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<th><strong>Responsible</strong></th>
<th>Name: Ian Peerless</th>
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<td>[Person who is responsible for writing the document, i.e. author]</td>
<td>Job Title: Director</td>
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<th>Names: Ronald Schreurs, Dorian Scholz, Alberto Romay</th>
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<td>[Persons who have endorsed the document]</td>
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<td>Updated software description &amp; completed Sections 7 and 8</td>
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<td>7</td>
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<td>Added fleet status screen, gas alarm adjustments, gamepad blue button, autonomy junctions, mission reports with videos/recording/snapshots, questions &amp; answers.</td>
<td>6, 7, 9, 14, 16</td>
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<td>9</td>
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<td>Added video recording to remote control screen. Updated screen shots. Clarified how to set up waypoint tasks. Added how to set up junctions. Added new view options to Mission Report. Added ExR-1 specifications</td>
<td>7</td>
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<tr>
<td>10</td>
<td>2019-12-02</td>
<td>Updated how to launch a mission and explained “Site Config” &amp; “Feedback” options. Added cold weather behaviour to Q&amp;A.</td>
<td>8, 11, 20</td>
<td>Ian Peerless</td>
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<td>20</td>
<td>Alberto Romay</td>
</tr>
<tr>
<td>11</td>
<td>2020-03-31</td>
<td>Removed “hibernation” feature &amp; refined charger wording. Added a remark about auto-immobilisation. Added picture of docking station buffer bolt. Added image and description of new “User Management” screen. Added typical data consumption &amp; battery life. Robot specifications updated.</td>
<td>5, 6, 8, 12, 13, 14, 19, 21 - 23</td>
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<td>12</td>
<td>2021-07-20</td>
<td>Added ExR-2 and full 3D navigation. Created a separate deployment manual. Updated the information throughout the manual.</td>
<td>Multiple</td>
<td>Alberto Romay</td>
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1. **Introduction**

This document is one of four that will help operators to use their robots safely and effectively:

- ExR-1 Robot Operator Operating Instructions
- ExR-2 and Docking Station Operating Instructions
- Robot System Operating Guide.
- Robot System Deployment Guide.

The instructions focus on the safe operation of the robots especially with respect to their use in potentially explosive gas environments. The others provide additional information about the robot systems and their use. If there’s a conflict between the documents, the instructions will always prevail.

This operating guide:

- Describes each key part of the robot system:
  - Robots.
  - Control stations that are used to communicate with the robot.
  - Docking stations that recharge the robots’ batteries.
  - Cloud software that enables users to interact with robots.
- Explains how to set up autonomous missions.
- Recommends how robot operatives should be trained.
- Provides advice for operating robots.

The guide will be updated and made available to robot fleet managers and first line support as new robot hardware and software is deployed.
2. **Robots**

Once deployed, users will have little reason to interact with robots. However, the major components are shown on the drawings below. Robot specifications are included in Section 9.

**ExR-1 Robot Platform**

- **Basic configuration:**
  - IECEx & ATEX zone 1 areas from -20°C to +50°C
  - II 2 G Ex db ia mb gb IIB T4 Gb
  - 4G/LTE Antennas
  - Three cameras in a single module. (Three lights are installed in an identical, adjacent module)
  - Controls
  - Induction charger
  - Microphone

**ExR-2 Robot Platform**

- **Basic configuration:**
  - IECEx & ATEX zone 1 areas from -40°C to +55°C (depending on options)
  - II 2 G Ex 60079-46 IIB T4 Gb
  - Panning, digital zoom, inspection camera
  - Controls
  - 4G/LTE antenna
  - LiDAR localisation and collision avoidance
  - AI/ML computational unit (inside hull)
  - Drive camera
  - Microphone
  - Induction charger

The only controls mounted on each robot are the red emergency stop switch and the black on/off switch. When the red emergency stop switch is pressed downwards it immobilises the drive motors. The robot can’t be driven until the switch is released by rotating it and letting it spring.
upwards. When the black switch is rotated anticlockwise to the “off” position the power supply to all components (except some circuits in the electronics box) is shut-off.

There’s a range of options that can be added to a robot:

<table>
<thead>
<tr>
<th>Option</th>
<th>ExR-1</th>
<th>ExR-2</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra drive camera module</td>
<td>Not available</td>
<td>In the rear of the robot</td>
<td>Only one of these options can be installed.</td>
</tr>
<tr>
<td>Extra inspection module</td>
<td>Not available</td>
<td>Facing upwards from the rear of the robot</td>
<td></td>
</tr>
<tr>
<td>Inspection module thermal</td>
<td>Facing forwards</td>
<td>Facing forwards or in the inspection module panning</td>
<td>It replaces the light in the inspection module panning.</td>
</tr>
<tr>
<td>Falco VOC module</td>
<td>Up to 3 of these options can be installed on top of the hull.</td>
<td>Up to 2 of these options can be installed inside the hull.</td>
<td></td>
</tr>
<tr>
<td>Honeywell toxic gas module 3000 Mk II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honeywell toxic gas module Sensepoint XRL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simtronics hydrocarbon gas module</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eaton MEDC DB20 speaker</td>
<td>Not available</td>
<td></td>
<td>COMING SOON</td>
</tr>
<tr>
<td>Det-tronics acoustic analyser module</td>
<td>Not available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex high power induction charger &amp; docking station</td>
<td>Not available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quick charger with power socket module</td>
<td></td>
<td>Supplied as standard instead of the induction charger</td>
<td></td>
</tr>
<tr>
<td>WiFi</td>
<td></td>
<td>Can be combined with 4G LTE</td>
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</tr>
<tr>
<td>GPS</td>
<td>Not available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pepperl &amp; Fuchs switches</td>
<td></td>
<td></td>
<td>Installed when ambient temperatures won’t exceed 50C</td>
</tr>
<tr>
<td>Electronics box check valve</td>
<td></td>
<td></td>
<td>Installed if there’s an exceptional risk of water entering the electronics box</td>
</tr>
<tr>
<td>Elevating mast</td>
<td>Not available</td>
<td>Raises the inspection module panning to head height</td>
<td>COMING SOON</td>
</tr>
<tr>
<td>IR leak detection module</td>
<td>On top of the hull.</td>
<td>Not available</td>
<td></td>
</tr>
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</table>
3. **Control Stations**

Robots are controlled with a:
- PC with a screen resolution of at least 1920 x 1080 and Google Chrome.
- Gamepad for driving the robot (Xbox is recommended).
- Mouse or trackpad for operating the cursor on the PC’s screen.

It’s important that there are no intrusive firewalls between the control station and the cloud software (see below).

<table>
<thead>
<tr>
<th>Port</th>
<th>Protocol</th>
<th>IP</th>
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<tbody>
<tr>
<td>3478</td>
<td>UDP</td>
<td>Will be given to you by Energy Robotics</td>
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4. **Docking Stations & Charging**

The robot automatically charges itself using the induction charger built into its docking station. In autonomy mode the robot will automatically undock and redock. At the end of a remote control mission the operative should approach the docking station in “slow speed” mode and in the direction indicated in the diagram below. Provided the robot is reasonably straight and central when approaching the docking station, the robot will automatically align the induction charging plates using the plastic strips under its hull. To facilitate robot alignment, the robot should approach the docking station in a straight line for at least 3 meters.

Once the front of the robot’s hull is pressing against the front of the docking station the operative should stop driving forwards and switch off the motors by pressing the red button on the gamepad. The robot will “go to sleep” (to reduce power consumption) and begin to charge using the induction charger. There can be a delay of up to 120 seconds before this happens.

Once the induction charger is connected, the “Wireless Charger” and “Charging” boxes on the cloud software will be checked. Hovering the cursor over the charging box will reveal the charging current. It takes approximately 6 hours to recharge fully an empty ExR-1 battery pack and 12 hours for an ExR-2 battery pack.
The docking station should be powered up at all times since charging may be disrupted if it’s switched on when the robot’s already docked. Also, it’s best not to switch off the robot (using the black On/Off switch) when the robot is in the docking station since this too can disrupt charging. If this happens pull the robot 30cm back and switch it off and on again.

When a driver checks the “Wake Up” box the robot video streams will typically appear within 1 minute. The robot is then ready to use although it’s best to allow some gas sensors 30 minutes to warm up before starting a mission (see their instructions).

A power socket module (when fitted) enables the robot to be charged within 3 hours. This requires the robot to be manually plugged into a power supply using a quick-charger that can be ordered with the robot. The quick-charger’s lead is typically 3 meters long. If the robot is docked you should first switch off power to the induction charger. When inserting the quick-charge plug, rotate the entire body clockwise before tightening the ring around its base. You can check the status of the charging using the LEDs and instructions on the quick charger.

5. **Cloud Software**

Robots are operated and data is collected using the “cloud”. Access is granted as described in Section 7.2. Six types of screens are available as described below.

5.1. **Fleet Management and Fleet Status**

Fleet Management is the first screen that appears when users log on. It allows them to connect to any robot to which they've been granted access. Scrolling down reveals more robots.
5.2. Driver Screen

Once a user has connected to a robot, most of the display information is intuitive:

- The major functions are summarised in the picture below.
- For safety reasons, only one operative can control a robot at any given time. The logo towards the top right of the screen will show who that is. To take over control, click on that icon.
- All video and LiDAR streams are displayed on the control station. Clicking on the “Expand” icon of any video stream window moves it to the largest window.
- To take a snapshot, hover the cursor over any video stream and then click on the Point of Interest (POI) icon that appears in the top-left corner. Then use the cursor to select the area of interest and click on the “Accept” button to capture the image. Alternatively you can take a full-size picture without selecting the POI icon.
- Snapshots are displayed in the “Media Log” once they have been uploaded to the server (this happens automatically after taking them) and can be viewed in large scale by clicking on them. From there they can be saved to the local machine by right clicking the full-sized picture and selecting “Save As...”.
- To take a video, a mission must be active. This is done by undocking the robot and driving to the location of interest (Videos are currently only recorded if the robot status is “Mission Active”). Once ready, hover the cursor over any video stream and click on the “Video” icon (small circle) that appears in the top-left corner. The message “recording” will appear. To stop recording click the “Video” icon again.
- Videos will be available only after the robot is back in the docking station (to save bandwidth when driving, videos are not uploaded immediately). Videos are displayed in the Mission Report website under “Recorded Media” and can be viewed in large scale by clicking on them. From there they can be saved to the local machine by right clicking the full-sized picture and selecting “Save As...”.

The Fleet Status screen (see below) is accessed by clicking on the “navigation menu” icon to the top left of the fleet management screen.
- The icons at the top of the “Media Log” can be used to filter the time of the last events e.g. images from the last 4 hours. Additionally, the “cloud download” icon to the right can be used to download a complete set of recordings as a zip file.
- The audio stream of the microphone can be started and paused by clicking on the “Microphone” window.
- The screen shows the gas levels for those gas detectors that are fitted to the robot. The gas alarm levels for the robot can be adjusted by clicking on the icon to the top right of each gas display window. An audio/visual alarm is emitted when the alarm level is exceeded.
- The autonomy controls are grouped together. When the “Keep Awake” box is ticked the robot won’t sleep. If it’s unticked the robot will save 4G costs and battery power by sleeping (whether or not it’s docked).
- Select a mission using the drop-down box. To launch the mission, click on the “Play” button to the left of the mission drop-down box, to cancel the mission press the button again. Missions will usually be started when the robot is in a docking station. However it’s also possible to launch “line-following” missions when the orange line is visible in the down-facing camera.
- Using the cursor to activate the “Stop” button has the same effect as pressing the emergency stop switch on the gamepad. The drive motors are isolated until the switch is released. This is done using “Auto” or the green button on the gamepad.
- The gas detectors and lights controls are accessed by clicking on “More”.
- The top right of the screen shows the robot’s status. A tick adjacent to each item indicates:
  o Mission Active – robot has been commanded to move and it’s not charging anymore.
  o Wireless Charger– the robot’s coil is connected to that in the docking station.
  o Charging – current is flowing into the battery pack.
  o E-Stop Released – the robot’s emergency stop has been released ready to drive.
- Motors Enabled – the robot’s motors are not isolated anymore, so the robot can be driven manually or autonomously (this takes a few seconds to change after checking the “Auto” box or pressing the green gamepad button).
- Driving – the robot is in motion.
- Gas Detectors On – The gas detectors are powered up (they have individual warm-up times and only after this time the gas displays will start showing measurement values).
- Manual Control – the robot is being controlled from this control station by a driver.
  - Hovering over an icon or text will often provide more information.
  - Drivers can change the robot location on the screen by clicking on the “Site Config” option in the navigation menu to the top left of the screen. They can report issues to our engineers using the “Feedback” option in the user menu to the top right of the screen.

The gamepad controls are illustrated below:
- The green button activates remote control by enabling the gamepad and drive motors.
- The blue button switches from remote control to autonomous driving.
- The yellow button deactivates remote control by disabling the gamepad.
- The red button on the gamepad stops the robot and isolates the motors, identical to the “Stop” icon.
- The analogue joysticks are used to drive (left stick) and steer (right stick) the robot.
- For ExR-2, the right stick rotates the inspection module panning if the button under the LB button is held down.
- Holding down the LB/RB buttons changes speed mode (slowest - no buttons pressed, fastest - both buttons pressed).

When in autonomous mode, the robot will stop if the connection to the driver’s control station is broken for more than 5 seconds. This means that an active control station is required for the robot to be operational in autonomous mode. The robot will also stop if it loses sight of the orange line. In this situation an audio/visual alarm will be triggered on the robot control screen.
5.3. **Mission Editor**
This screen enables planners to construct and edit autonomous missions as described in Section 6.

5.4. **Mission Report**
A typical mission report screen is as follows.

The data for a mission is displayed by clicking on the relevant block to the left of the screen.

- The gas detector values are displayed on the adjacent graphs.
- The plan will be green where the gas levels were below the lower alarm level, amber where they were between the two alarm levels, and red where they were above the upper alarm level. Section *Error! Reference source not found.* describes how to set the alarm levels.
- Other information that has been gathered at Waypoints is displayed in the right-hand part of the screen.
- Snapshots and gas readings are uploaded immediately. Other recordings are uploaded when the robot returns to its docking station. Video and sound recordings are limited to 2 minutes for each action.

To study a chart in more detail:

- Hover the cursor over a point on the chart to get a digital reading.
- Zoom in with the mouse wheel or by left-clicking and dragging.
- Pan by using the shift key, left-clicking and dragging.

5.5. **Engineer Screen**
This screen is used by ExRobotics and Energy Robotics and will not usually be used by customers.
6. **Autonomous Missions**

6.1. **Overview**
A robot mission is typically a circuit that starts and finishes at a docking station. During the circuit the robot will perform actions for points of interest when the robot is located at a waypoint:

- A typical action is to record a video, snapshot, sound, or sensor reading.
- Actions are targeted at points of interest (POIs). This is a 3D location at which the appropriate camera or sensor is targeted. Examples of POIs are valves, flanges and pumps. To target the POI the robot will usually need to change its azimuth (rotate) and in some cases will require a camera to lift its field of view (elevate). There can be more than one action at a POI.
- Waypoints are 2D locations from which POIs are observed. There can be multiple POIs at a waypoint. In Line-following navigation, waypoints are defined by an array of chili-tags.
- There can be multiple waypoints on a mission.

Robots perform their missions using orange lines on the ground (line following navigation), chili-tags (tag based inspections) and/or a virtual model created by the robot’s LiDAR module (full 3D navigation). The deployment guide describes how to establish the required infrastructure. This manual describes how to use that infrastructure using this mission editor screen.
6.2. **Line Following Navigation**

A planner will:

For undocking, define the exit direction of the robot when leaving the docking station. When the robot “undocks” it drives in reverse until the middle point between the “Dock 1” and the “12:00” tags. Then the robot will rotate and exit the docking station to start following the line in one of three possible directions: 03:00 (robot rotates 90 degrees clockwise), 06:00 (robot rotates 180 degrees), or 09:00 (robot rotates 90 degrees counter-clockwise).

- From the Mission Editor screen select action “Undocking”
- Select the Exit Direction (e.g. 09:00)
- Write a name in Select Action Name e.g. “Undock”
- Click “Save”

For waypoints that are used as junctions where a robot selects between alternative routes.

- From the Mission Editor screen select action “Junction”
- Select Exit Direction (e.g. 06:00).
- Select the waypoint number for the Junction (the number on the chili-tag).
- Give the action a name e.g. “Junction 1”
- Click “Save”

6.3. **Tag Based Inspections**

1. Launch an autonomous mission from the Robot Control screen and stop the mission a few meters before the waypoint at which actions are to be performed (with the orange line visible from the floor cam).
2. Open the Mission Editor screen.
3. Click on “Create Mission” and give a name
4. Click on “Add new action” and press the play button. The robot will drive to the tag and stop between it and the 12:00 tags.
5. Rotate the robot (and elevate the camera) using the left/right icons on the mission editor until the sensor is pointing at the POI.
6. Select from the drop-down menus the desired action, sensor, waypoint number and give a recognisable name (e.g. equipment TAG number) to the action.
7. If “Full-size” is not selected, a region of interest ROI needs to be selected and a photo must be taken. For this, hover the mouse over the image and use the buttons that appear in the top-left corner.
8. Click on “Add Action”.
9. Repeat steps from step 5. for all actions that might be required at that waypoint.
10. Drive manually to the line and repeat steps from 4. for other waypoints.
11. Finally, click on the yellow “Disk” icon on the bottom-right to save the mission.

All inspection actions (e.g. Photo) can also be defined and executed at junction waypoints. For this you just need to add the actions that you require to the waypoint number as described previously and then add a “Junction” action to the same waypoint number.
Actions are listed by waypoint in the right-hand column of the mission editor. Planners can create missions by ticking the actions to be performed and saving the mission using a recognisable name.

When a mission is to be performed, select and launch the mission from the Robot Control screen (see Section Error! Reference source not found.). Actions will be recorded in the mission report.

6.4. Full 3D Navigation
This is only available for ExR-2 robots. The robot can drive without the need of physical guidance such as a line. Using its 3D sensors, the robot can extract geometrical information of the surrounding environment. The robot can be used to record this environment so that it can learn how to reach points of interest.

To teach a mission, the following steps need to be taken:

1. Open the Mission Editor which you can find by clicking on the burger menu on the top-left corner
2. Press the green button on your gamepad to enable motors
3. Undock and drive back at least 1m away from the docking station (see image below)
4. Turn in the direction you want to drive
5. Click on yellow button "Create Mission"

6. Give a unique name and click "Create"

7. Add a new route by clicking on the grey button "Add new route"
8. Give a unique name and click the black circle icon to start recording

9. The button will turn red indicating that recording is in progress

10. Start navigating through the environment until you reach your first waypoint.

11. You have three options: photo, video or waypoint.

12. For photos and videos, you may need to rotate the inspection module panning as described in Section 5.2. Once the POI is in the Field of View (FoV), you can take a video, a full-size picture, or a framed picture as described in Section 5.2. Then give a name to the POI (possibly a tag number) and click on “Add action”.

13. For a waypoint, give a name to your waypoint and click the yellow button "Add action".


15. Repeat these steps until you’ve covered all of the POIs.

16. Drive back to the docking station and stop 1m before the docking station, see image.
17. Click on the red button to stop recording the mission

18. Accept the confirmation dialog

19. Your mission is now saved

20. Drive over the docking station to charge the robot and wait for the "Mission Active" box to get unticked

For the robot to repeat the taught mission:

1. Change to the “Driver Screen”
2. Select the mission from the “Robot Control” list
3. Click the “Play” icon.
7. **Operating Robots**

7.1. **Operative Training**

Experienced operatives will explain the safety items in the Robot Operating Instructions and Guide to new operatives and key site personnel. They’ll also show new operatives how to use the control station.

In particular they should emphasise the importance of careful driving:

- Impact damage to facilities, people and the robot can be avoided by careful driving.
- Always check the surroundings using all cameras before enabling the drive motors.
- When starting a mission and reversing away from the docking station, the driver should use ExR-1’s back camera or ExR-2’s inspection module panning to ensure there are no obstructions.
- Test the controls after leaving the docking station and before commencing a mission.
- Approach hazards such as ledges, sumps, ramps, overhead obstructions and the docking station with the speed set in “slow” mode. Allow for communications latency.
- Don’t spot turn on grass/mud/anti-slip gratings/gravel because this might cause a track to jam. (Spot turns are when you drive the robot left or right with no forwards or backwards motion).
- The robot isn’t designed to climb stairs or gradients above 30 degrees. It may topple over. It can however cross steps up to 20cm (ExR-1) and up to 10cm (ExR-2). Approach them perpendicularly.
- The downward facing camera can enable precise positioning.
- The warranty doesn’t cover impact damage.
- The robot must be returned to the docking station at the end of a mission and before the battery is fully discharged. If the battery charge reaches 0% the sensors may work but the robot won’t drive which will require a visit to the site and robot recovery to the docking station. This will also invalidate the battery warranty.
- To prevent over-heating, robots either monitor the average current being drawn from the battery pack or the temperature of the battery pack. If either is too high a warning will be displayed on the control station. The driver should stop the robot and wait 15 minutes for the batteries to cool before recommencing the mission. If the driver does not act, or the current is too high, the drive motors will be isolated for 15 minutes. If this happens the robot should be returned to the docking station and ExRobotics consulted before another mission is launched.
- The robot is designed to prevent unsafe driving so in some situations it will auto-immobilise itself e.g. when voltage is applied to the power socket or when the keep awake box has not been checked.

New operatives should not drive the robot alone until they’ve demonstrated they understand these items and that they can safely navigate the robot around typical routes.
7.2. Authorisation and Authentication
Customers will appoint a Fleet Manager(s) that controls access to robots. He/she will allocate the following roles to individuals:

- Drivers control robots.
- Viewers access the data streams from robots.

Fleet Managers will control access with the “User Management” screen (see below) which is accessed from the User Menu (see Section 5.1).

When a new user is registered they will receive an E-Mail that will prompt them to change their password before full access is granted. It’s then possible to connect to robots by visiting this address using Google Chrome: https://login.energy-robotics.com.

7.3. Customer support
Every customer will have an ExRobotics account manager that will:

- Agree the specifications for each robot and the associated support package.
- Organise robot deliveries and deployment support until a customer has sufficient experience to be independent.
- Act as the first point of contact for customer queries.
- Organise any maintenance or repairs that may be required. Each incident will be given a unique “ticket number”.
- Agree the timing of any new software updates and upgrades.

The customer will have access to the account manager’s E-Mail address and mobile phone number. As a contingency ExRobotics can be contacted by E-Mail at sales@exrobotics.global

7.4. **Software releases**
ExRobotics can update and upgrade robot software remotely over the 4G public network. Before the software is updated the account manager will:

- Agree with the customer whether the release is applicable and any charges that will apply.
- Decide when the release can best be installed to minimise disruption to the customer.

7.5. **Routine Maintenance**
When the opportunity arises, the customer will perform simple routine maintenance:

- The camera and light windows will be cleaned with a damp, soft cloth. Sometimes the grease used to provide a weather-tight seal can be smeared across the window. This is best removed using windscreen washer fluid.
- The charger plates and 4G antenna will be cleaned with a damp/soft cloth.
- The area around the docking station will be cleared of debris and leaves.
- The robot will be inspected for visible damage. In particular, if the wire antennas are too bent they should be replaced. New wires must be sourced from ExRobotics to maintain the robot’s Ex status. They screw onto their bases.
- The tracks will be checked for visible wear and obstructions. They’ll be replaced if necessary.
- The gas detectors (if fitted) will be calibrated at the intervals specified by the supplier.
- Batteries should be regenerated every 3 months or when their performance deteriorates. Batteries can be regenerated by fully depleting them by driving the robot with its lights on until it stops and then fully recharging them with the quick charger. Repeat this another 2 times. For ExR-2 the batteries can be replaced as described below.

7.6. **Replacing tracks**
Track life will depend on the terrain and nature of the robot’s routes. However, they should last for at least 40km. Replacement tracks will be supplied by ExRobotics to maintain the robot’s anti-static performance. To replace a track:

- Remove the aluminium ring on the outside of the front sprocket that retains the track.
- Loosen the 6 screws that clamp each front sprocket assembly to the hull. 4 of these screws are accessed through holes in the sprocket and require an extra-long hexagonal key. Ensure they remain engaged in the nuts inside the hull. Release the track tensioning screw on the front of the robot by turning it anti-clockwise using a hexagonal key. Push the sprocket assemblies towards the rear of the robot.
- Slide the old track off the side of the sprockets and slide the new track on.
- Tighten the tensioning screw until the centre of the track deflects by 12mm when lightly pressed in its centre (see diagram below). Tighten the 6 screws clamping each sprocket assembly and reinstall the aluminium ring.

![Track tensioning screw]

![Press centre of track]

**Optimum deflection 12mm**

### 7.7. Calibrating gas detectors

The sensors should be calibrated in accordance with the instructions of the gas detector’s supplier. They’re available in the resources section of the ExRobotics’ website.

ExR-1 gas sensors can be accessed via the hatch between the tracks on the left hand side of robots which is secured with two hexagonal socket-head screws (see picture). ExR-2 gas sensors are accessed by removing the upper cladding.

### 7.8. Replacing ExR-2 batteries

ExR-2’s batteries can be replaced by removing the front hull cladding and the battery pack lid behind. When replacing the batteries make sure that:

- Only batteries supplied by ExRobotics are used. Any other batteries will invalidate the robot’s Ex certification.
- The foam strips around the inside of the battery enclosure remain secure.
- The thermal sensors between the batteries and their gap pads are not dislodged.
- The bolts connecting the battery leads to the terminals are torqued to 3.6 Nm with a calibrated torque wrench.
- Ty-raps are used to ensure the battery leads and other wires cannot be trapped between two metal parts.
- The bolts on the battery pack lid are re-torqued to 7 Nm with a calibrated torque wrench.

ExRobotics will provide remote support the first time a customer performs this task.
7.9. Changing ExR-2 SIM cards
ExR-2 SIM cards are located inside the communications module which is inside the hull beside the mast. To change SIM cards:

- Remove the top hull plate.
- Remove the front of the communications module’s front enclosure.
- Change the SIM.
- Make sure you do not damage the flameproof joint surfaces around the front enclosure and back enclosure. Also ensure that the O Ring is correctly seated.
- Re-torque the bolts securing the front to the back enclosures to 7 Nm with a calibrated torque wrench.

ExRobotics will provide remote support the first time a customer performs this task.

7.10. Security
Robots are fitted with security features:

- People cannot connect to the robot unless they have the necessary authentication.
- The 4G network provider will be able to locate the robot when it’s powered on.
8. **Questions and Answers**

8.1. **What is my robot’s status**
ExR-2 robots include status indicators that show the robot’s status. These are located in the communications module and can be seen through the slots in the hull opposite the mast. Common configurations are as follows:

![Robot Asleep Diagram](image)

![Robot Awake Diagram](image)

If you’re experiencing problems with the robot and the status indicators are different from those above please inform your Account Manager.

8.2. **Why can’t I connect to a robot?**
ExRobotics check whether each robot connects to the server before it’s deployed. Therefore connection issues are often because the control station hasn’t connected to the server. The most common reason is that a customer firewall has blocked access.

The connection to the robot consists of two types, one for the control commands via HTTPS over TCP and one for very low-latency video signals via WebRTC over UDP. To be able to control the robot from a computer within corporate networks both connection types need to be allowed by both the corporate and the computer firewall. Your account manager can advise you of the Protocols, Ports and IP addresses.

8.3. **Why has my robot stopped working in cold weather?**
If the temperature of the main chip in the electronics box drops below 0°C the robot will shut down. There is protective software to prevent this happening but if necessary relocate the robot somewhere warmer. When its temperature is above 0°C switch the robot off and on again and it should come back to life.
8.4. **Why doesn’t my controller work?**
This is usually because your control station thinks it’s connected to more than one controller.
(devices like USB mice or keyboards with extra multimedia buttons can be interpreted as “controllers”). You can check the situation by going to [https://html5gamepad.com/](https://html5gamepad.com/) Disconnect any additional devices that are identified as controllers. The website also enables you to test your main controller.

8.5. **How much data will the robot transfer over its wireless connection?**
When the robot is “asleep” it transfers around 1GB of data per month. During a mission most of the data is consumed by the video streams. This typically amounts to 1 GB per hour.

Untick the “keep awake” box when the robot isn’t being used. This will shut down the cameras and gas detectors that use most of the 4G bandwidth. Re-ticking the box will wake the robot.

8.6. **How long will the robot’s batteries last?**
In operation this depends on usage and the age of the batteries. However, the life of a full battery pack will usually lie between:

- 90 minutes (ExR-1) or 150 minutes (ExR-2) if a robot’s driven continuously.
- 7 hours if it’s static with its sensors on (but no lights).

Usually, a robot should be stored on its docking station when not in use so it will be charged via its induction charger. However sometimes this isn’t possible (e.g. during transport). In this case a full ExR-1 battery pack will last:

- 2 years if the robot is switched off using its black on/off switch.
- 2 days if it’s static and asleep (i.e. the “keep awake” option on the control station is not checked).

Never leave the quick charger connected to the robot but not to a power supply. This will reduce a full battery’s life to 6 weeks even if the robot is switched off.

Although this should be avoided, ExR-2 robots will automatically shut-down if the battery voltage is too low. This protects the batteries which should be undamaged unless the robot isn’t connected to a charger within 2 weeks.

Sometimes the 3 batteries in a robot’s battery pack become “unbalanced” and battery life declines significantly. They may be re-generated as described in Section 7.5.

8.7. **Why am I surprised by the battery level reported by the cloud software?**
ExR-1 robots estimate their battery charge percentage using the measured voltage. This is inaccurate and non-linear so you may experience unexpected changes in capacity.

ExR-2 robots have a more sophisticated chip that calculates battery charge percentage based on power used. In most situations this will be accurate. However, if the robot is switched on after the quick charger has been plugged into the robot the battery percentage will always be reported as 0%.
8.8. **How do I refresh my control screen?**
If your control screen doesn’t seem to be displaying the correct information try pressing “F5” on your computer’s keypad.

8.9. **Why does my robot “drift” to the left or right**
Track deformation can cause a robot to drift to the left or right although you think you’re driving straight. You’ll need to correct its course. Autonomous navigation automatically makes these corrections.

8.10. **Why have I experienced unexpected behaviour while operating a robot?**
If this occurs:
- Press F12 immediately after the event occurs.
- Click on the "Console" tab that appears.
- Right click somewhere in the console window and select "Save as..." from the Context menu.
- Use the Feedback option on the Driver’s screen to send the file and an explanation to our engineers.

8.11. **How do I wash a contaminated robot?**
You can use a water jet/spray to wash the robot if for example it may have been exposed to hazardous chemicals. However, do not point the jet directly at:
- Camera and light module windows.
- The microphone opening in the robot’s front panel.
- The on/off switch or emergency stop.
- Any exposed hexagonal plugs including those on the top of the drive module.
- The vent on the front of the Crowcon gas detector.
- The exposed joints and window on the IR leak detection module.
- The battery pack inside the ExR-2 robot’s hull. After washing, open the battery pack and dry its inside if necessary.
9. **Robot and Docking Station Specifications**

### 9.1. **Worksite and Climate: ExR-1 Robot**

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temp. Range</td>
<td>-20°C to +50°C</td>
</tr>
<tr>
<td>Equip. Protection Level</td>
<td>Gb (Zone 1)</td>
</tr>
<tr>
<td>Explosion Group</td>
<td>IIB (ethylene)</td>
</tr>
<tr>
<td>Temperature Class</td>
<td>T4 (maximum surface temperature 135°C)</td>
</tr>
<tr>
<td>Ingress Protection</td>
<td>Equivalent to IP54 (dust protected, splashing water resistant).</td>
</tr>
<tr>
<td>Ground Conditions</td>
<td>Mixed hard surfaces, slabs, pebbles, metal gratings &amp; grass</td>
</tr>
<tr>
<td>Height Change</td>
<td>Essentially level site with ledges ≤ 20 cm high and slopes ≤ 35° steep</td>
</tr>
<tr>
<td>Corrosion &amp; Erosion</td>
<td>Maritime conditions</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Rain, light snow and standing water</td>
</tr>
<tr>
<td>Light conditions</td>
<td>Day and night</td>
</tr>
</tbody>
</table>

### 9.2. **Worksite and Climate: ExR-2 Robot & Docking Station**

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temp. Range</td>
<td>-40°C to +55°C depending on options. -40°C to +50°C if fitted with Pepperl + Fuchs switches</td>
</tr>
<tr>
<td>Equip. Protection Level</td>
<td>Gb (Zone 1)</td>
</tr>
<tr>
<td>Explosion Group</td>
<td>IIB (ethylene)</td>
</tr>
<tr>
<td>Temperature Class</td>
<td>T4 (maximum surface temperature 135°C)</td>
</tr>
<tr>
<td>Ingress Protection</td>
<td>Battery pack is IP44 (protected against most wires and splashes). Other components are equivalent to IP57.</td>
</tr>
<tr>
<td>Ground Conditions</td>
<td>Mixed hard surfaces, slabs, pebbles, metal gratings &amp; grass</td>
</tr>
<tr>
<td>Height Change</td>
<td>Essentially level site with ledges ≤ 10 cm high and slopes ≤ 35° steep</td>
</tr>
<tr>
<td>Corrosion &amp; Erosion</td>
<td>Maritime conditions</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Rain, light snow and standing water</td>
</tr>
<tr>
<td>Light conditions</td>
<td>Day and night</td>
</tr>
</tbody>
</table>
## 9.3. Standard ExR-1 Specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. width</td>
<td>690 mm</td>
</tr>
<tr>
<td>Max. length</td>
<td>950 mm</td>
</tr>
<tr>
<td>Max. height</td>
<td>560mm, including antennas</td>
</tr>
<tr>
<td>Min. ground clearance</td>
<td>40 mm</td>
</tr>
<tr>
<td>Robot Weight</td>
<td>Less than 100kg</td>
</tr>
<tr>
<td>Speed</td>
<td>Proportionally controllable speed up to 2 km/hour. Driver can switch between fast and slow speed modes</td>
</tr>
<tr>
<td>Turning Circle</td>
<td>Spot steering around robot’s central axis</td>
</tr>
<tr>
<td>Range</td>
<td>Up to 2 km depending on accessory usage</td>
</tr>
<tr>
<td>Mission Duration</td>
<td>2 to 8 hours depending on the proportion of driving</td>
</tr>
<tr>
<td>Switches</td>
<td>Power on/off and emergency stop mushroom</td>
</tr>
<tr>
<td>Recovery</td>
<td>Robot can be controlled using smartphone or pad, lifted by 4 operators or lifted using appropriate forklift, slings or trolley</td>
</tr>
<tr>
<td>Markings</td>
<td>Each Robot has stickers affixed with: Regulatory Ex-certificate notation; Hazard warnings; Privacy caution</td>
</tr>
<tr>
<td>HP induction charger RX</td>
<td>60W non-ex induction charging. Robot docks, charges &amp; undocks autonomously. Empty batteries are fully recharged in 12 hours.</td>
</tr>
<tr>
<td>Non-Ex Docking station</td>
<td>Docking station with integrated 60W induction charger</td>
</tr>
<tr>
<td>Camera module</td>
<td>Forward and backwards/upwards facing 18 MP digital video cameras. Forwards/downwards facing 1.2 MP digital video camera. All with live video transmission to web-browser interface. Zoomed, still images and video recordings can be taken and downloaded from the web-browser interface</td>
</tr>
<tr>
<td>Light module</td>
<td>3 x 690 Lm LED lights illuminate the fields of view of the 3 cameras</td>
</tr>
<tr>
<td>Microphone</td>
<td>Mono microphone transmits sound to the web-browser interface</td>
</tr>
<tr>
<td>Crowcon methane gas module</td>
<td>Standard for Emissions Detector with Gas Mapping – see specifications in Sections 6.6 &amp; 6.8</td>
</tr>
<tr>
<td>Remote control</td>
<td>Remote control via Energy Robotics cloud with audio &amp; video live streaming (SD quality) &amp; manual capture of audio, photos &amp; videos (HD quality). Customer to provide laptops with Google Chrome &amp; Xbox gamepads connected</td>
</tr>
<tr>
<td>Online mission report</td>
<td>Mission data accessible via a dedicated cloud-interface. Data stored for 30 days.</td>
</tr>
<tr>
<td>Multi-user access &amp; rights management</td>
<td>Cloud-based interface that allows customers to control access to the robots in their fleet. User types include “Driver”, “Viewer” &amp; “Fleet Manager”.</td>
</tr>
<tr>
<td>Autonomous line following navigation</td>
<td>Standard for Emissions Detector – see specifications in Sections 6.8</td>
</tr>
<tr>
<td>4G LTE communications</td>
<td>Public, 4G LTE, high security VPN, connection to the Energy Robotics cloud. Customer controls access using a multi-user rights management interface</td>
</tr>
<tr>
<td>Product updates</td>
<td>Improvements to existing hardware and software are included for 3 years.</td>
</tr>
<tr>
<td>Packaging</td>
<td>Robot (and docking station) are supplied in a re-usable flight case. €800 will be deducted from next order if flight case is returned undamaged to ExRobotics.</td>
</tr>
<tr>
<td>Service</td>
<td>User replaceable tracks and Honeywell gas detection “noses”</td>
</tr>
</tbody>
</table>
## 9.4. Standard ExR-2 Specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. width</td>
<td>660 mm</td>
</tr>
<tr>
<td>Max. length</td>
<td>960 mm</td>
</tr>
<tr>
<td>Max. height</td>
<td>670 mm, flexible antennas are 50mm above this level</td>
</tr>
<tr>
<td>Min. ground clearance</td>
<td>60 mm</td>
</tr>
<tr>
<td>Robot Weight</td>
<td>100 - 120 kg depending on options</td>
</tr>
<tr>
<td>Speed</td>
<td>Proportionally controllable speed up to 2 km/hour. Driver can switch between fast and slow speed modes</td>
</tr>
<tr>
<td>Turning Circle</td>
<td>Spot steering around robot’s central axis</td>
</tr>
<tr>
<td>Range</td>
<td>Up to 2 km depending on accessory usage</td>
</tr>
<tr>
<td>Mission Duration</td>
<td>2 to 8 hours depending on the proportion of driving</td>
</tr>
<tr>
<td>Switches</td>
<td>Power on/off and emergency stop mushroom</td>
</tr>
<tr>
<td>Recovery</td>
<td>Robot can be controlled using smartphone or pad, lifted by 4 operators or lifted using appropriate forklift, slings or trolley</td>
</tr>
<tr>
<td>Markings</td>
<td>Each Robot has stickers affixed with: Regulatory Ex-certificate notation; Hazard warnings; Privacy caution</td>
</tr>
<tr>
<td>Power socket</td>
<td>Supplied with non-Ex charger (100-230 VAC 50-60Hz supply) that will fully recharge robot in 3 hrs</td>
</tr>
<tr>
<td>Inspection module panning optical</td>
<td>Forward facing 18 MP digital video camera/690 Lm LED that pans ±180°. Live video transmission to web-browser interface. Zoomed, still images and video recordings can be taken and downloaded from the web-browser interface</td>
</tr>
<tr>
<td>Drive camera module</td>
<td>Forwards/downwards facing 1.2 MP digital video camera/ 690 Lm LED with the same functionality as the inspection module panning optical.</td>
</tr>
<tr>
<td>Microphone</td>
<td>Mono microphone transmits sound to the web-browser interface</td>
</tr>
<tr>
<td>Remote control</td>
<td>Remote control via Energy Robotics cloud with audio &amp; video live streaming (SD quality) &amp; manual capture of audio, photos &amp; videos (HD quality). Customer to provide laptops with Google Chrome &amp; Xbox gamepads connected</td>
</tr>
<tr>
<td>Online mission report</td>
<td>Mission data accessible via a dedicated cloud-interface. Data stored for 30 days.</td>
</tr>
<tr>
<td>Multi-user access &amp; rights management</td>
<td>Cloud-based interface that allows customers to control access to the robots in their fleet. User types include “Driver”, “Viewer” &amp; “Fleet Manager”.</td>
</tr>
<tr>
<td>Autonomous route repetition</td>
<td>Robot uses its LiDAR to “memorise” a route, waypoints, points of interest, &amp; tasks. LiDAR also enables robot to avoid obstacles &amp; drop-offs</td>
</tr>
<tr>
<td>Product updates</td>
<td>Improvements to existing hardware and software are included for the duration of the RaaS agreement.</td>
</tr>
<tr>
<td>Packaging</td>
<td>Robot (and docking station) are supplied in a re-usable flight case. €800 will be deducted from next order if flight case is returned undamaged to ExRobotics.</td>
</tr>
<tr>
<td>Service</td>
<td>User replaceable batteries, SIMs, tracks and gas modules.</td>
</tr>
</tbody>
</table>