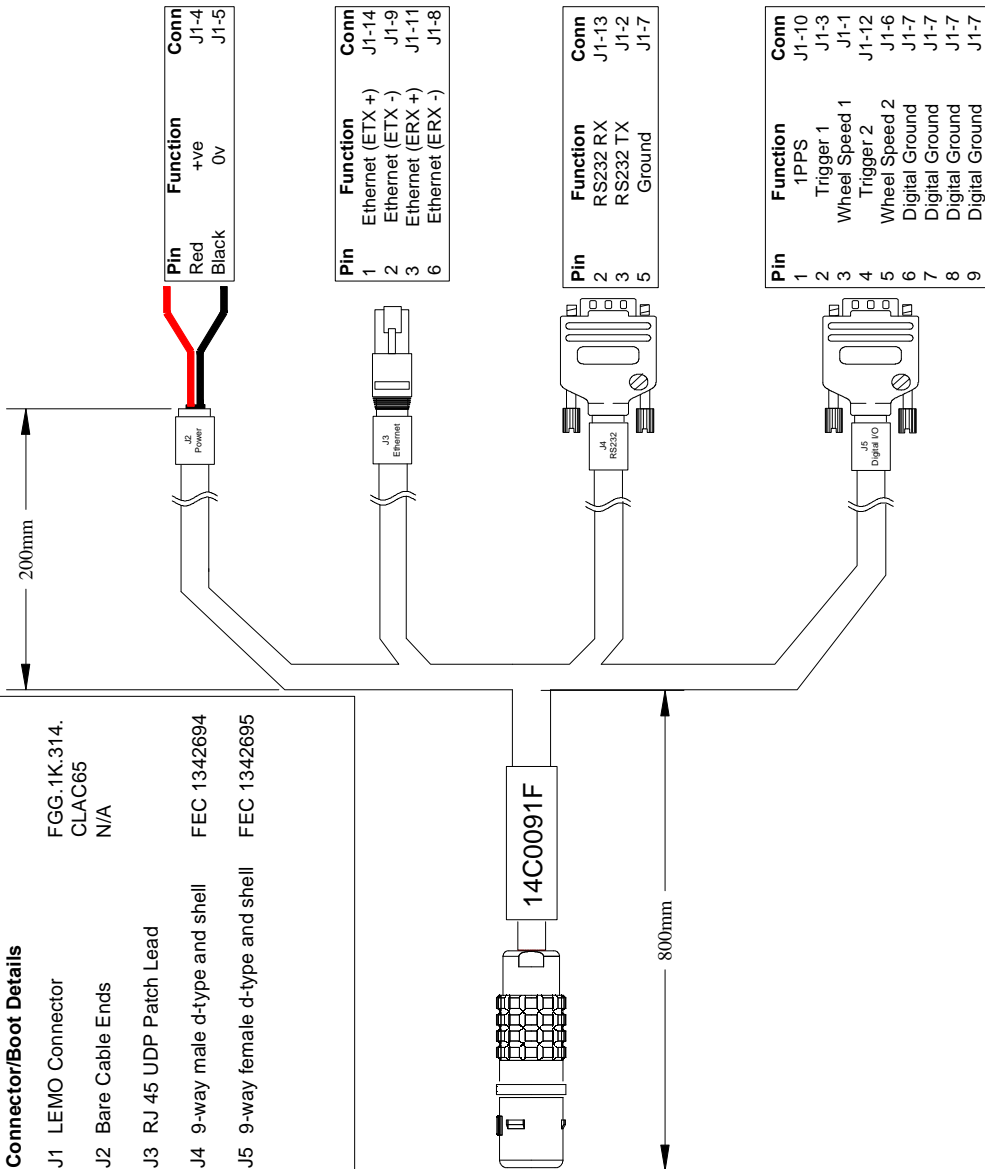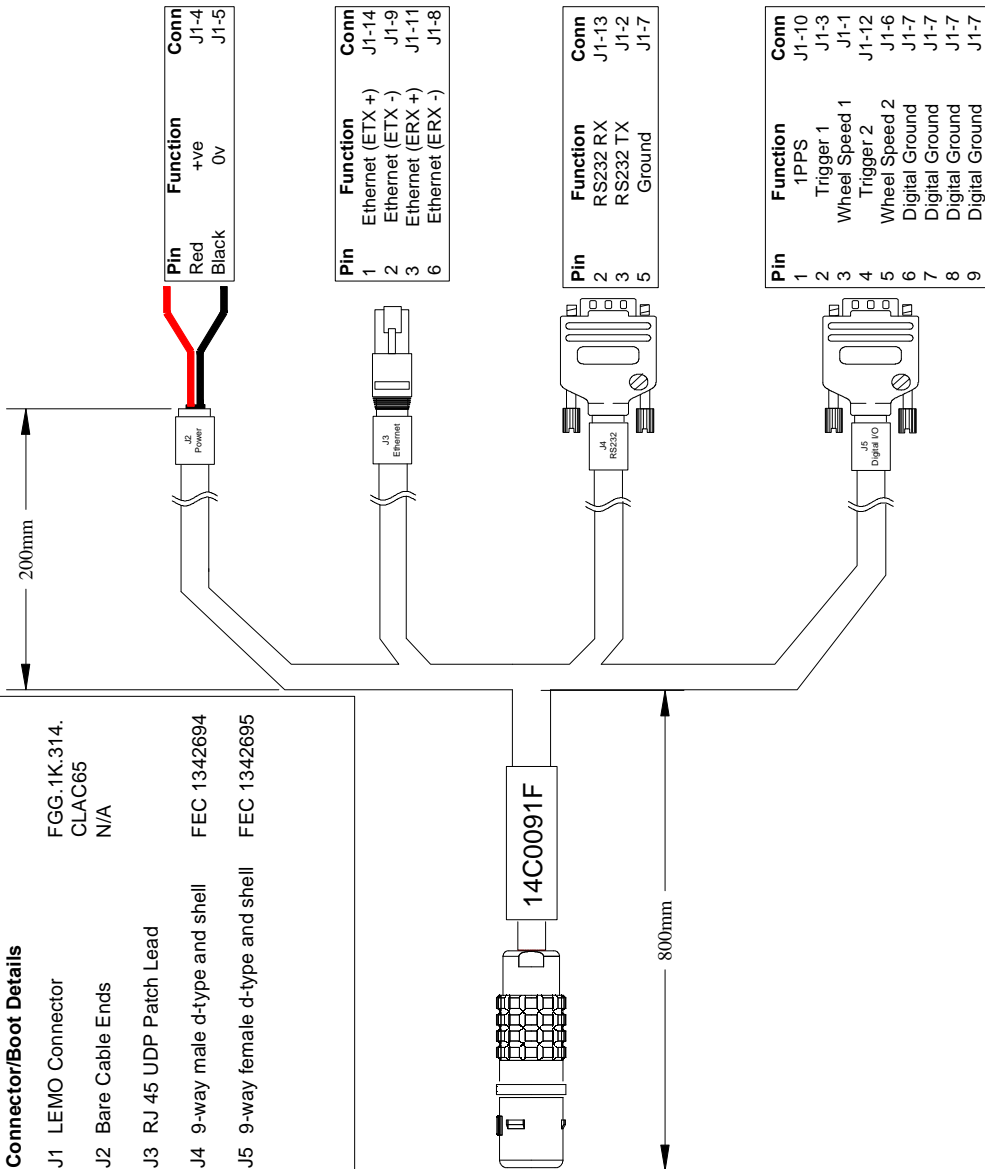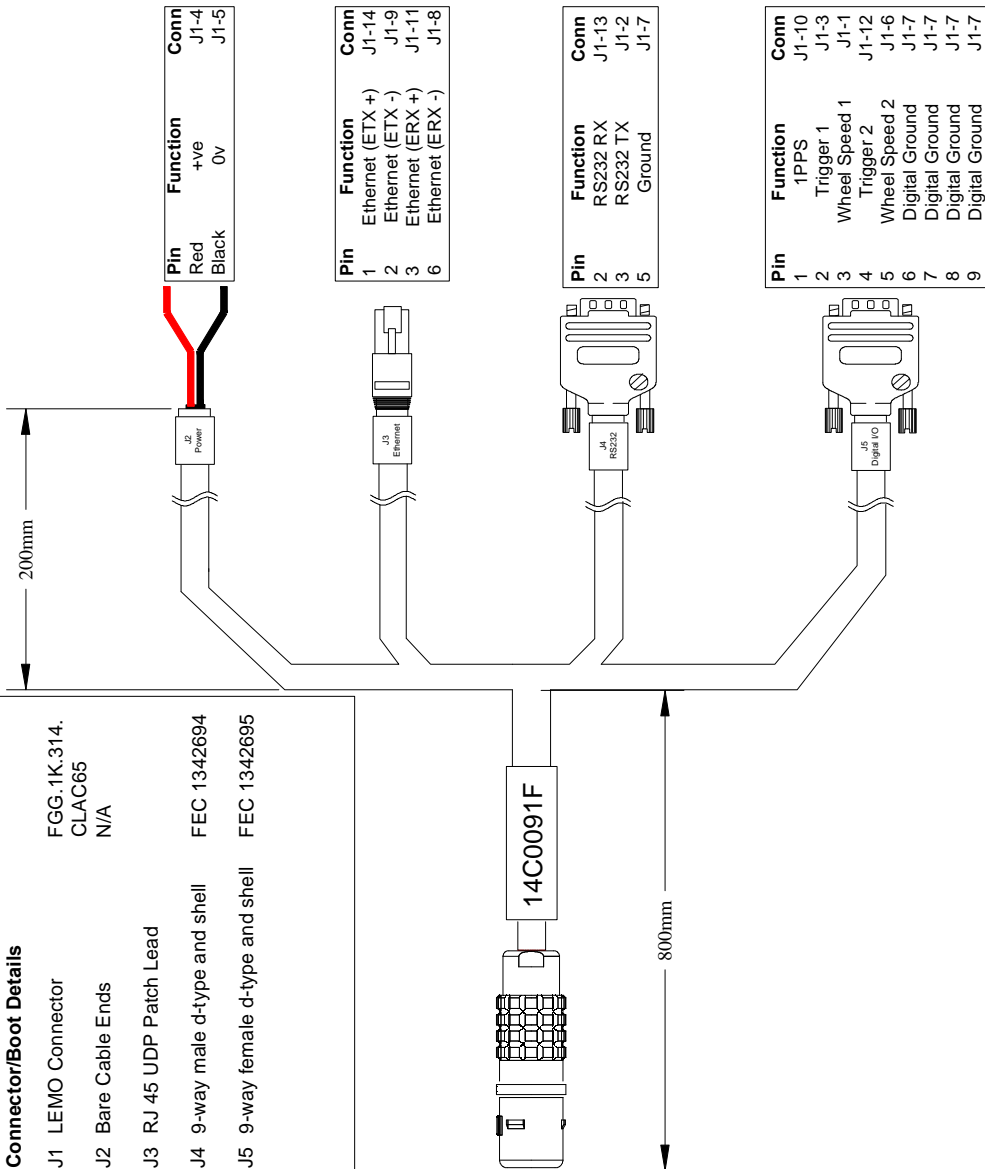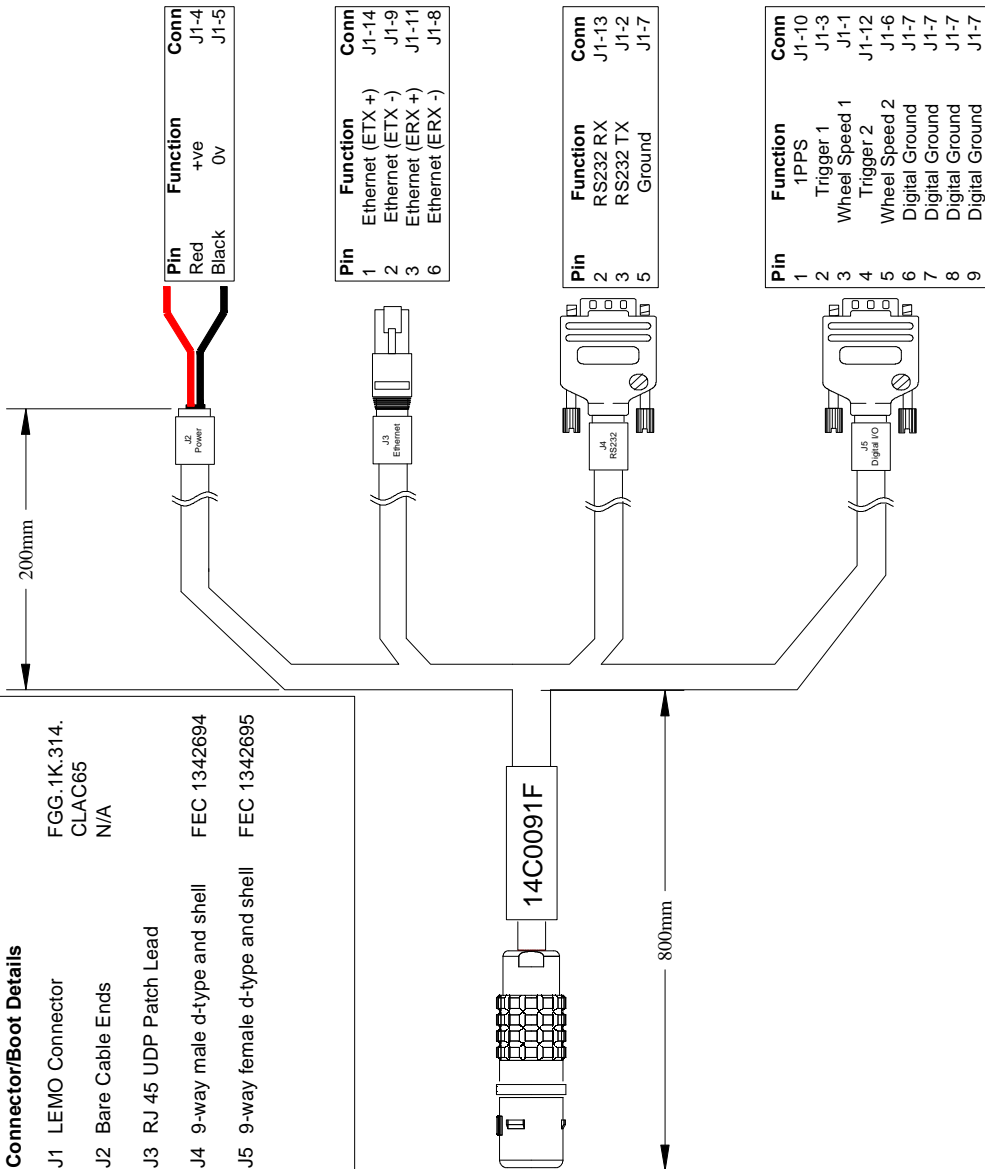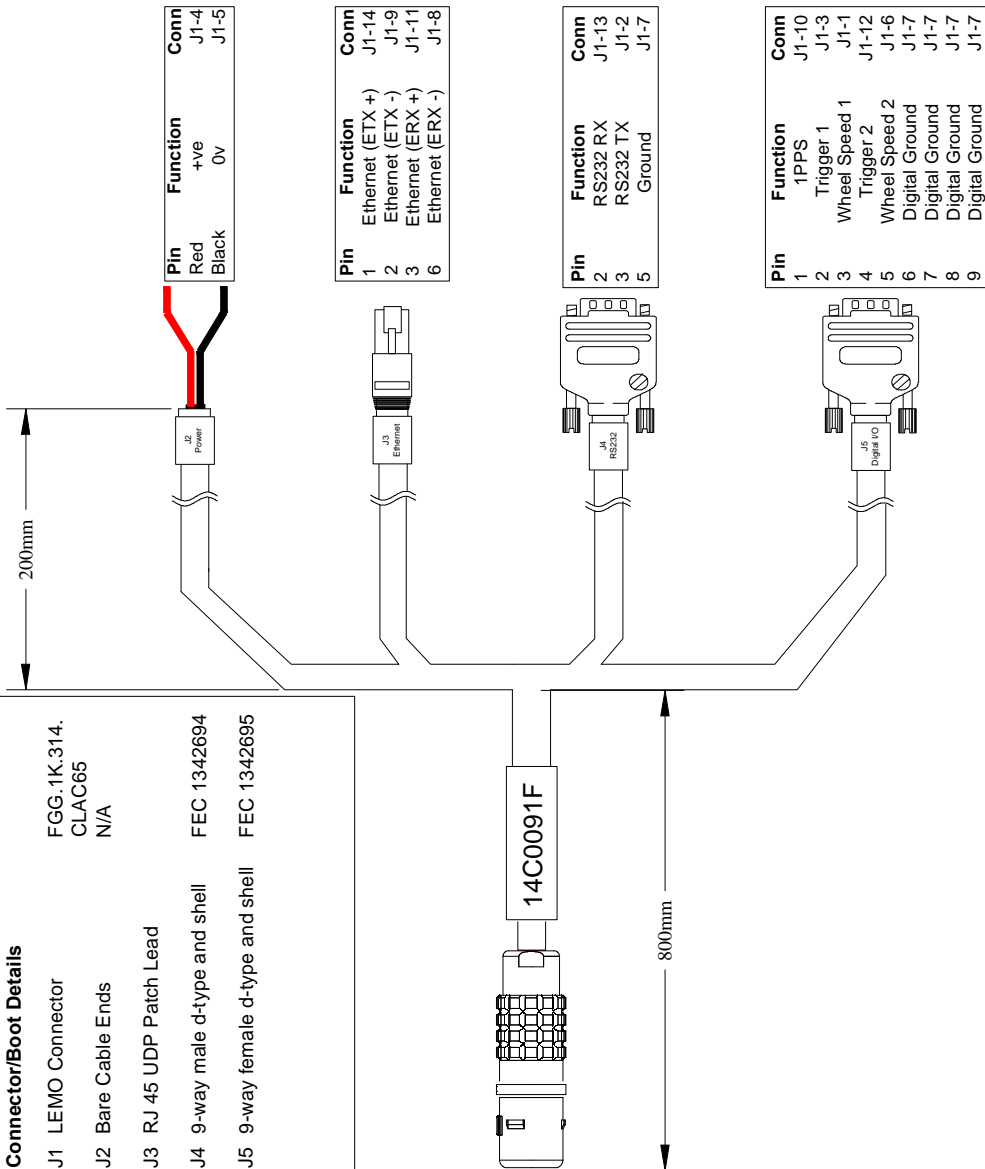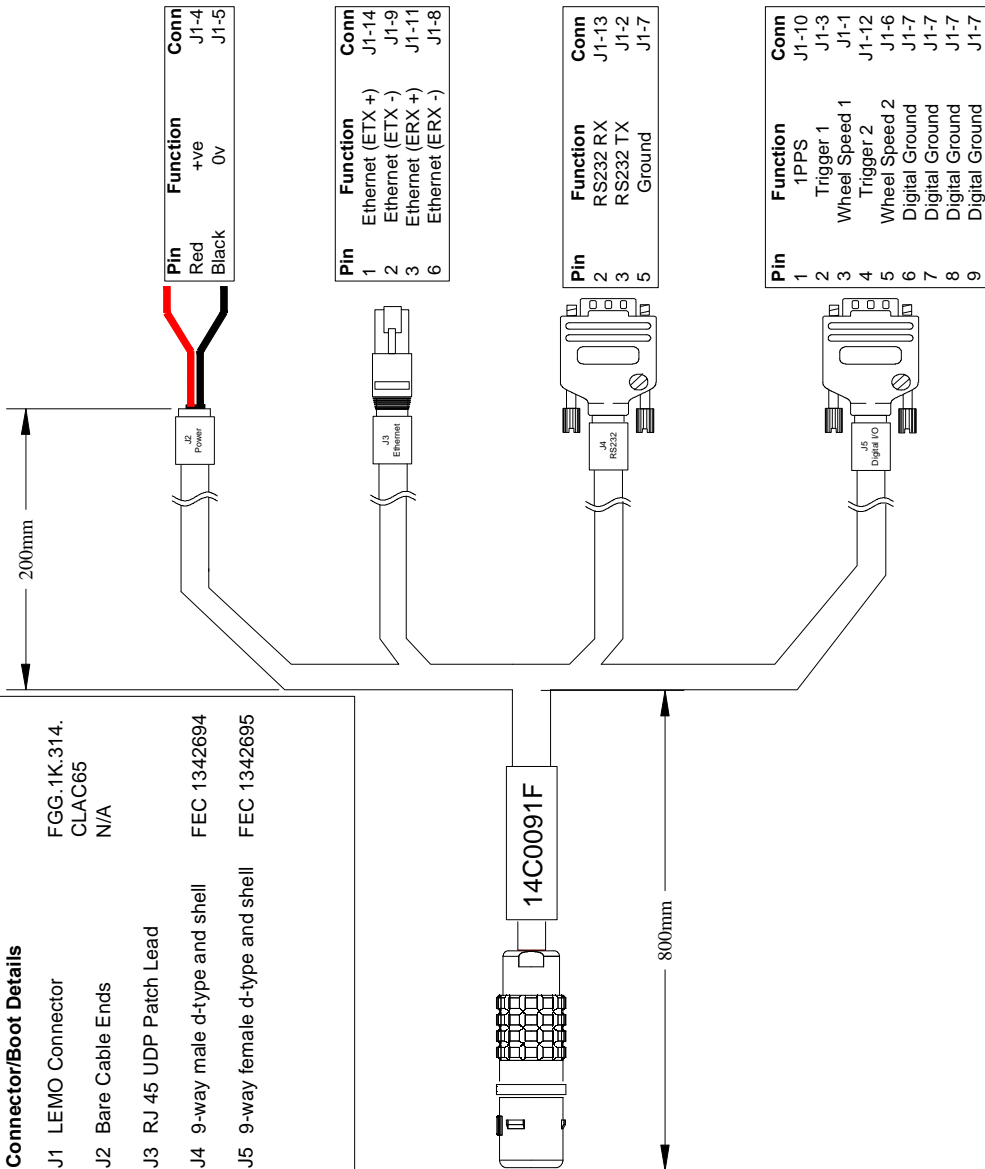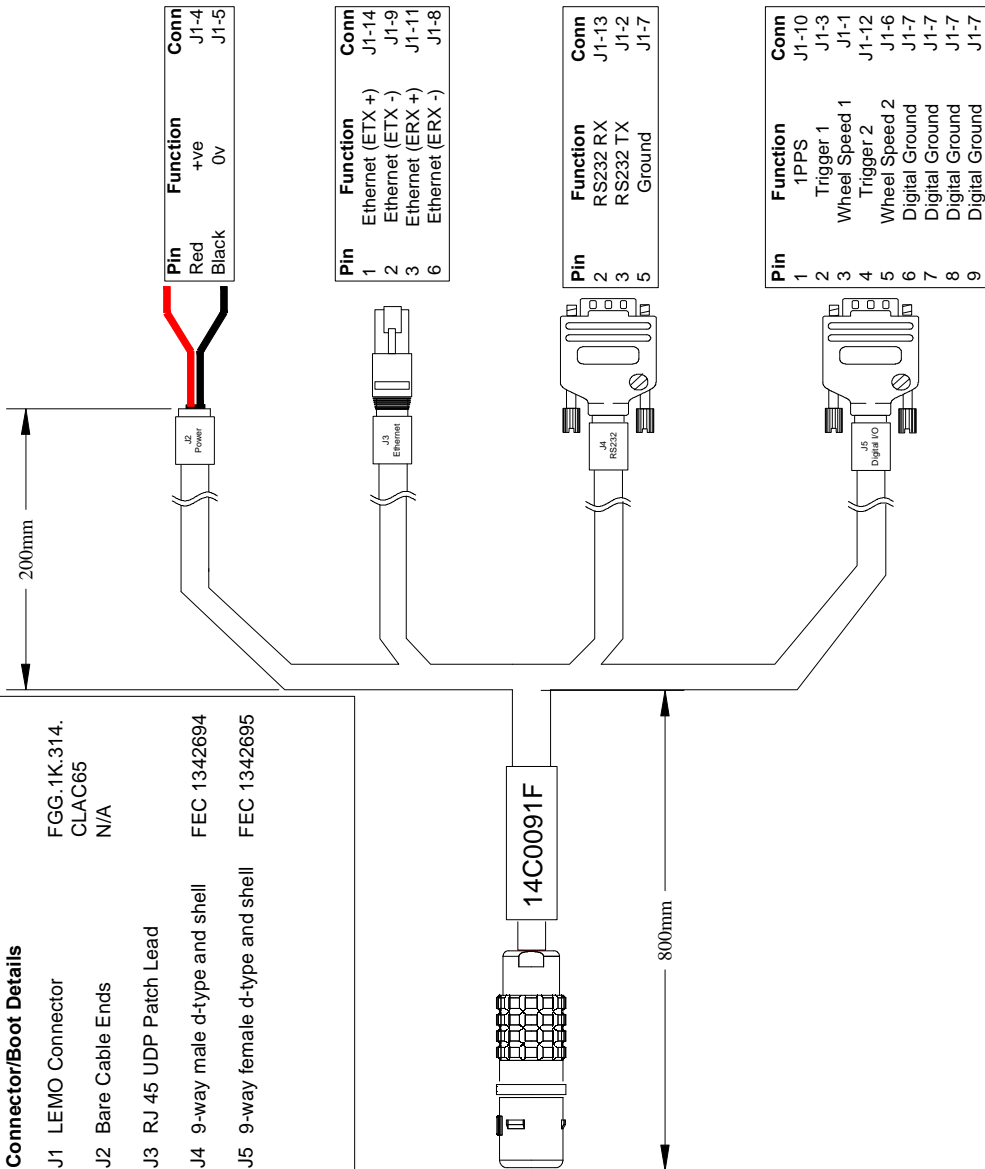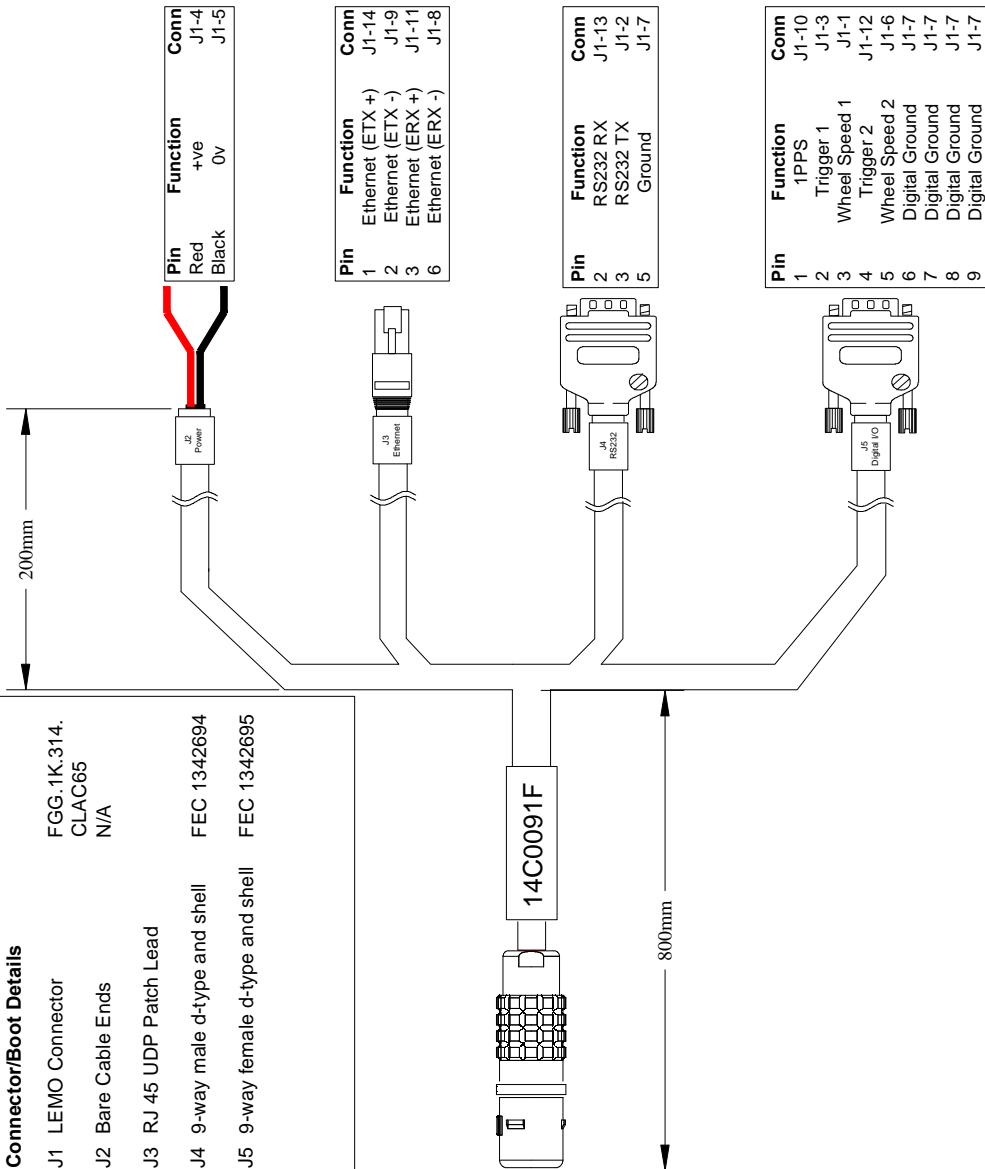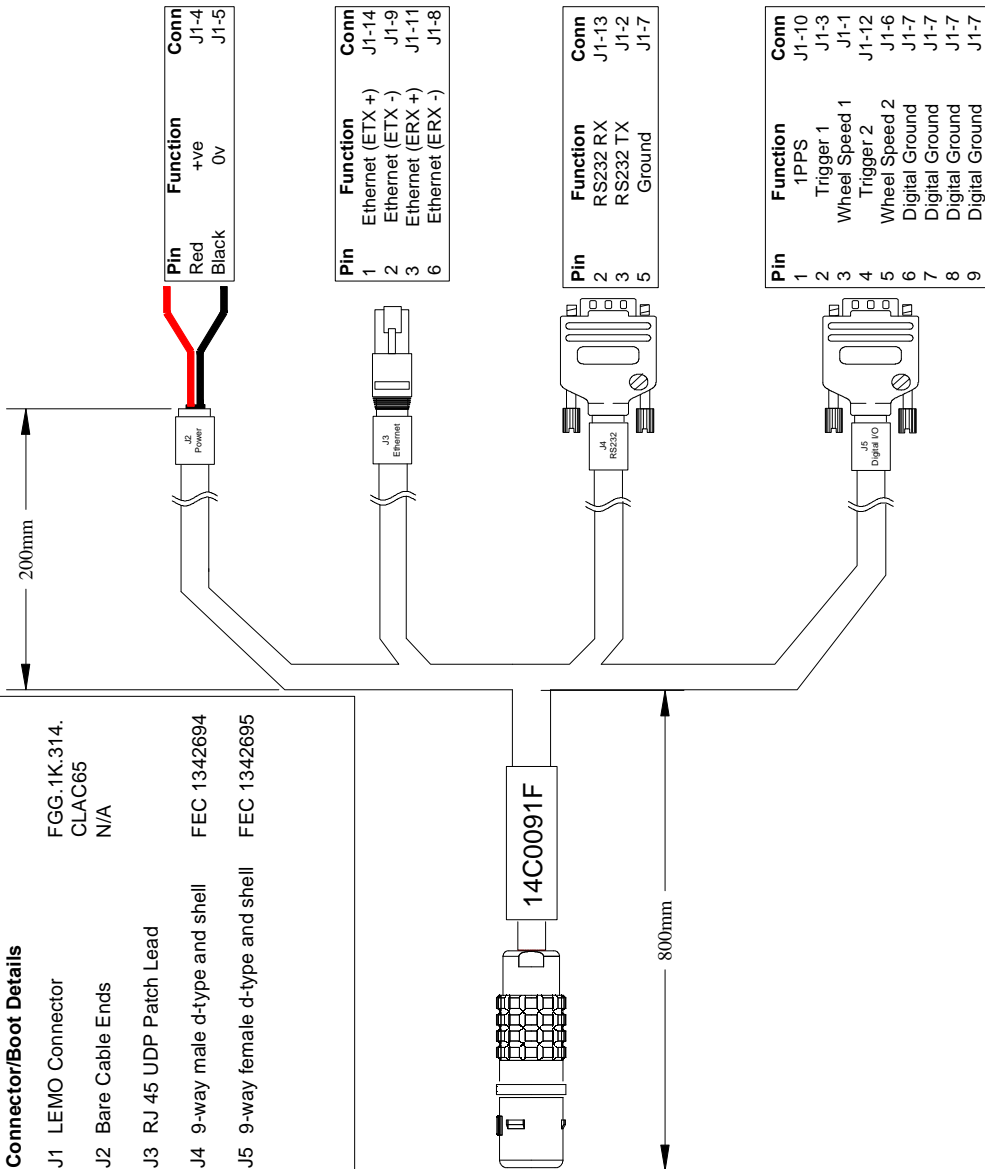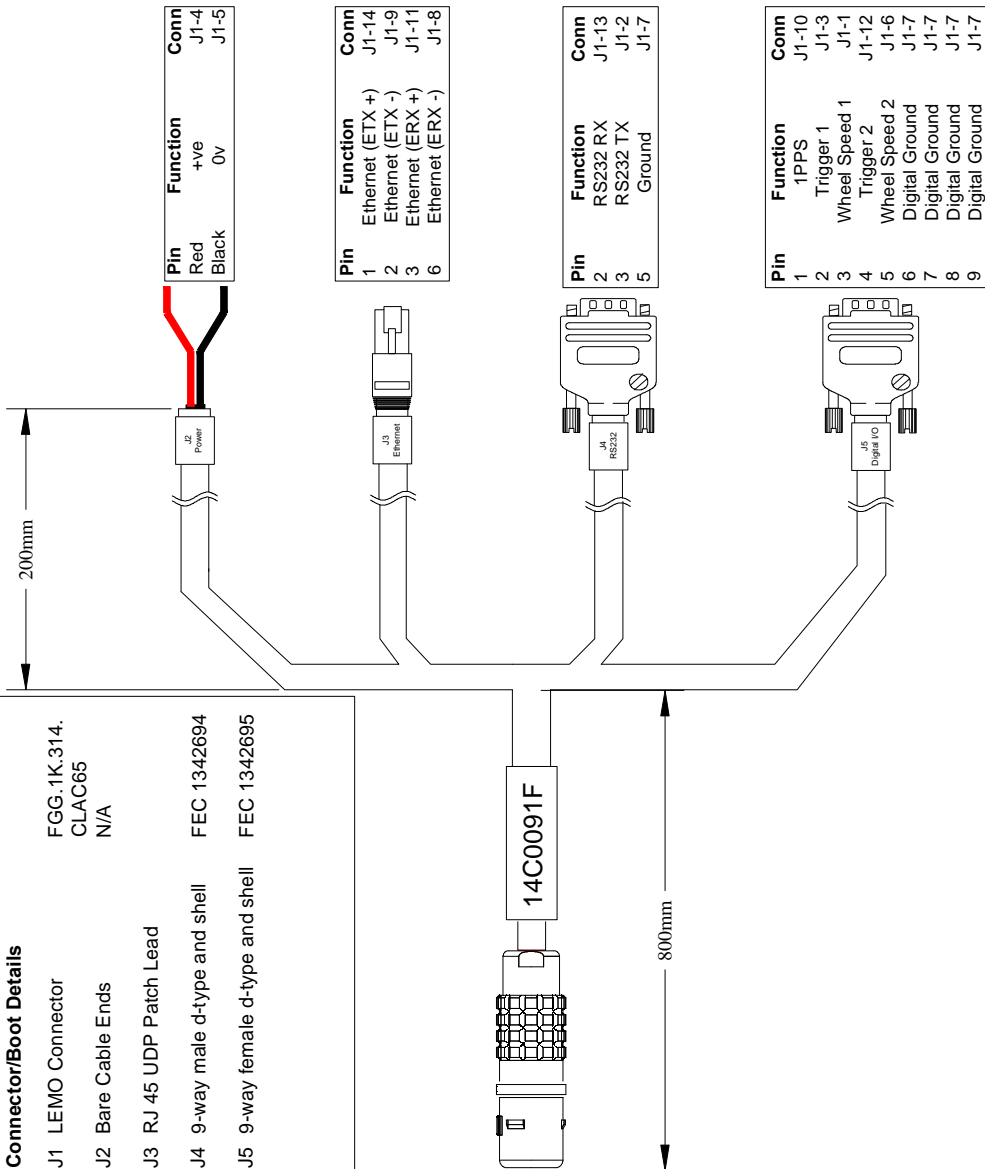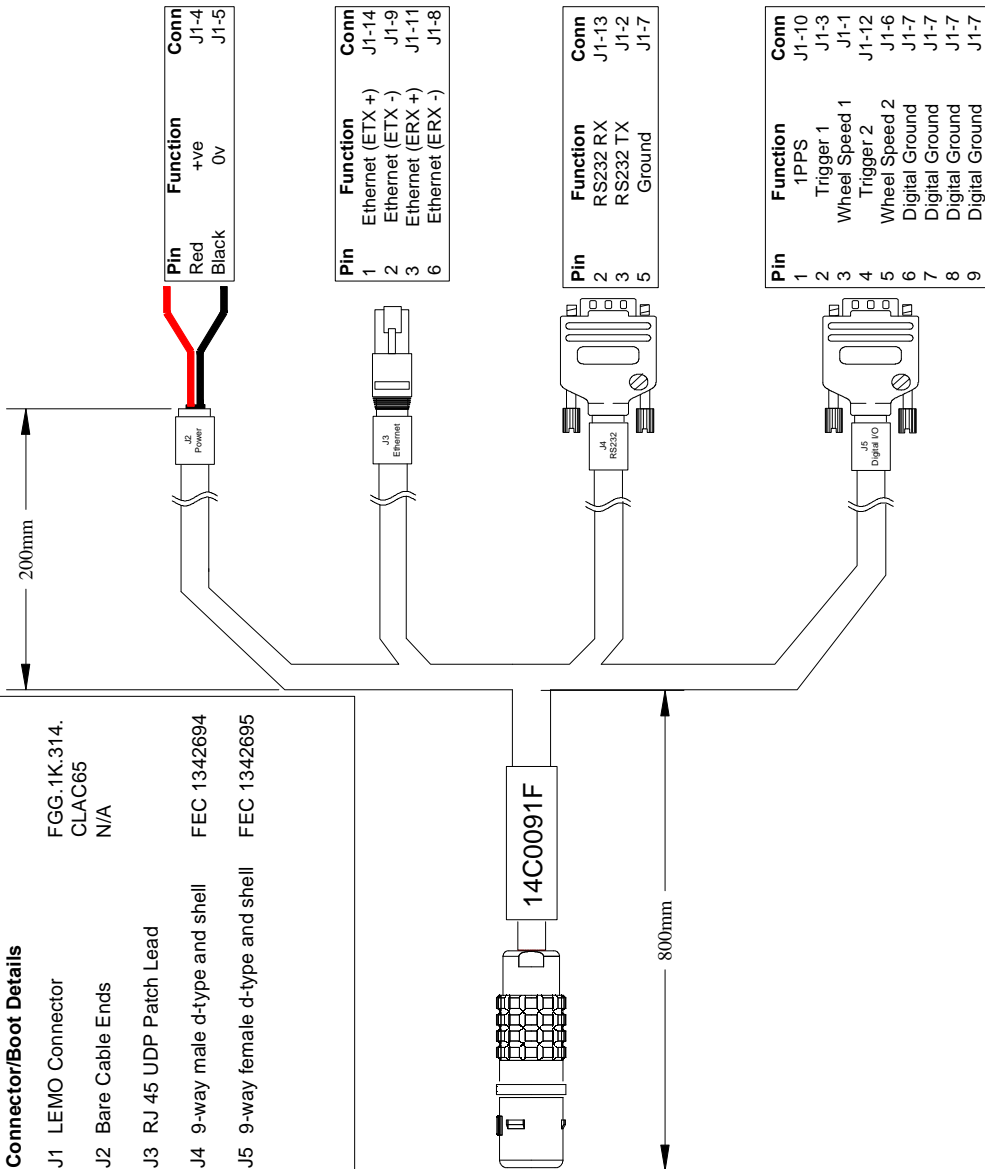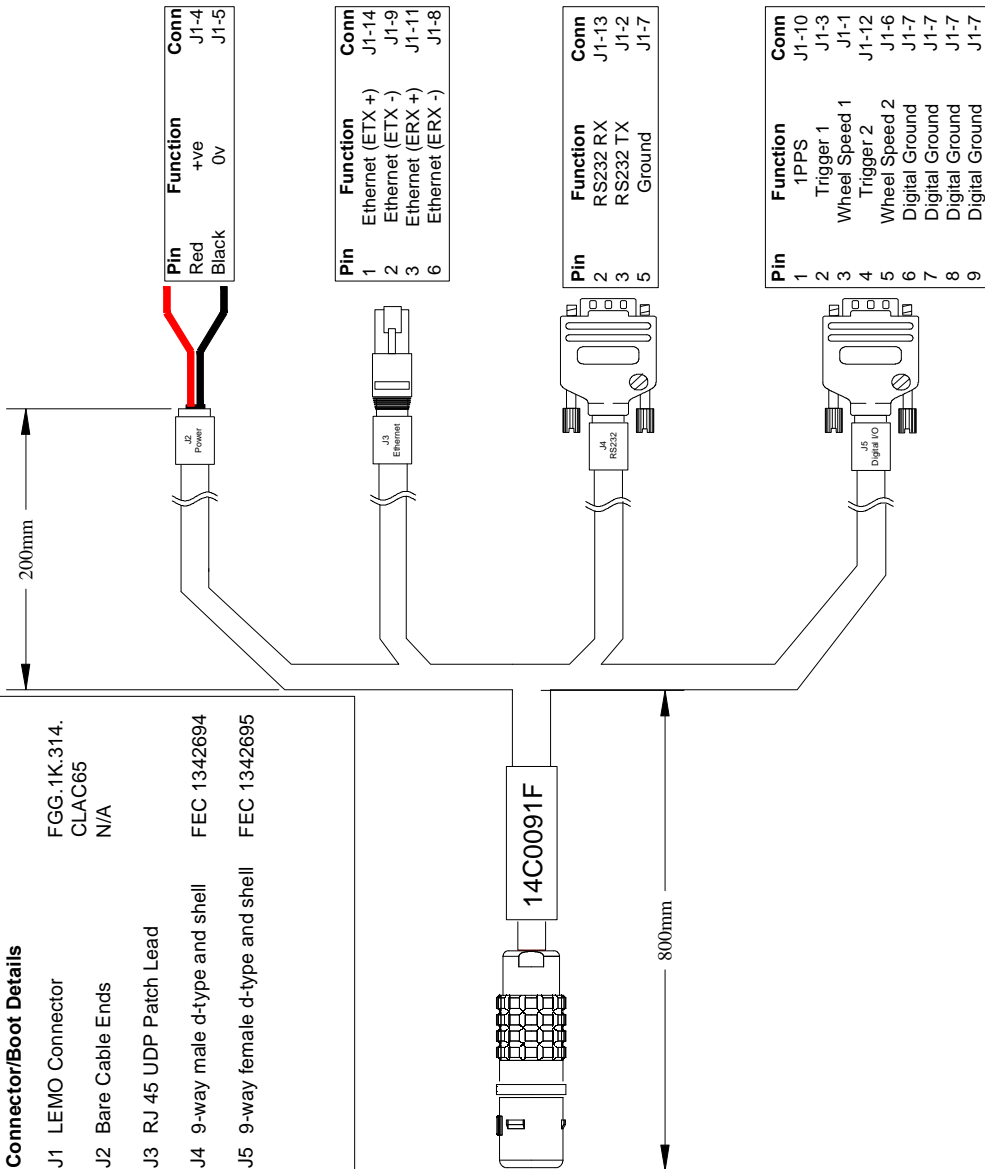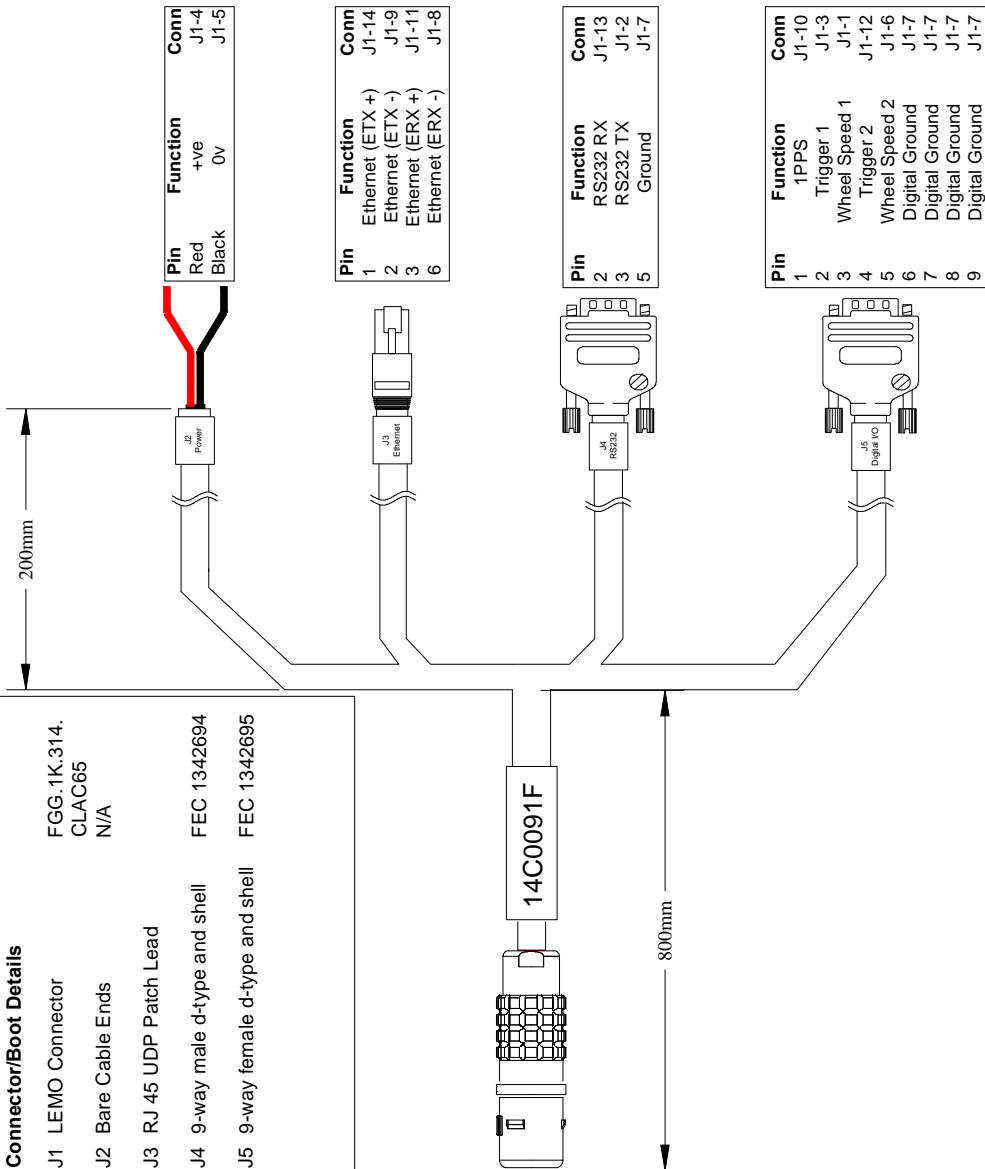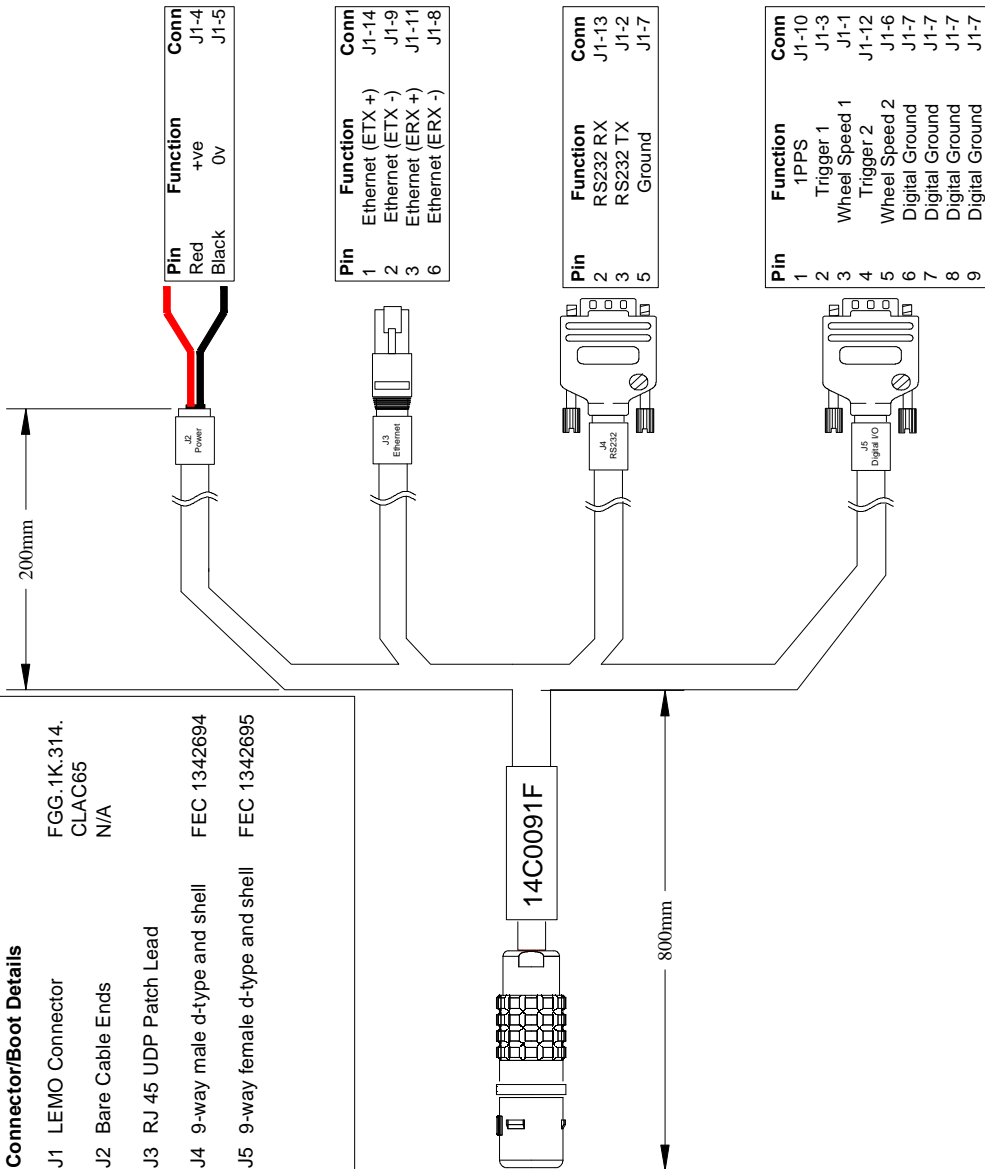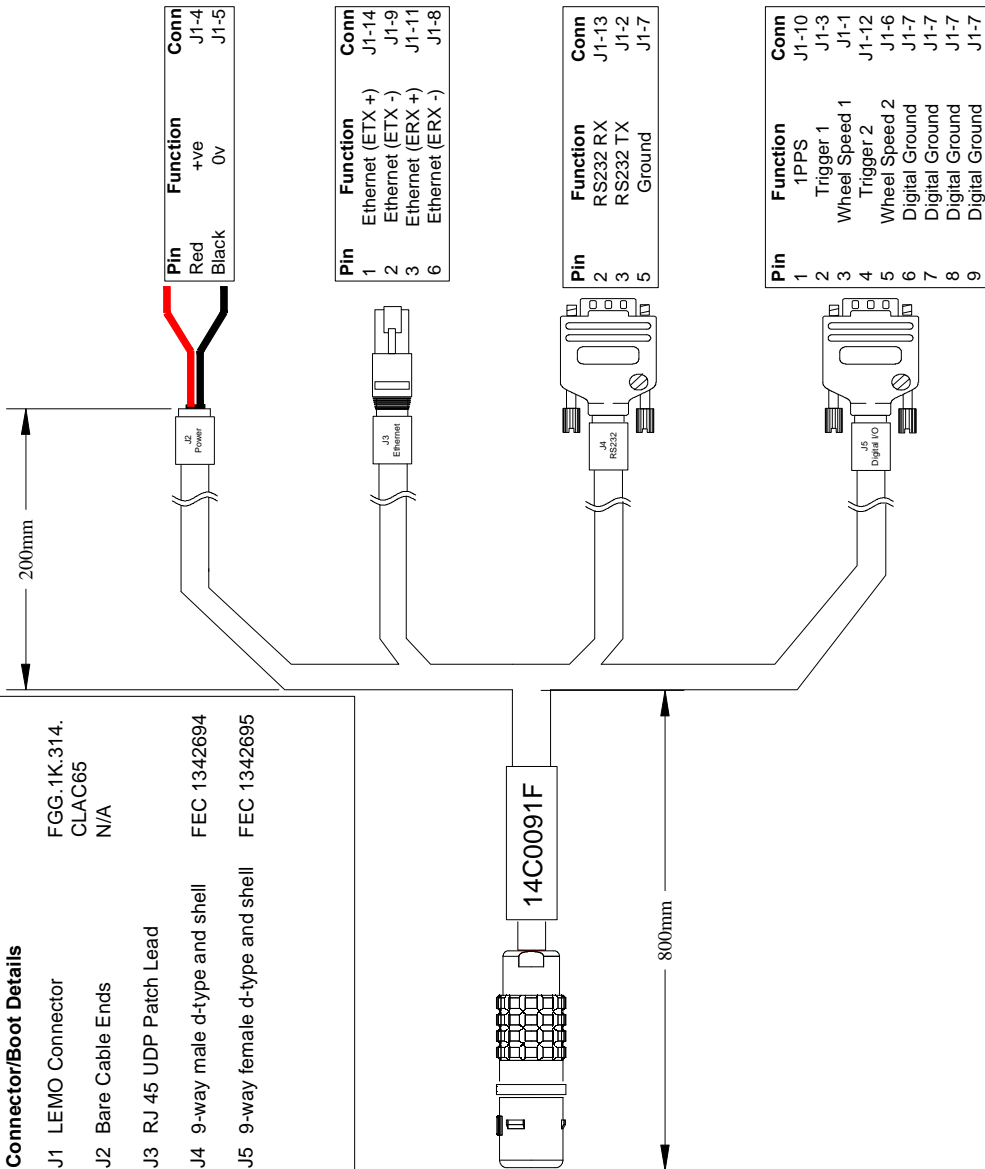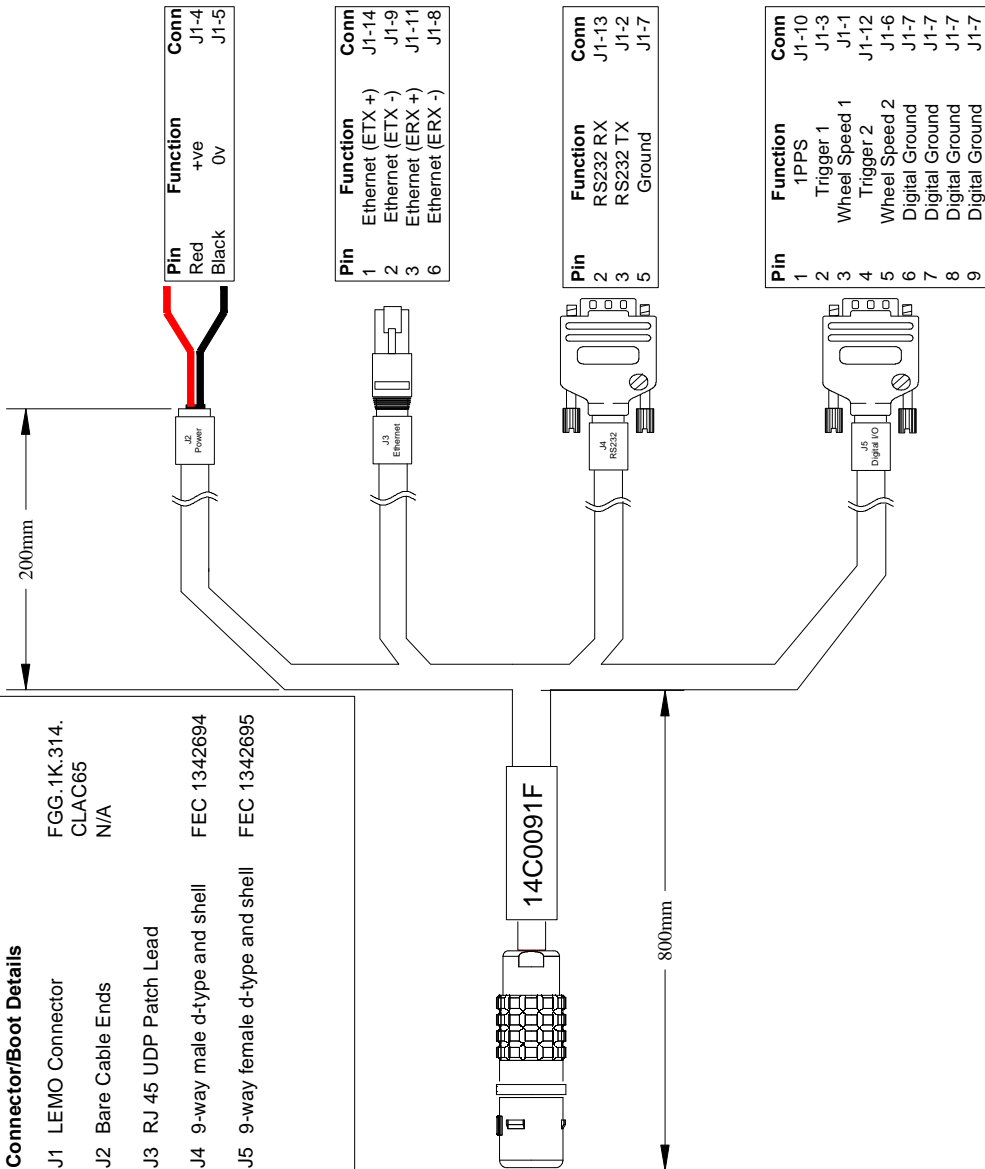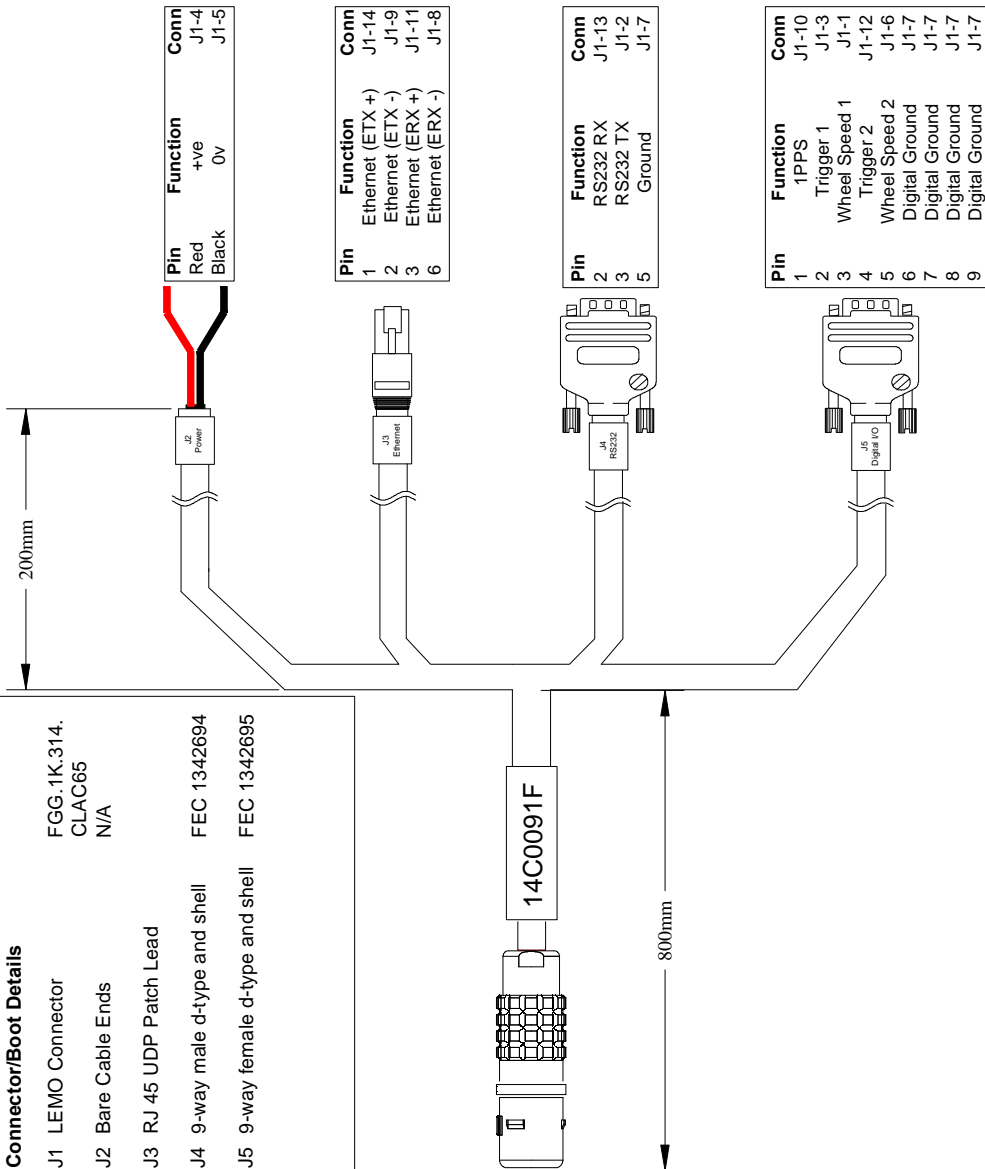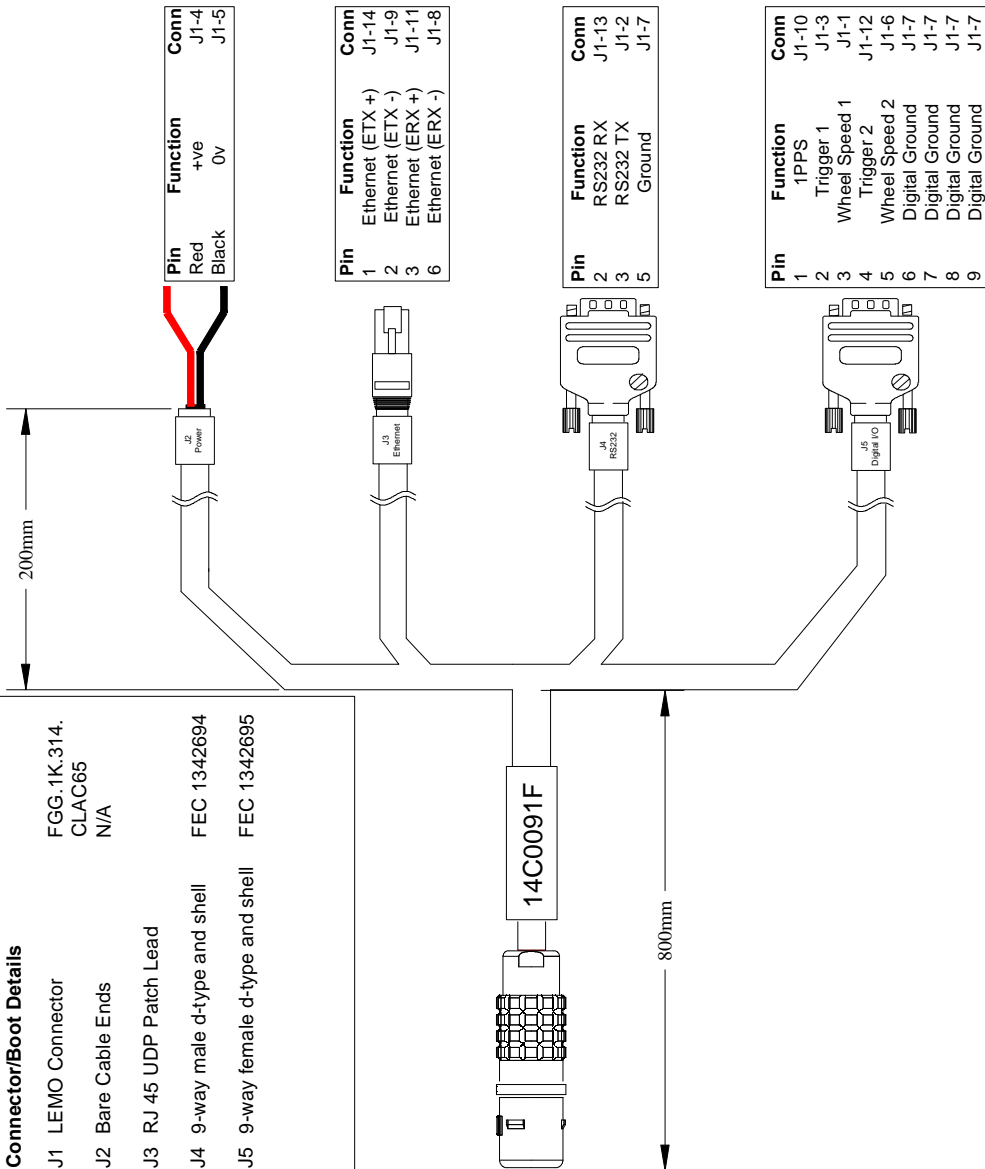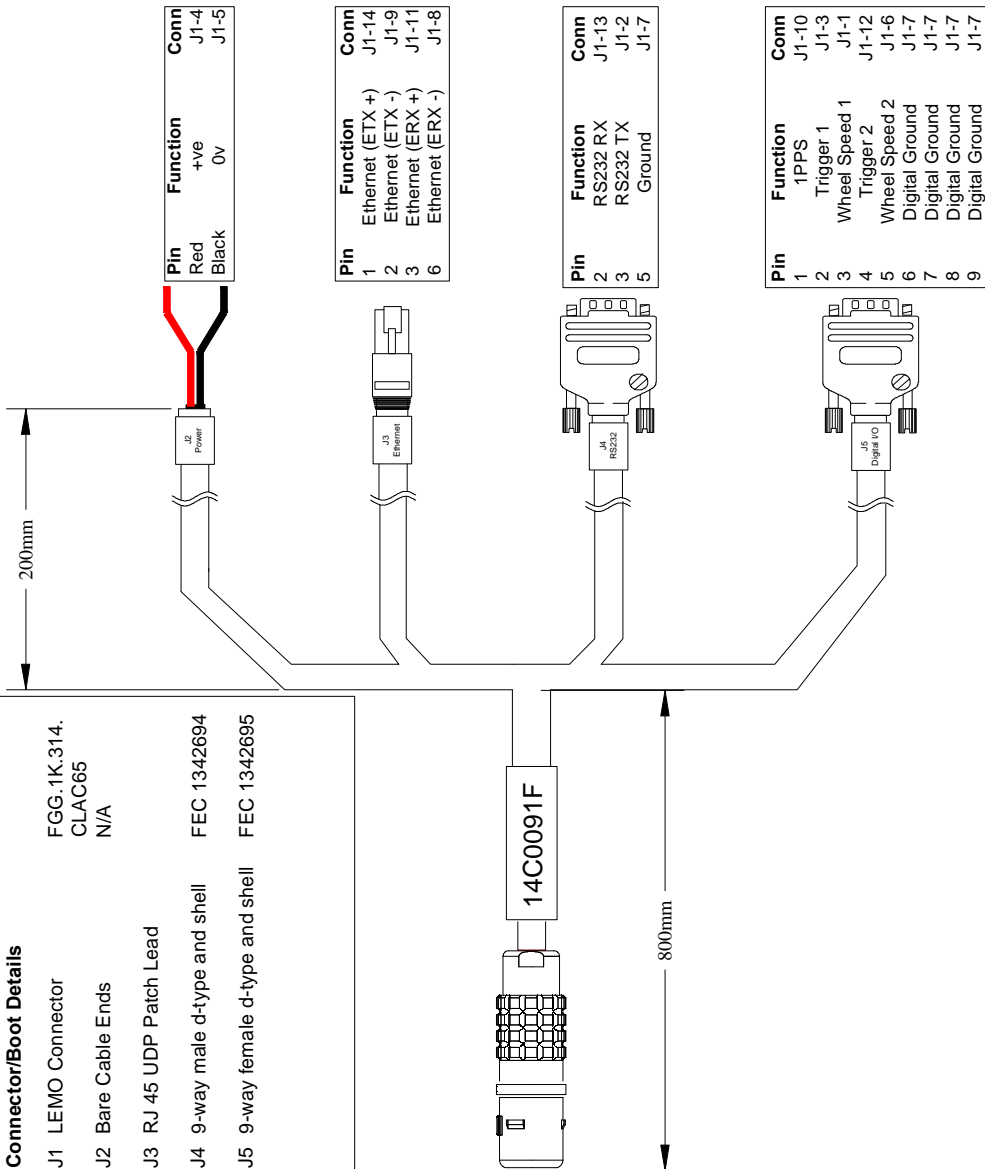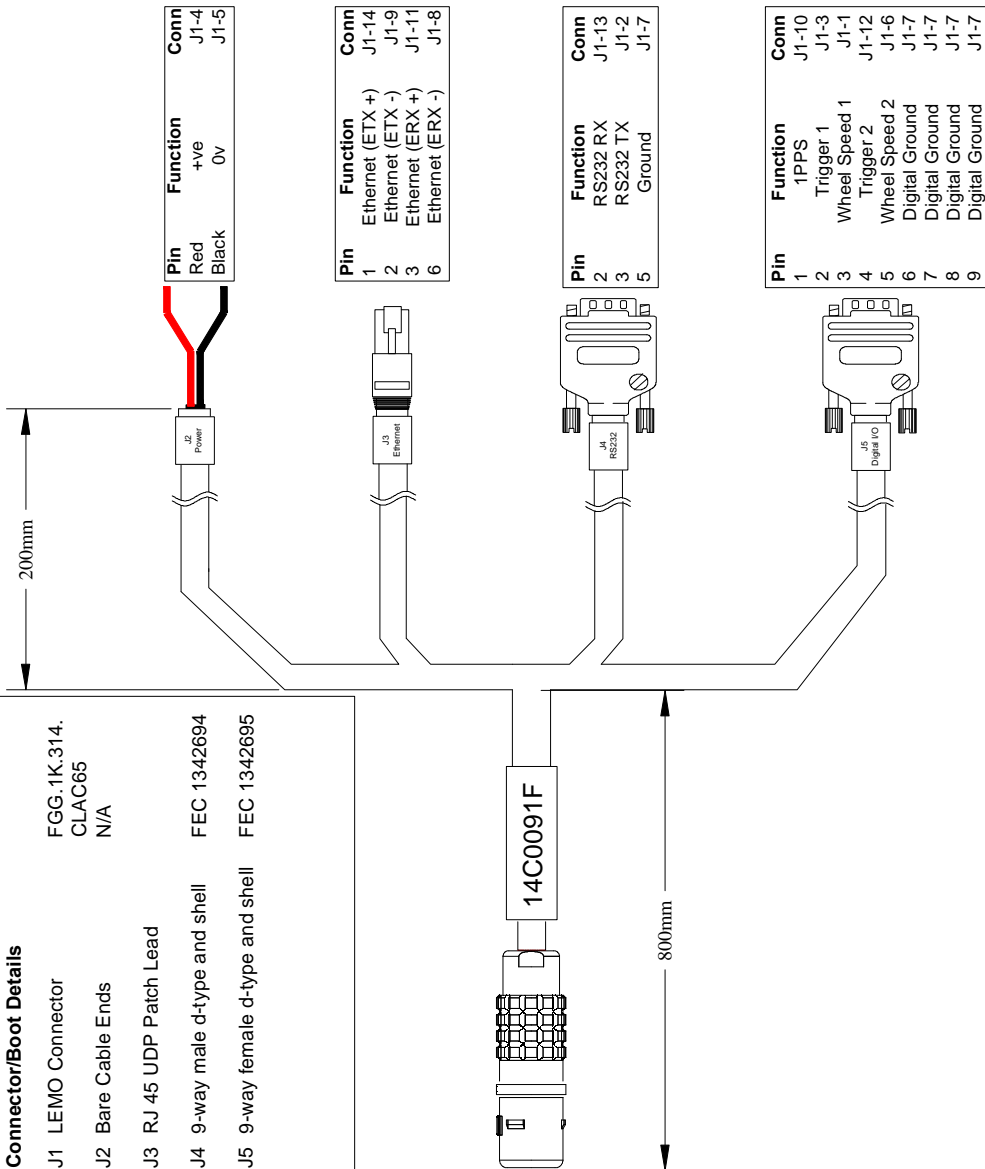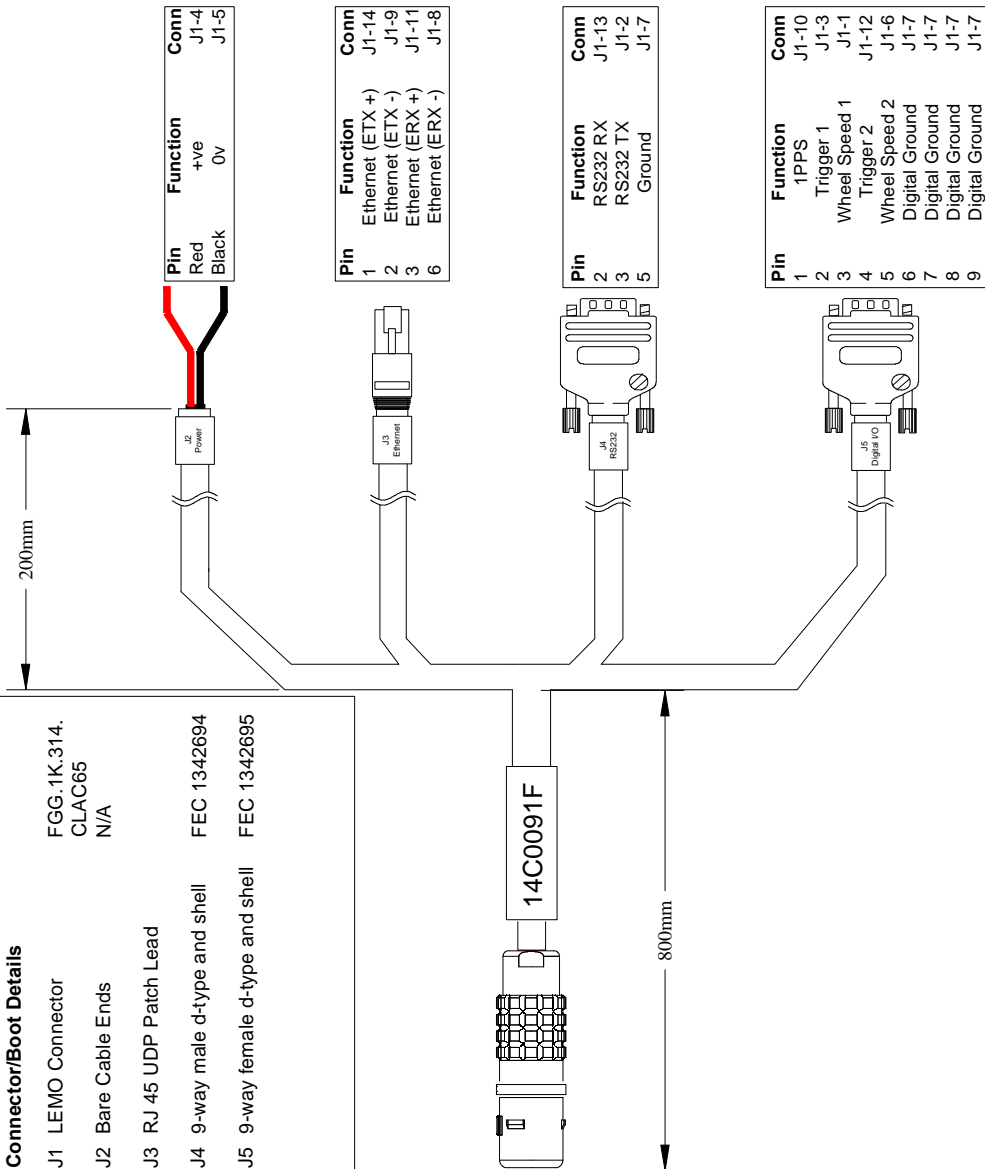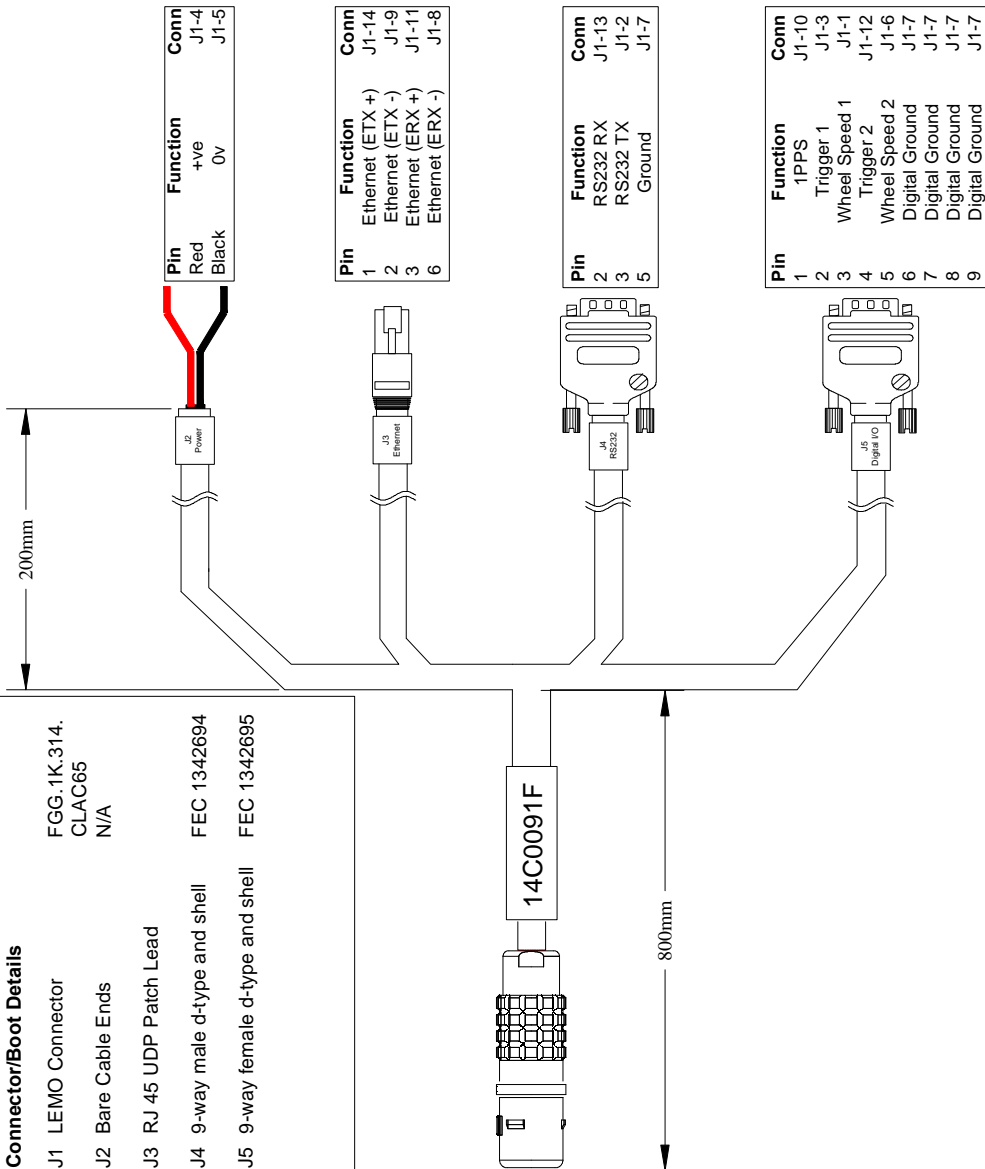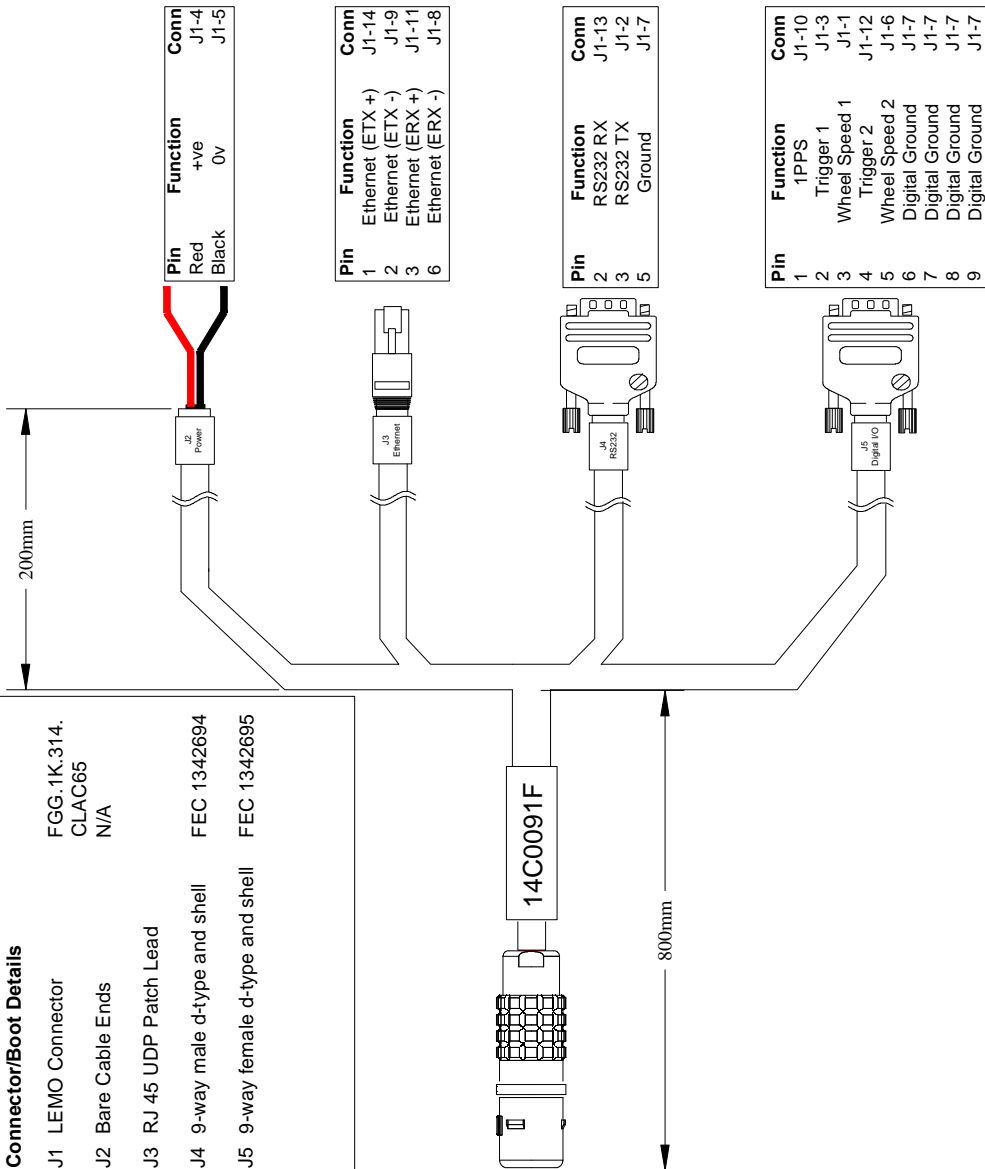
Table 20. List of available drawings

Drawing	Description
14A0067x	xNAV200/500 system outer dimensions
14A0071x	xNAV250/550 system outer dimensions
14C0091x	xNAV user cable
14C0216x	xNAV land cable
14C0217x	xNAV UAV cable
14C0218x	xNAV to Lidar Y cable
14C0219x	LIDAR Adaptor cable

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
  LINEAR: 0.02
  ANGULAR: 0.1
DEBUR AND BREAK SHARP EDGES

DRAWN BY	APATEL
DATE	08/10/2019
MATERIAL	Various
WEIGHT	374g
	A3	Not to scale

THIRD ANGLE PROJECTION

NOTES:
Rev B models can be identified by
having a serial number greater than
SN16010. With the xNAV500 there
are no external changes with Rev B.

Confidential Information
The information in this document is confidential and
must not be disclosed to other parties or used to build
the described components without the written
permission of Oxford Technical Solutions.

DRAWING NO: 14A0067   REV: B
                          SHEET 1 OF 1

TITLE:
xNAV500

Oxford Technical Solutions
77 Heyford Park
Upper Heyford
Oxfordshire
OX25 5HD
www.oxts.co.uk

OXTS

NOTES:
Rev B of the xNAV550 is 5mm shorter than Rev A and there for the measurement point is 5mm closer to the mounting holes. Rev B models can be identified by having a serial number greater than SN16010.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: 0.02
ANGULAR: 0.1
DEBUR AND BREAK SHARP EDGES

DRAWN BY	APATEL
DATE	08/10/2019
MATERIAL	Various
WEIGHT	400g
	A3	Not to scale

THIRD ANGLE PROJECTION

Confidential Information
The information in this document is confidential and must not be disclosed to other parties or used to build the described components without the written permission of Oxford Technical Solutions.

DRAWING NO: 14A0071

TITLE: xNAV550

REV: B
SHEET 1 OF 1

Oxford Technical Solutions
77 Heyford Park
Upper Heyford
Oxfordshire
OX25 5HD
www.oxts.co.uk

OXTS

Dimensions: 132.10, 125, 36, 7, 22.94, 79.12, 22.94, 77, 24.10, 23.04

Z = 15mm

1 2

Oxford Technical Solutions
77 Heyford Park
Upper Heyford
Oxfordshire
OX25 5HD
www.oxts.com

Confidential Information

Scale:	Not to scale		
Projection:	N/A	Print Size:	A4
Units:	mm	Tolerances:	5mm

Print Size scale: 0 10 20 30

Notes:

J3 is a RJ45 UTP patch lead which is cut to length and terminated at J1.

Wire Types:
J2-Red, J2-Black   16/0.2
All others   7/0.12
J1-14 & J1-9 Twisted pair
J1-11 & J1-8 Twisted pair

Cables outers braided and connected to J1-5, J1 shell and J3 shell (through cable assembly braiding).

Please populate all unused pins with empty crimps.

Ensure that the cable legend text precisely matches that given in diagram.

All wires not included in cable assemblies should be 7/0.12 and wires in cable assemblies can be changed to 7/0.12 wire with a join before entering the LEMO connector (J1). These joins should be staggered to avoid a single large bulge in the cable.

Cable legends should be 10mm from the connectors.

The two cables going to J2 should be shielded and insulated together until 60mm from the end when the insulation should end with the shielding terminated inside of it. The two individual cables should then have 5mm stripped off of their ends and tinned.

Document:
xNAV200 User Cable

Part #:   14C0091F

Date: 10/07/2013   **Sheet:**   1 of 1

Connector/Boot Details

J1	LEMO Connector	FGG.1K.314.
		CLAC65
J2	Bare Cable Ends	N/A
J3	RJ 45 UDP Patch Lead	
J4	9-way male d-type and shell	FEC 1342694
J5	9-way female d-type and shell	FEC 1342695

J2 Power

Pin	Function	Conn
Red	+ve	J1-4
Black	0v	J1-5

J3 Ethernet

Pin	Function	Conn
1	Ethernet (ETX +)	J1-14
2	Ethernet (ETX -)	J1-9
3	Ethernet (ERX +)	J1-11
6	Ethernet (ERX -)	J1-8

J4 RS232

Pin	Function	Conn
2	RS232 RX	J1-13
3	RS232 TX	J1-2
5	Ground	J1-7

J5 Digital I/O

Pin	Function	Conn
1	1PPS	J1-10
2	Trigger 1	J1-3
3	Wheel Speed 1	J1-1
4	Trigger 2	J1-12
5	Wheel Speed 2	J1-6
6	Digital Ground	J1-7
7	Digital Ground	J1-7
8	Digital Ground	J1-7
9	Digital Ground	J1-7

200mm

800mm

14C0091F

Scale:	Not to scale
Projection:	N/A
Print Size:	A4
Units:	mm
Tolerances:	5mm

Notes:

J3 is a RJ45 UTP patch lead which is cut to length and terminated at J1.

Wire Types:
J1-4 to J2-1+2, J1-5 to J2-3+4   16/0.2
J1-14 & J1-9 Twisted pair
J1-11 & J1-8 Twisted pair
All wires not included in cable assemblies should be 7/0.12 and wires in cable assemblies can be changed to 7/0.12 wire with a join before entering the LEMO connector (J1). These joins should be staggered to avoid a single large bulge in the cable.

All cables outers fully braided (no gaps) and connected to J1-5 + J1,J3 and J6 shells and all D-sub surounds (through cable assembly braiding). All gaps in shielding due to wiring joints to be shielded (electrically connected and mechanically entirely emcompasing to all shielding)

Please populate all unused pins with empty crimps.

All connections to J1 Lemo should be individually sleeved with suitable heat shrink

Ensure that the cable legend text precisely matches that given in diagram.

Cable legends should be 10mm from the connectors.

Connector/Boot Details

J1	LEMO Connector	FGG.1K.314.
J2	M12 4 Pole Male Pin	CLAC65 Binder 99 1429 814 04
J3	RJ 45 UDP Patch Lead	See Notes
J4	9-way male d-type and shell	FEC 1342694
J5	9-way female d-type and shell	FEC 1342695
J6	M12 8 Pole Female Pin	Binder 99 1486 812 08

J2 Power

Pin	Function	Conn
1+2	+ve	J1-4,J6-4
3+4	0v	J1-5,J6-7

J3 Ethernet

Pin	Function	Conn
1	Ethernet (ETX +)	J1-14
2	Ethernet (ETX -)	J1-9
3	Ethernet (ERX +)	J1-11
6	Ethernet (ERX -)	J1-8

J4 RS232 In

Pin	Function	Conn
2	RS232 RX	J1-13
5	Ground	J1-7

J5 Digital I/O

Pin	Function	Conn
2	Trigger 1	J1-3
3	Wheel Speed 1	J1-1
4	Trigger 2	J1-12
5	Wheel Speed 2	J1-6
6	Digital Ground	J1-7
7	Digital Ground	J1-7
8	Digital Ground	J1-7
9	Digital Ground	J1-7

J6 LIDAR

Pin	Function	Conn
4	Supply+	J2-1+2
5	RS232 TX	J1-2
7	Ground	J2-3+4,J1-7
8	1PPS	J1-10

200mm

14C0216A

5M

Revison History:
191023 New Drawing

Drawing #:	14C0216A	Document:	xNAV Land Cable	MRP #:	110-00932-301	Date:	23/10/2019	Sheet:	1 of 1

Connector/Boot Details

J1	LEMO Connector	FGG.1K.314.CLAC65	
J2	Bare Cable Ends	N/A	
J3	M12 8 Pole Female Pin	Binder 99 1486 812 08	
J4	9-way male d-type and shell	FEC 1342694	
J5	9-way female d-type and shell	FEC 1342695	

200mm

J2 Power

J3 LIDAR

J4 RS232 In

J5 Digital I/O

14C0217A

300mm

J2 Power

Pin	Function	Conn
Red	+ve	J3-4
Black	0v	J3-7

J3 LIDAR

Pin	Function	Conn
1	Ethernet (ETX +)	J1-14
2	Ethernet (ETX -)	J1-9
3	Ethernet (ERX +)	J1-11
4	Supply+ J1-4+J2-Red	
5	RS232 TX	J1-2
6	Ethernet (ERX -)	J1-8
7	Ground	J1-5+J2-Blk
8	1PPS	J1-10

J4 RS232 In

Pin	Function	Conn
2	RS232 RX	J1-13
5	Ground	J1-7

J5 Digital I/O

Pin	Function	Conn
2	Trigger 1	J1-3
3	Wheel Speed 1	J1-1
4	Trigger 2	J1-12
5	Wheel Speed 2	J1-6
6	Digital Ground	J1-7
7	Digital Ground	J1-7
8	Digital Ground	J1-7
9	Digital Ground	J1-7

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Scale:	Not to scale	
Projection:	N/A	
Units:	mm	
Print Size:	A4	
Tolerances:	5mm	

0 10 20 30

Notes:

Wire Types:
J2-Red, J2-Black, J3-4 to J14, J3-7 to J1-5 16/0.2
J1-14 & J1-9 Twisted pair
J1-11 & J1-8 Twisted pair

All wires not included in cable assemblies should be 7/0.12 and wires in cable assemblies can be changed to 7/0.12 wire with a join before entering the LEMO connector (J1). These joins should be staggered to avoid a single large bulge in the cable.

All cables outers fully braided (no gaps) and connected to J1-5, J1 Shell & J3 Shell and all D-sub surrounds (through cable assembly braiding). All gaps in shielding due to wiring joints to be shielded (electrically connected and mechanically entirely emcompasing to all shielding)

Please populate all unused pins with empty crimps.

All connections to J1 Lemo should be individually sleeved with suitable heat shrink

Ensure that the cable legend text precisely matches that given in diagram.

Cable legends should be 10mm from the connectors.

The two cables going to J2 should looped back from J3, shielded and insulated together until 60mm from the end when the insulation should end with the shielding terminated inside of it. The two individual cables should then have 5mm stripped off of their ends and tinned.

Revison History:
191023 New Drawing

Drawing #:	14C0217A	Document:	xNAV UAV Cable	MRP #:	110-00933-301	Date:	23/10/19	Sheet:	1 of 1

OXTS

Confidential Information

The information in this document is confidential and must not be disclosed to other parties or used to build the described components without the written permission of Oxford Technical Solutions.

Print Size:	A4
Scale:	N/A
Units:	mm
Tolerences:	5mm
Projection:	N/A

Notes:

J2 is a RJ45 UTP patch lead which is cut to length and terminated at J1.

J3 is a M12 8 pole lead which is cut to length and terminated at J1.

Cable Ident to show both part number and www.oxts.com

Cable Ident to positioned at the center of the Ethernet cable

All part numbers for guide only suitable alternatives may be used

Trim and sleeve all unused wires in J1

Edit History:
New Drawing 191023

Date:	190905
MRP Part #:	110-00934-301
Drawing #:	14C0218A
Document:	

xNAV to LIDAR Y Cable

Sheet: 1 of 1

Connector/Boot Details

J1	M12 8 Pole Female Pin	Binder	99 0486 287 08
J2	Ethernet Patch Lead Black Only half required	RS 557-086	
J3	M12 8 Pole Male Pin	Binder	77-3429 0000 50708-0200

Cable Lenghts:

All	200mm

J1			J2	J3
Pin	Colour	Function	Pin	Pin
1	Green/White	Tx+	1	N/A
2	Green	Tx-	2	N/A
3	Orange/White	Rx+	3	N/A
4	Yellow	Supply+	NC	4
5	Grey	RS232 TX	NC	5
6	Orange	Rx-	6	N/A
7	Blue	Supply Return	NC	7
8	Red	1PPS	NC	8

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J1 J2 J3

200mm

Connector/Boot Details

J1	M12 8 Pole Female	99 1486 812 08
J2	M12 4 Pole Male Plug	HARTING 21033291401
J3	See Notes	
J4	9-way female d-type and shell	FEC 1342695
J5&6	9-way male d-type and shell	FEC 1342694
Screw Lock	Female NiPt D screwlock assembly,8mm	RS 453-886

J2 Power

Pin	Function	Conn
1	Supply+	J1-4
3	Supply return	J1-7

J3 Ethernet

Pin	Function	Conn
1	Ethernet (ETX +)	J1-3
2	Ethernet (ETX -)	J1-6
3	Ethernet (ERX +)	J1-1
6	Ethernet (ERX -)	J1-2

J4 RS232/RX

Pin	Function	Conn
3	RS232 RX	J1-5
5	Ground	J1-7&J5-5
2	RS232 TX	J5-2

J5 RS232/TX

Pin	Function	Conn
2	RS232 TX	J4-2
5	Ground	J4-5

J6 Digital I/O

Pin	Function	Conn
1	1PPS	J1-8
6	Digital Ground	J1-7
7	Digital Ground	J1-7
8	Digital Ground	J1-7
9	Digital Ground	J1-7

14C0219B

200mm

300mm

Scale:	Not to scale
Projection:	N/A
Units:	mm
Print Size:	A4
Tolerances:	5mm

0 10 20 30

Notes:

J3 is a RJ45 UTP patch lead which is cut to length and terminated at J1.

J2 is a M12 patch lead which is cut to length and terminated at J1.

Wire Types:
J2-Red, J2-Black   16/0.2
J1-1 & J1-2 Twisted pair
J1-3 & J1-6 Twisted pair
All wires not included in cable assemblies should be 7/0.12

All cables outers fully braided (no gaps) and connected to J1 & J3 Shell and all D-sub surrounds (through cable assembly braiding). All gaps in shielding due to wiring joints to be shielded (electrically connected and mechanically entirely emcompasing to all shielding)

Please populate all unused pins with empty crimps.

Ensure that the cable legend text precisely matches that given in diagram.

Discard thumb screws from J4 & J6 back shell, fit two 8mm screwlocks with spring washer and nut through D-sub mounting holes

Cable legends should be 10mm from the connectors.

Revison history:
200121 Drawing Update

Drawing #:	14C0219B	Document:		Lidar Adapter Cable		MRP #:		110-00935-302	Date:	21/01/20	Sheet:	1 of 1