ExR-1 Robot

Operating Guide

LET'S DEPLOY SOME ROBOTS TOGETHER!

EX ROBOTICS

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Document Change Log:

Version #	Date of re-issue	Changes Made	Page	Author of Change
1	2019-01-22	First draft		Ian Peerless
2	2019-03-25	Updated software description & completed Sections 7 and 8	Many	Ian Peerless
3	2019-03-26	Incorporated comments from Iwan & Dorian	Many	Ian Peerless
4	2019-04-09	Included customer comments	Many	Ian Peerless
5	2019-05-03	Updated gamepad information, track replacement, and chili-tag positioning. Minor points of clarification based on deployments.	5, 10 & 12	Ian Peerless
6	2019-05-31	Renamed document & added mission planning & reporting	5	Ian Peerless
7	2019-07-16	Added fleet status screen, gas alarm adjustments, gamepad blue button, autonomy junctions, mission reports with videos/recordings/snapshots, questions & answers.	6, 7, 9, 14, 16	Ian Peerless
8	2019-08-31	Revised use of the "Keep awake" button Alarm if autonomous mission is interrupted Launching an autonomous mission explained "Spot turn" limitations expanded Corrected docking station electrical connections Simpler chili-tags at waypoints explained Why doesn't my controller work? How do I wash a contaminated robot?	7 9 10 11 12 14 18 18	Ian Peerless
9	2019-10-16	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	7 7,11 9,10 10,11 11 20	Ian Peerless Alberto Romay
10	2019-12-02	Updated how to launch a mission and explained "Site Config" & "Feedback" options. Added cold weather behaviour to Q&A	8,11 20	Ian Peerless Alberto Romay
11	2020-03-31	Removed "hibernation" feature & 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 & battery life. Robot specifications updated.	5,6,8 12 13 14 19 21 - 23	Ian Peerless

Contents

1. Introduction

This document is one of two that will help operators to use their ExR-1 robots safely and effectively. The documents are the "ExR-1 Robot Operating Instructions" and the "ExR-1 Robot Operating Guide". The former focuses on the safe operation of the robot especially with respect to its use in potentially explosive gas environments. The latter provides additional information about the robot and its use. If there's a conflict between the documents, the instructions will always prevail.

This robot 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.
- Recommends how robot operatives should be trained.
- Presents the steps required when deploying robots.
- Provides advice for operating robots.

The guide will be updated and sent to robot fleet managers 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 drawing below. Robot specifications are included in Section 10.
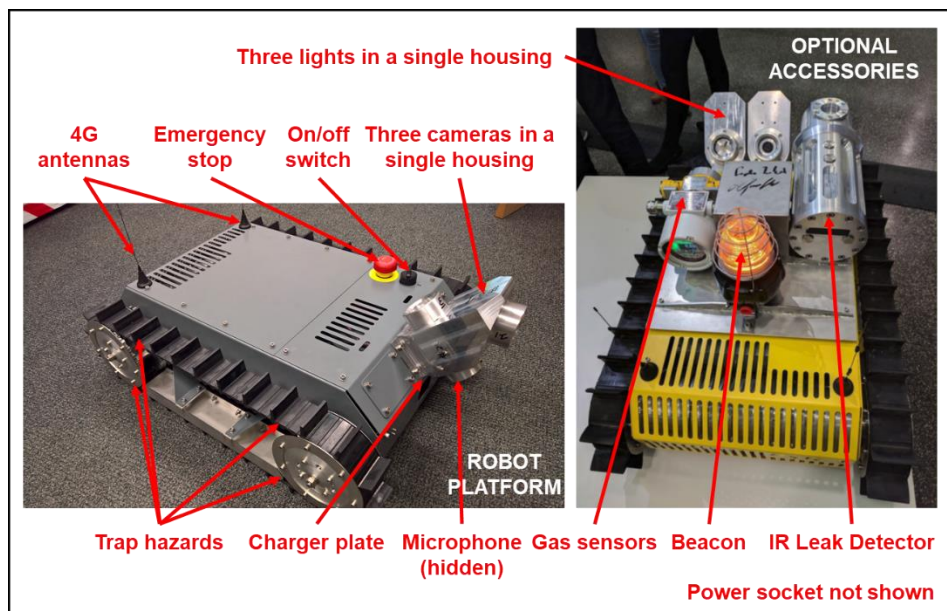
The only controls mounted on each robot are the red emergency stop switch and the black on/off switch. When the red emergency stop switch is pressed downwards it immobilises the drive motors. The robot can't be driven until the switch is released by rotating it and letting it spring upwards. When the 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.

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Robots may be supplied with optional accessories from the following list:

- One or two light modules with three LEDs pointing in the same directions as the cameras.
- A Crowcon IR MAX or a Simtronics GD10-P00 sensor that detects hydrocarbon gases.
- A Falco 1.1 sensor that detects VOCs (volatile organic compounds – see Wikipedia).
- A Honeywell 3000 Mk II sensor that detects toxic gases.
- An Infrared Leak Detection Module which is built around a FLIR G300a camera.
- A hazard warning beacon. If fitted, the beacon will be permanently illuminated when the robot is away from the docking station.
- A power socket. This is supplied with a quick charger that can be plugged into the socket.
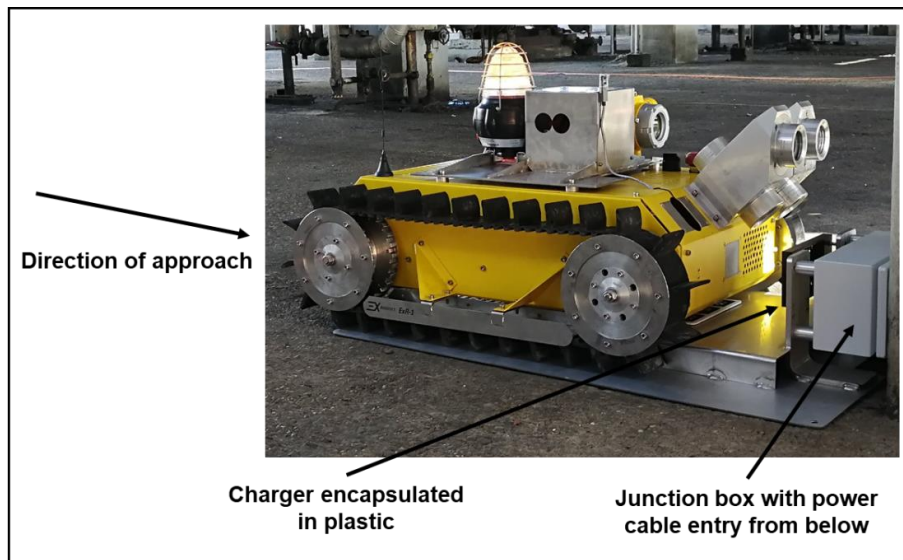
3.   Control Stations

Robots can be controlled using PCs or smart phones (Apple or Samsung phones are recommended). This guide describes the PC configuration which requires:

- A laptop with a screen resolution of at least 1920 x 1080 and Google Chrome.
- A gamepad for driving the robot (Xbox is recommended).
- A mouse or trackpad for operating the cursor on the PC's screen.

4.   Docking Stations

The robot automatically charges itself. At the end of a 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 charging plates using the plastic strips under its hull.

Once the front of the robot's hull is pressing against the front of the docking station the operative should stop driving forwards, activate the emergency stop switch on the control screen and deactivate the "Keep Awake" setting. The robot will automatically enter "In Dock" and "Charger Connected" status, and charge itself.

When the robot is charging on the docking station it "sleeps" to conserve power and to reduce 4G network charges. It takes 2 days to charge a fully-depleted battery. The battery level is reported every 18 minutes.

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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 can disrupt charging. If this happens pull the robot 30cm back and switch it off and on again.

When a driver checks the "Keep Awake" setting the robot video streams will typically appear within 1 minute. The robot is then ready to use although it's best to allow gas sensors 30 minutes to warm up before starting a mission.

When starting a mission and reversing away from the docking station, the driver should carefully examine the back camera or the mirror on the front of the docking station (if fitted) to ensure there are no obstructions.
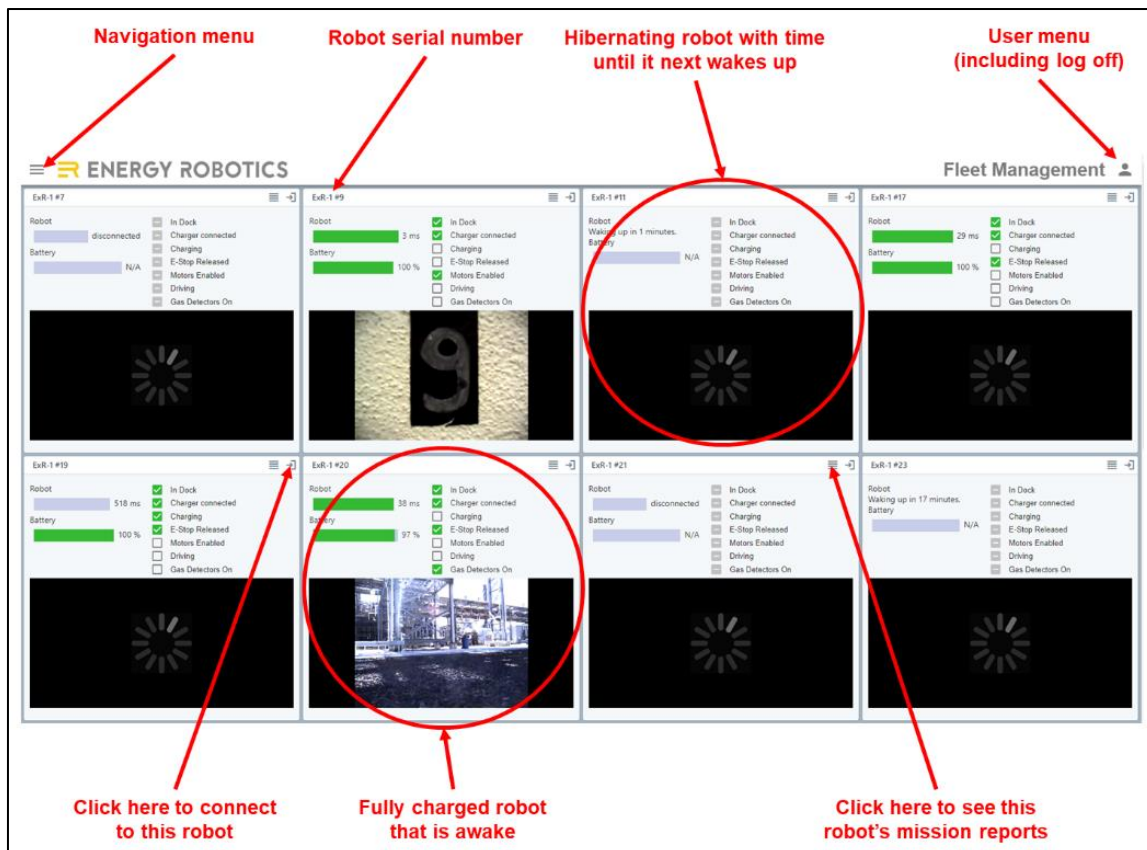
A power socket (when fitted) enables the robot to be charged within 3 hours. This requires the robot to be manually plugged into a power supply using a quick-charger that can be ordered with the robot. The quick-charger's lead is typically 3 meters long. If the robot is docked you should first switch 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. Five types of screens are available as described below.

5.1. Fleet Management and 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.

The Fleet Status screen (see below) is accessed by clicking on the "navigation menu" icon to the top left of the fleet management screen.

Red or Yellow circle indicates there's an issue with the robot. Clicking on the circle reveals the type of issue.

List of robots in the fleet

Click here to connect to the robot or to see its mission report

5.2. Robot Control

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

- The major functions are summarised in the picture below.
- All three video streams are displayed on the control station. Usually the highest resolution, forward-facing inspection video will be in the largest window. 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 "Take Photo" 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.
- Snapshots are displayed in the "Event 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 not recorded if the robot status is "In Dock"). 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 again the "Video" icon.
- 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 icons at the top of the "Event 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 starts playing automatically and can be paused and re-started 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. Only launch a mission when an orange line is visible in the Floor Cam window (so the robot can orientate itself) or when the robot is in a docking station.
- 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.
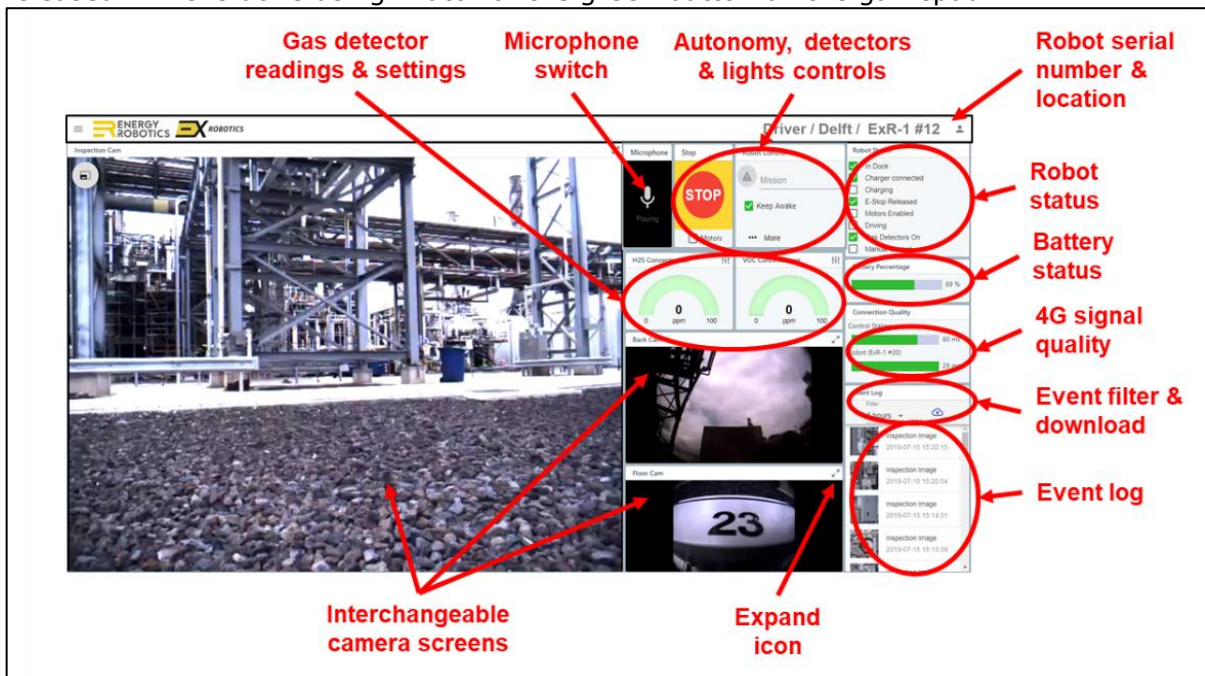
- The gas detectors and lights controls are accessed by clicking on "More".
- The top right of the screen shows the robot's status. A tick adjacent to each item indicates:
  - In Dock – robot is on the docking station.
  - Charger connected – the robot's coil is connected to that in the docking station.
  - Charging – current is flowing into the battery pack.
  - 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.
- 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.
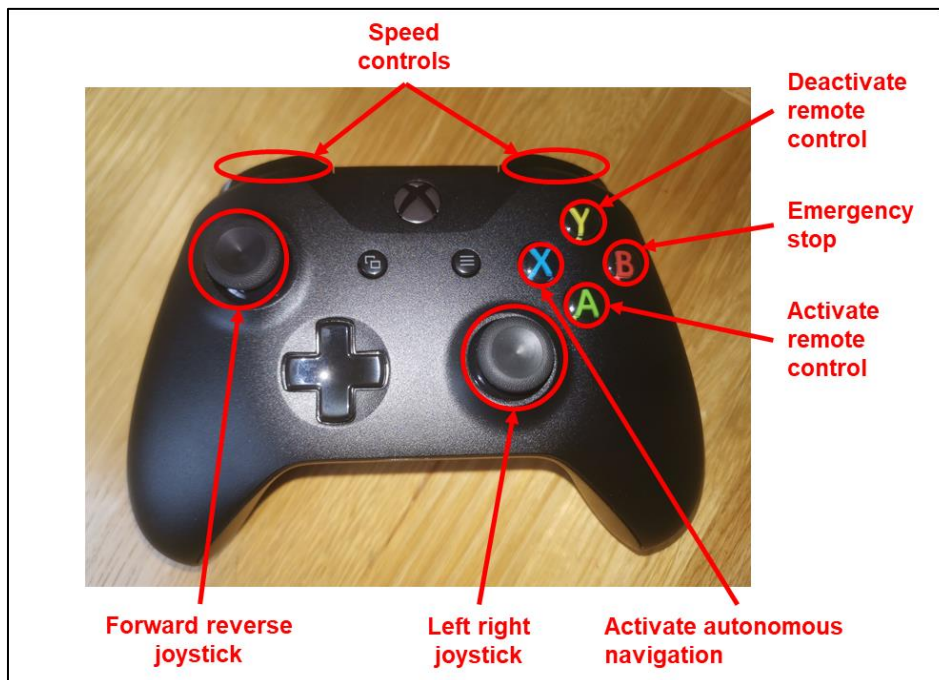
5.3. Mission Editor

This screen enables planners to construct and edit autonomous missions.

A robot mission is typically a circuit following an orange line 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. Waypoints are defined by an array of chili-tags (see Section 7.5).
- There can be multiple waypoints on a mission.

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A planner will:

1. 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"
2. 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).
3. Open the Mission Editor screen.
4. Press the play button. The robot will drive to the POI tag and then stop between the POI and 12:00 tags.
5. Enter the waypoint number (the number on the chili-tag).
6. Rotate the robot (and elevate the camera) using the left/right icons on the mission editor until the sensor is pointing at the POI.
7. Tick the action to be performed.
8. Frame any image using drag and drop and then take the picture.
9. Click "save" and give the action a recognisable name (e.g. equipment TAG number).
10. Repeat these steps for all actions that might be required at that waypoint.
11. Use the left/right icons to point the robot at the 12:00 tag.
12. Open the Robot Control screen and relaunch the autonomous mission.

Create actions for a Point of Interest

Create and select missions

Actions available for each waypoint

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Waypoints can also be used at junctions where a robot can select between alternative routes or can return the way it's come.

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

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 5.2). Actions will be recorded in the mission report.

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 5.2 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.
- Return to the default view by double clicking.

6. Operative Training

Experienced operatives will explain the safety items in the ExR-1 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 three cameras before enabling the drive motors.
- 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 and don't spot turn in high speed mode. These actions might cause a track to "freeze". (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 high. 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 robot will shut-down 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 the robot monitors the average current being drawn from the battery. If it's 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 (see Section 8.1).
- 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. Deployment

7.1. Preparations
The robot order will specify:

- The operating conditions for the robot (temperature range, equipment protection level, explosion group, temperature class, and ingress protection).
- The accessories that are to be installed on the robot.
- The type of sensor that is to be installed in the Honeywell gas detector (if fitted).
- Whether the customer or ExRobotics will supply the 4G SIM card for the robot. The SIM needs to be delivered to ExRobotics' Delft facility before the robot is assembled.

Before a robot is delivered, ExRobotics will verify that the robot is suitable for the deployment location and will agree a position for the docking station with the customer. The customer will also complete any MOC (management of change) and/or risk assessments they might require.
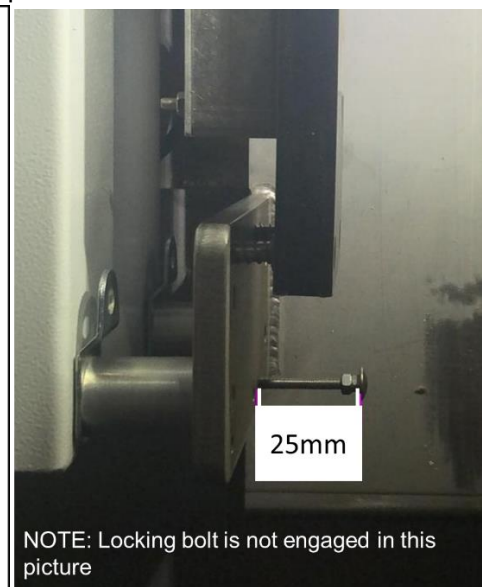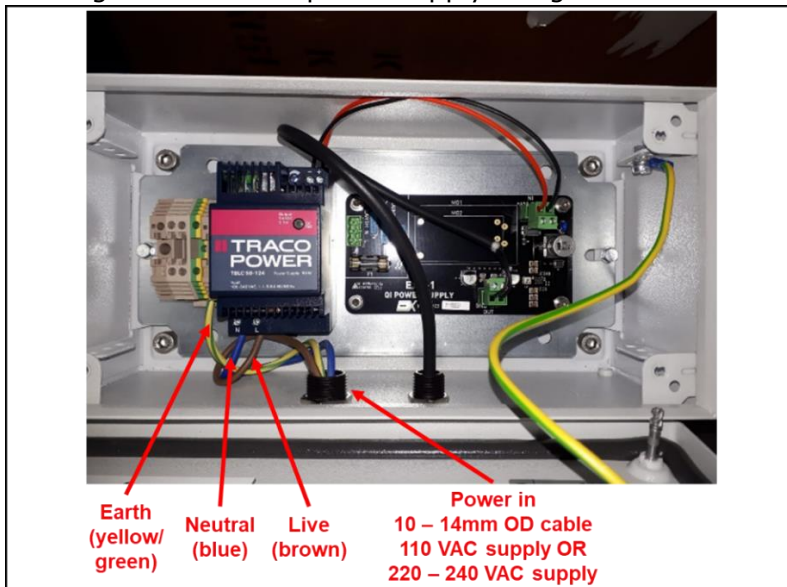
Key issues when verifying a robot is suitable for a location are:

- The robot will not be exposed to conditions out-with the validity of its Ex certificates.
- There are navigable routes without excessive steps, narrow gaps, and low overhangs.
- The routes enable the robot to perform the necessary inspections.
- There's a good 4G signal wherever the robot must be remotely controlled. This will be tested with the type of SIM card that's to be installed in the robot. Ideally the total latency between the control station and robot should be less than 250 ms and the upload bandwidth should be at least 5 MBit/s.

The docking station is 100.5cm long, 70.2cm wide and 20cm high (55cm high with a robot installed). It will:

- Have access to a 110/120V or 220V/240V AC power supply.
- Be located in a safe zone – it isn't certified for potentially explosive environments.
- Be on a hard surface (not gravel or grass) that's essentially horizontal.
- Allow the robot to approach the docking station in a straight line for at least 3 meters (this helps with alignment).
- Have the strongest practical 4G signal – it's especially important that the robot has a strong signal before and after a mission.
- Be sheltered from climactic extremes (e.g. direct sunlight in the tropics, prevailing winds and snow in arctic environments).

The customer will secure the docking station to the ground using the holes in each corner of the docking station. Unless a specific power lead has been requested, they will also connect the docking station to the power supply using the connections pictured below.

Earth (yellow/green)   Neutral (blue)   Live (brown)   Power in 10 – 14mm OD cable 110 VAC supply OR 220 – 240 VAC supply

25mm

NOTE: Locking bolt is not engaged in this picture

The docking station includes two dome headed bolts that press against the front of the robot's hull to ensure it's docked in the correct position. They're usually withdrawn during transport. If so, they should be turned anti-clockwise until the distance from the rear of the dome to the front of the charger plate is 25mm. Then lock each bolt using the locking nut.

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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 and mission reports 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 set 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. Robot Delivery

Robots should be charged using a docking station (or the quick charger if fitted) immediately after delivery because the battery will slowly lose power. Then as soon as practical the customer should:

1. Verify that the robot connects to the control station(s).
2. Test the emergency stop.
3. Check the tension in the tracks (see Section 8.4).
4. Check that the robot stops when the 4G signal is lost.
5. Calibrate the gas sensors (if fitted).
6. Ensure that the robot is fully operational and can be accessed from the relevant control station(s).

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7. Dock the robot and check it charges.
8. Walk around the robot's routes and check for obstructions or items that might be damaged.
9. Test drive the robot around its routes to check the 4G connection.
10. Ensure all robot users are familiar with the robot operating instructions and this manual.
11. Sign the delivery note and return it to ExRobotics.

The first time a customer deploys a robot an ExRobotics representative will be on-site to assist with this process.

7.4. Setting up autonomous routes

If a robot is supplied with the autonomy option it will follow an orange line without any human intervention.

For demonstration purposes the line will typically be of orange tape. Although the line is self-adhesive it's best to use glue for additional durability. To increase the tape's serviceable life lay it in dry, warm conditions and try to position it so it won't be abraded by the robot's tracks or other vehicles.

For longer, permanent routes it's best to use RAL2009 (orange) paint. ExRobotics can provide advice on paint types and line-painting machines.

"Chili-tags" can be positioned at up to 80 waypoints where the robot needs to perform pre-defined operations – e.g. docking, junctions, aiming cameras, and recording sensor readings. Section 7.5 specifies how to set up waypoints.

When setting up an autonomous route avoid sharp 90º bends because the robot will lose sight of the line. Instead use curves or multiple, smaller bends (e.g. 4 x 22.5º). For the same reason, when crossing a step approach it in a perpendicular direction otherwise the robot may twist when mounting the step and lose sight of the line.

In congested areas the orange line needs to be carefully positioned. Straighter lines are best because a robot will stray around the line when turning corners.

7.5. Setting up waypoints

The location and tasks to be performed at a waypoint are defined by chili-tags. A typical tag is illustrated below:
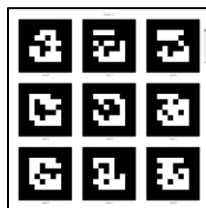
Each tag carries a label at its top that defines its task and an arrow to its right that defines its orientation. There are three categories of tag:
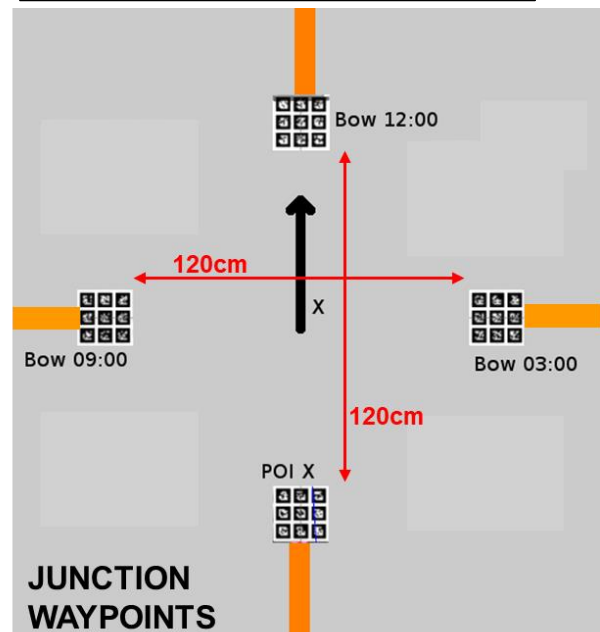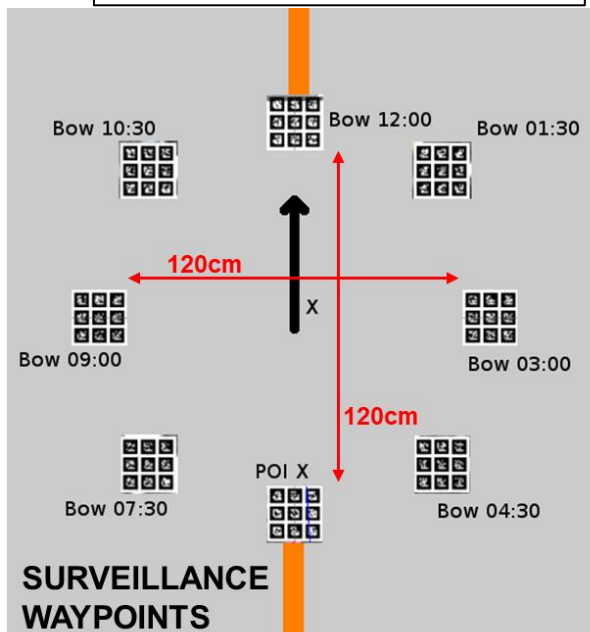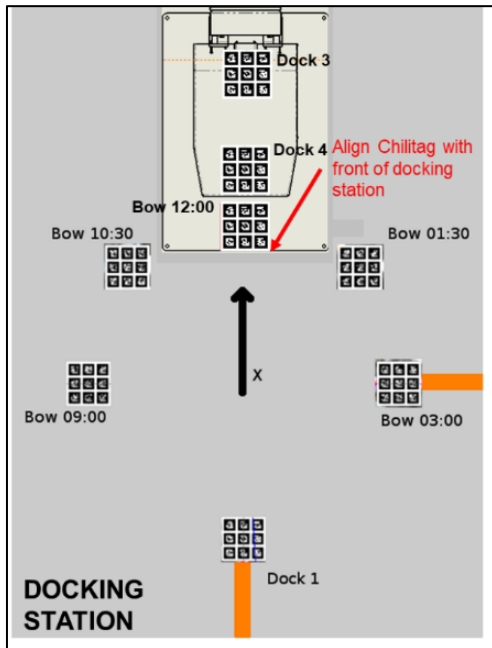
- Dock tags are used at the docking station (Dock 1, Dock 3, Dock 4).
- POI tags are used to identify a waypoint. The tasks to be performed at that waypoint are programmed using the Mission Editor. (POI 1, POI 2, POI 3, etc.)
- Bow tags supplement the robot's rotational control (they indicate points around a notional "clockface" at each waypoint). (Bow 01:30, Bow 03:00, Bow 04:30 etc.)

The positioning of the chili-tags is illustrated below. The arrow on each tag should face in the same direction as that in the diagram:

- The Dock and Bow 12:00 tags are always required at docking stations.
- If a robot is to undock to the right, the Bow 01:30 and Bow 03:00 tags are required.

- If a robot is to undock to the left, the Bow 09:00 and 10:30 tags are required.
- At other waypoints the POI and Bow 12:00 tags are always required. The other Bow tags are optional. If necessary, they can be used to increase the accuracy of a turn because the robot will adjust its "internal compass" if a tag is in sight. The chili-tags are supplied with a template so that they can be glued accurately in position as pictured below.

8.   Operations

8.1.   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:

- Phone - +31 88 003 9300
- E-Mail at sales@exrobotics.global

8.2.   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.

8.3.   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 their supplier.

The last three items are the only interventions that can be performed by the customer without compromising the robot's ATEX and IECEx certification. Any other damage will be reported to ExRobotics.

8.4.   Replacing tracks
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
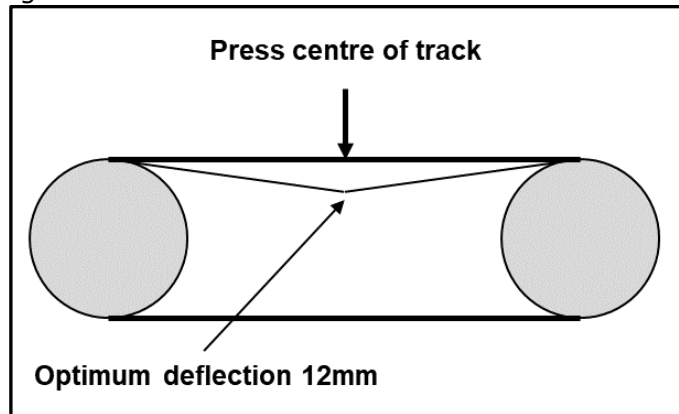
8.5. Calibrating gas detectors

The gas sensors can be accessed via the hatch between the tracks on the left hand side of the robot which is secured with two hexagonal socket-head screws (see picture below). 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.

8.6. Security

The robot is 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.

9. Questions and Answers

9.1. 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.

9.2. Why has my robot stopped working in cold weather?

If the temperature in the electronics box drops below 0ºC 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 0ºC switch the robot off and on again and it should come back to life.

9.3. 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/ Disconnect any additional devices that are identified as controllers. The website also enables you to test your main controller.

9.4. 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.

9.5. 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 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 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.

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9.6. 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.

9.7. 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.

9.8. Does the induction charger generate harmful magnetic fields?

If the robot isn't in the dock there will be no magnetic field because the transmitting coil isn't switched on unless it detects a receiving coil. The magnetic field away from the charger will be very low when the robot is being charged because the induction field is "shaped" for maximum efficiency and losses are minimal. For more information click on this link:

https://www.wirelesspowerconsortium.com/blog/qi-wireless-charging-and-cardiovascular-electronic-devices

10. ExR-1 Robot Specifications

10.1. Worksite and Climate

Description	Specification
Operating Temp. Range	-20C to +50C
Equip. Protection Level	Gb (Zone 1)
Explosion Group	IIB (ethylene)
Temperature Class	T4 (maximum surface temperature 135C)
Ingress Protection	IP54 (dust protected, splashing water resistant)
Ground Conditions	Mixed hard surfaces, slabs, pebbles, metal gratings & grass.
Height Change	Essentially level site with ledges up to 20 cm high and slopes up to 30 degrees inclination.
Corrosion & Erosion	Maritime conditions
Precipitation	All except deep snow.
Light conditions	Day (and night if optional lights are fitted)

10.2. Mobility Platform & Chargers

Description	Specification
Maximum Robot Width	690 mm
Maximum Robot Length	950 mm
Maximum Robot Height	560 mm including antennas
Minimum Robot Ground Clearance	40 mm
Robot Weight	Less than 100 kg.
Speed	Proportionally controllable speed up to 2.5 km/hour. Driver can switch between fast and slow speed modes.
Turning Circle	Spot steering around robot's central axis
Range	Up to 2 km depending on accessory usage.
Mission Duration	2 to 7 hours depending on the amount of driving
Switches	Power on/off and emergency stop mushroom
Recovery	Robot to be lifted onto transport by 4 operators or using appropriate lifting equipment.
Maintenance	Robot is provided with a 1 year warranty. If robot requires maintenance customer to ship it to and from the nearest ExRobotics maintenance facility. Extended warranties are available
Markings	Each Robot has stickers affixed with: - Regulatory Ex-certificate notation - Hazard warnings - Privacy caution.
Docking station	When docked the robot charges its batteries autonomously. They are fully recharged in 2 days. Customer to secure the docking station to the ground and connect the junction box to a power supply.

Power socket	When connected to quick charger the robot will fully recharge in 3 hrs.
Quick charger	Non-Ex-charger (100-230V, or 100VAC 50-60Hz supply). Customer to install appropriate wall plug.
Light module	3 LED lights illuminate the fields of view of the 3 cameras.
Hazard warning beacon	Emits a steady orange visual warning

10.3. Sensing

Description	Specification
Forwards vision	Forward facing 18 MP digital video camera with live video transmission to web-browser interface. Zoomed, still images and video recordings can be taken and downloaded from the web-browser interface.
Floor vision	Forwards/downwards facing (3 MP) digital video camera with the same functionality as forwards camera.
Back vision	Backwards/upwards facing (3 MP) digital video camera with the same functionality as forwards camera.
Hearing	Mono microphone transmits sound to the web-browser interface.
Ion Science Falco 1.1 gas detector AND/OR	Detects the concentration of volatile organic compounds. Customer is responsible for calibration.
Honeywell 3000 Mk2 gas detector AND/OR	Detects the concentration of one toxic gas. Customer is responsible for calibration.
Crowcon IR Max OR Simtronics GD10-P00 gas detector	Detects the concentration of light hydrocarbon gases. Customer is responsible for calibration.

10.4. Connectivity Control & Monitoring

Description	Specification
Basic Remote Control	Robot can be controlled and sensors observed using a web-browser interface. Work station can be: - a laptop with Google Chrome and an Xbox gamepad connected. - a smartphone (Apple with Safari or Samsung with Google Chrome browser). Gas alarms are available on the laptop interface if detectors are fitted. Audio and visual recordings appear and can be downloaded from the laptop interface.
Cloud infrastructure	The web-browser interface is located on a shared server located in the same region as the worksite.
Wireless Connection	Robot connects to the shared server via VPN over the public 4G-LTE network. - Robot supports LTE Bands A: B1-B5, B7, B8, B12, B13, B20, B25, B26, B29, B30, B41. - Customer to ensure adequate network coverage in at least one of these bands - Customer to provide micro-SIM card for robot. - Customer to ensure control stations can connect to the robot server via the internet with no obstructive firewalls. - Customer to ensure latency between control station and robot is less than 250 mS with an upload bandwidth from the robot of at least 5 MBit/s

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Basic Autonomous Navigation	Auto-docks/undocks, follows an orange line and sends gas alarms if detectors are fitted. Does not work in snow.
Basic Autonomous Inspection	Robot performs pre-programmed tasks and takes recordings at Waypoints that are marked with chilli-tags. Does not work in snow.
Mission Reporting	Gas maps and recordings are uploaded to the cloud.
Access Management	Customer controls access to robots in their fleet
SIMs	KPN SIMs with discounted roaming charges around the World