Fisheries Innovation & Sustainability

SMARTRAWL Phase 6- technical summary

FIS046

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Smartrawl Phase 6 Report

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1. Executive Summary

This document details the work conducted in Phase 6 of Smartrawl. The original scope for Phase 6 focused on further sea trials building on the trials completed in Phase 5. However, there were several issues that arose during the Phase 5 trials that meant the time was better utilised reworking the system such that future sea trials yielded solid data sets and results.

There are five key areas the rescoped Phase 6 focused on:

- Postmortem on the phase 5 system
- Resolving, repairing, and mitigating against future issues with water ingress into the system
- Investigation and repair around the AI module and its interface with the rest of the system
- Modification of the AI code such that the GPU would be utilised
- Creation of a fabrication pack including drawings, bill of materials and quotes for a revised gate design.
- Addition of buoyance and lift points to the existing gate.

The outputs of this phase were:

- A fully rebuilt latch bottle with replacement components and QC check sheet
- Refurbished camera electronics
- Replacement dome and seal, lip seal, vacuum test, and QC check sheet
- Wet testing with adjustment of camera images, file naming convention and fall-back data capture modification in the event the AI processing becomes blocked.
- Confirmation of the data pipeline: both strobes firing, in sync, images captured, passed to AI, AI processing, Ai decision action by latch logic, latch firing.
- Full fabrication drawings and Bill of Materials (BOM) for a revised gate design
- Quotes for fabrication of new design
- Installation of buoyancy and lift eyes to the current gate (Gate V1)
- 3D print files for JIG templates and scale 3D printable model.

2. Introduction

Smartrawl is an in-water sorting device which is retrofitted inside the extension of a commercial fishing trawl net. The system has three components: a stereo camera, taking images of animals in the trawl; a computer, with artificial intelligence to detect, identify and size animals; and a gate, controlled by the computer to open or close via the latch, catching or releasing animals. Smartrawl is designed with, and for, UK fishers, and their vessels to mitigate against discards and bycatch: the entire system needs no cables from the vessel and can be pre-programmed dependent on the fishermen's desired catch.

The stereo camera system takes paired images of animals as they pass by. The system consists of two cameras, 15cm apart, and two flash units, further apart (70cm), all controlled to trigger simultaneously and continuously (2 Hz) by a Single Board Computer (SBC). The camera, SBC, and batteries are housed in single underwater aluminium housing, as is each flash unit, all rated to a depth of 500m. The housing and flash units are mounted in a neutrally buoyant frame designed to protect the glass domes of the camera housing and flash units. This frame has been demonstrated to be robust and is easily retrofitted to the inside of the extension.

Images acquired by the stereo camera system are then processed by the AI algorithm where species are detected identified and measured. If specified species and sizes are detected the controller sends a signal to trigger the latch, enabling the gate to rotate into the catch position.

A patented gate system rotates using the force of water passing through the trawl to operate it. It does this by incorporating a cylindrical design with rotating conical sections which open and close off the cod-end, and adjacent doors to side panels in the extension, to catch or release animals. The force of water acts on vanes in the cylindrical gate to drive the rotation between the catch and release states. The rotation is restrained by a latch which is released under control of a computer. The cylindrical gate fits into the existing extension by virtue of its diameter being equal to that of the extension during trawling.

3. Milestones

Title	Description	Start Date	End Date	What will you do to achieve this milestone
Winter seas trial preparation completed	Prepare equipment for sea trials and data collection		02.12.2024	Prepare equipment for winter sea conditions, finalise contracts and training for selected trial vessels
Winter sea trials completed	Perform sea trails and review the data collected		31.03.2025	Sea trials completed, research and assessments completed and report ready for publication.

The Shetland field trials during phase 5 of the project marked the first full-scale deployment of the Smartrawl system aboard *Atlantia II*, testing its AI-driven stereo camera, gate, and latch mechanism. Despite weather and equipment delays, the system was successfully deployed and recovered from a small fishing vessel, demonstrating its ease of use. Initial gate tests revealed rotation inconsistencies due to internal obstructions and bearing issues, requiring reengineering. The first successful at-depth gate rotation was recorded, though occasional obstructions, affected performance. The fully integrated system was tested, but the latch and image overexposure required camera setting adjustments. Subsequent hauls revealed inconsistencies in system boot-up, latch engagement failures, and data acquisition issues, with stereo camera and strobe malfunctions preventing image validation.

Engineers later identified the causes for such malfunctions with leaks found in both the camera and latch bottle (housing for the latch battery and other electronics) and inconsistencies in power to strobes.

Following these trials, Phase 6 was re-scoped to respond to the identified modifications required to fix the system and gate re design.

List of re-scoped goals:

1. Postmortem on the phase 5 system
2. Resolving, repairing, and mitigating against future issues with water ingress into the system
3. Wet test the system in the Ocean Systems Laboratory (OSL)
4. Work towards GPU utilisation (Specialist contractor)
5. Full set of fabrication drawings for a revised gate design (Gate V2)

6. Complete bill of materials for gate design (Gate V2)
7. Quotes from manufacturers for fabrication of Gate V2 design
8. Lift eyes and buoyancy added to the existing gate (Gate V1)

4. Shetland Trials System Postmortem

4.1 Latch Bottle

On removing the latch bottle from the Pelican case in which it was transported back from Shetland, the latch bottle was found to be filled with water. Water couple be observed dripping from the top of the bottle when it was turned upside down. It was estimate about 50ml of water exited the housing. Whe the housing was opened it was discovered that all internal components were wet and signs of corrosion were visible. The corrosion or oxidisation of components can be caused by the electrochemical reaction with the salt and minerals in sea water. The battery was found to be still connected upon arrival and although it was soaked, it was still measuring at 15.5V.

A thorough inspection of the housing revealed that the centre blanking plug was found to be very loose, allowing for water ingress. The most likely situation was that this cap was only hand tight on leaving gthe workshop and loosed off in deployment. This is further supported by the Time vs Power Metric data recorded in Haul 4 which is detailed in section 4.3.

Detail inspection of the internal components confirmed that the majority were severly corroded and required replacement. The battery was also determined to be unsafe for furhter use and was correctly disposed of.

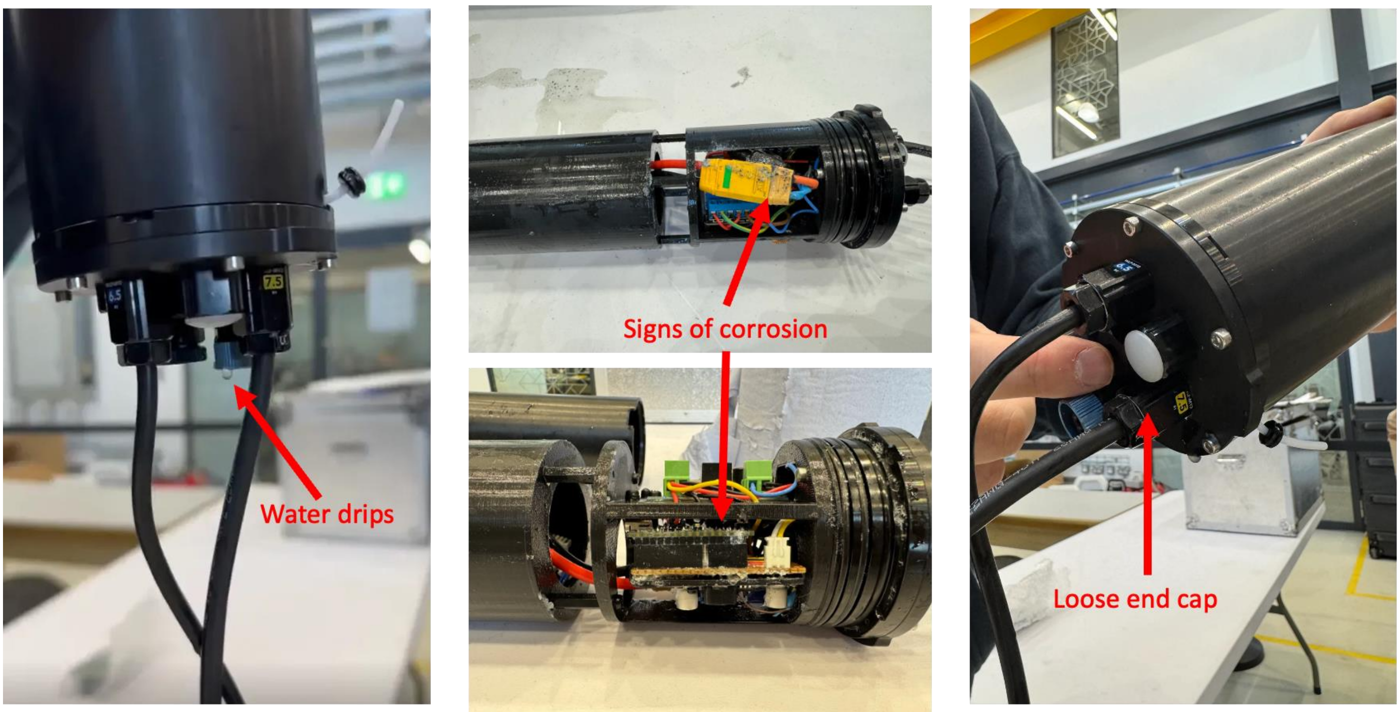


Figure 1: Latch bottle internals on inspection

Key Actions

The key actions from this section of the postmortem were:

1. The latch electronics required a complete refurbishment with all the damaged components being replaced at the expense of the National Robotarium.

2. The blanking cap should not have left the workshop being hand tight only. This is a failure of process. The fix is to improve the Quality Control checks ensuring all seals are fitted and all fasteners are correctly torqued up.

4.2 Camera System

When the camera housing was inspected moisture droplets were found on the camera dome housing. On opening the housing it was noted that water droplets had dripped down on electronics causing shorts. A few of the components directly under the dome were found to be corroded. This explained the eratic behaviour of the system in later deployments. A loose screw from the IMU board was also found inside the housing. Two possible sources for water ingress were identifed. Possibility one was an additional penetration for a pressure test port had been made in the housing, this could have leaked. Again this was found to be finger tight. Possibility two was that the dome seal on the dome with moisture droplets were found could have failed. This was more likely given that the water ingress volume was low and the effect of the leak was quite well localised to below the dome.

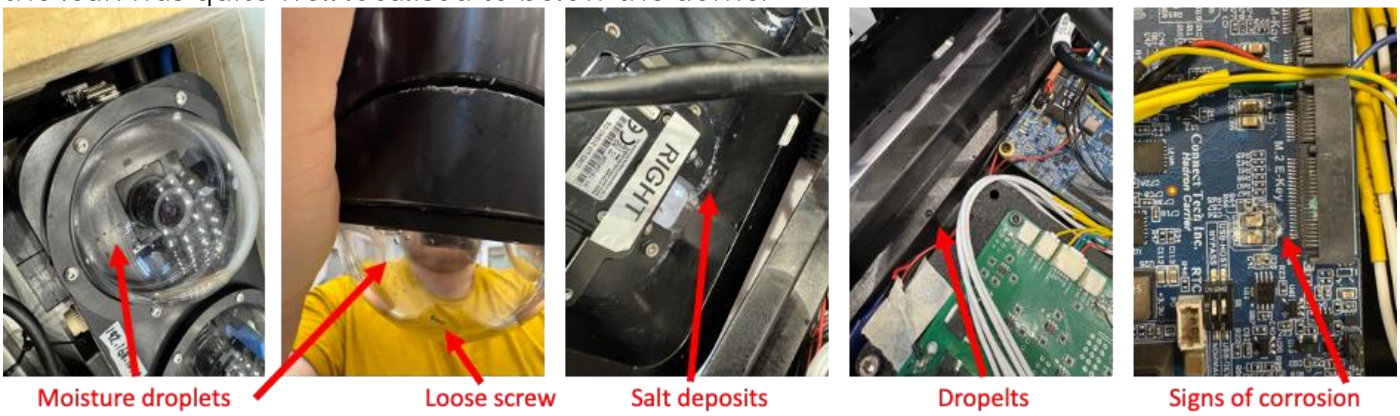


Figure 2 Camera housing internals

Key Actions

The key actions from this section of the postmortem were:

1. The carrier board needed refurbished and fully tested.
2. The Jetson board was also tested and found to be fully functional.
3. The loose screw was refitted, and all internal fasteners were thread locked into place
4. The Pressure Relief Valve that was found to be hand tight was replaced.
5. An extended vacuum test was done to validate dome seal, this failed.
6. The dome was removed and inspected.

4.3 Dome Seal inspection

On close inspection of the dome two issues were found. Issue one was a chip in the seal groove. This would allow the seal to extrude slightly under pressure and was the source of the moisture on the dome. The lip seal on the housing was also found to have been pinched.

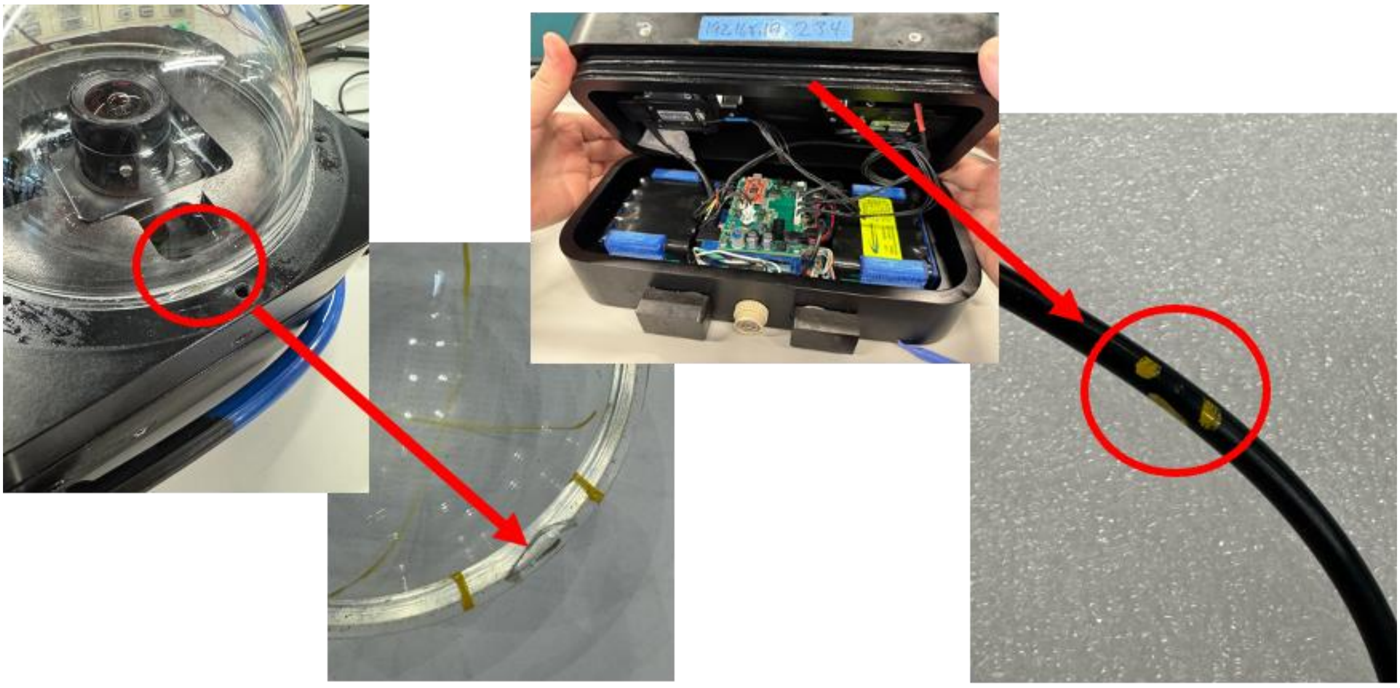


Figure 3 Camera dome and housing radial seal inspection

Key Actions

1. The damaged dome was replaced with a spare from stock.
2. It was reinstalled with a new seal.
3. The lip seal was also replaced.
4. An extended vaccum test was performed on the closed housing to verify the seal replacement had worked. -11Hg was held overnight and therefore the test passed/
5. Pre shipping QA check list to be prepared which includes checking all fasteners and blanks for correct torque.
6. The vaccum test port was blanked as a precaution.

Figure 4 Capped test PRV.

4.4 Strobe investigation

During the Shetland trials the strobes were seen to fire inconsistently or sometimes not firing at all. This impacted the quality of the images captured. On inspection it was thought there were two possible sources for this:

1. Not enough Power: The 3.3V trigger signal is being sent from the Jetson, but the power from the batteries is not reaching the strobe. This is due to either the P-FET switch not functional or the batteries voltage did not provide enough power.
2. Breakdown somewhere in the software pipeline causing trigger signal not being sent

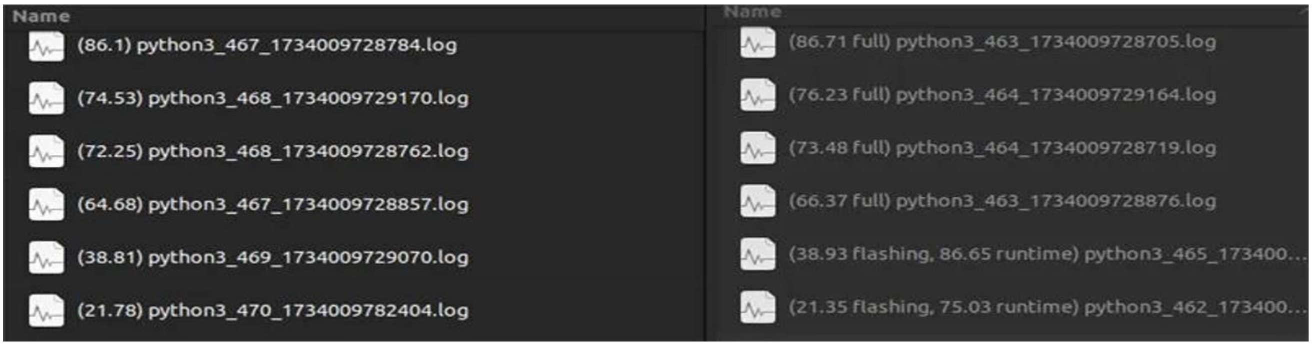


Figure 5 System Logs.

Looking at left side logs in figure 5, the time in parenthesis is the duration between the first AI module request to flash and the last. The files on the right-side show, the time in parenthesis is the duration of how long the strobes and cameras were being triggered for, as well as the total runtime even after the flashing and triggering had halted. These match up one-to-one (accounting for minor deviation of boot time etc). This indicates the failure point is the AI module, due to the halting of requests to trigger camera and strobes midway through the runtime as indicated by the pin command service (right side) logs. The AI module does not have logging capability developed for tracking of runtime/errors encountered, therefore understanding the failure of the AI module needs to be supported by the original developer.

Key Actions

1. It was confirmed that the image capture and strobes were haulted by the AI module. The logs and data that was captured were shared with Chris Moorhouse, the original developer of the AI module, as part of his investigation.
2. As a contigency a timeout was added so that if for any reason the AI module stopped the pipeline, after a few second the images would continue to be taken and saved, ensuring that at least data was collected.

5. Haul Data Analytics

5.1 Haul 1: 13th February at 10:57

It was confirmed that both strobes were flashing before deployment from the vessel deck and the gate was set to default release position. Upon recovery, the strobes were not flashing and only 4 fish were caught, which indicated there might be a miss fired causing gate rotation into catch position. A review of the go-pro footage revealed the gate rotation did not rotate throughout this haul.

5.2 Haul 1 Findings

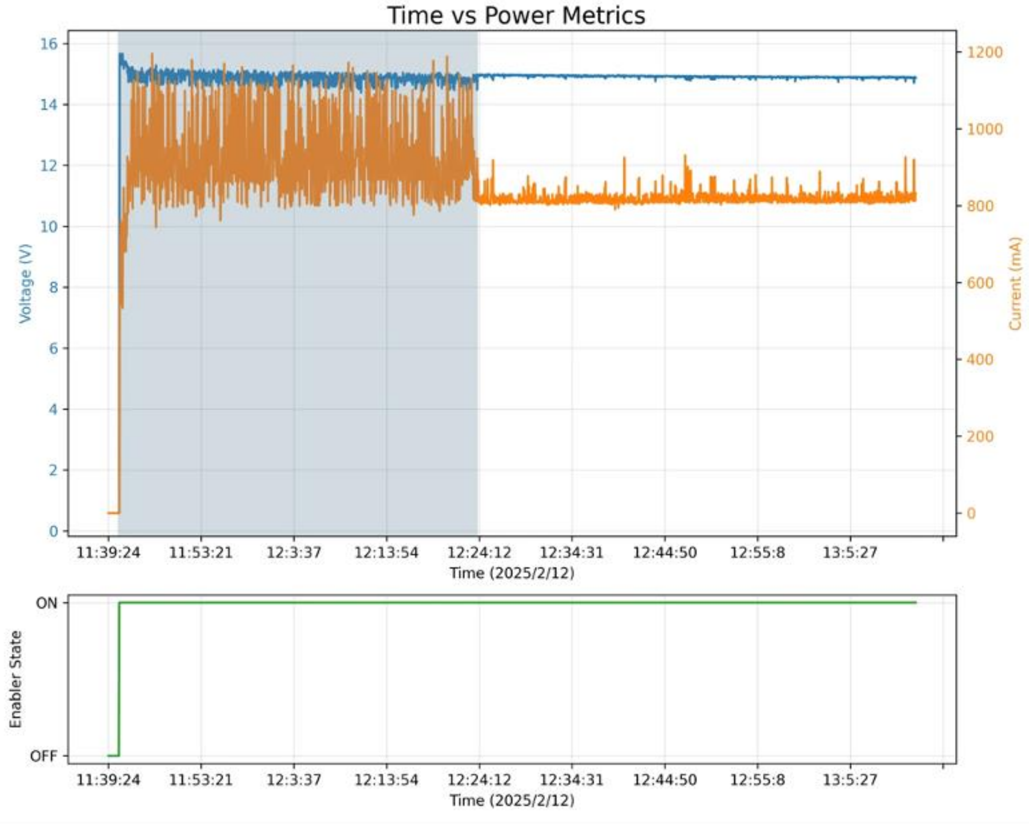


Figure 6 Haul 1 Time vs Power Metrics.

From the recorded sensory data, the first haul lasted one hour and thirty-three minutes, which aligns with the timestamps in the haul data during trials. This confirms that power from the latch battery was correctly supplied to the components inside the camera housing and that the sensors were operational. However, data logged by the AI system indicates that the camera system, strobe, and AI detection, were functional for only forty minutes. This finding is further supported by the power metrics highlighted in the shaded area of the figure 6. During this period, four fish were detected—one was too small, while the other three met the catch criteria, triggering the gate.

5.3 Haul 2: 13th February at 12:58

On this occasion the system required several reboots before it completed the startup cycle. Before deployment the gate was set to default release position and upon recovery, the strobes were found to not be flashing and only five fish were caught. The go-pro footage revealed no gate rotation throughout.

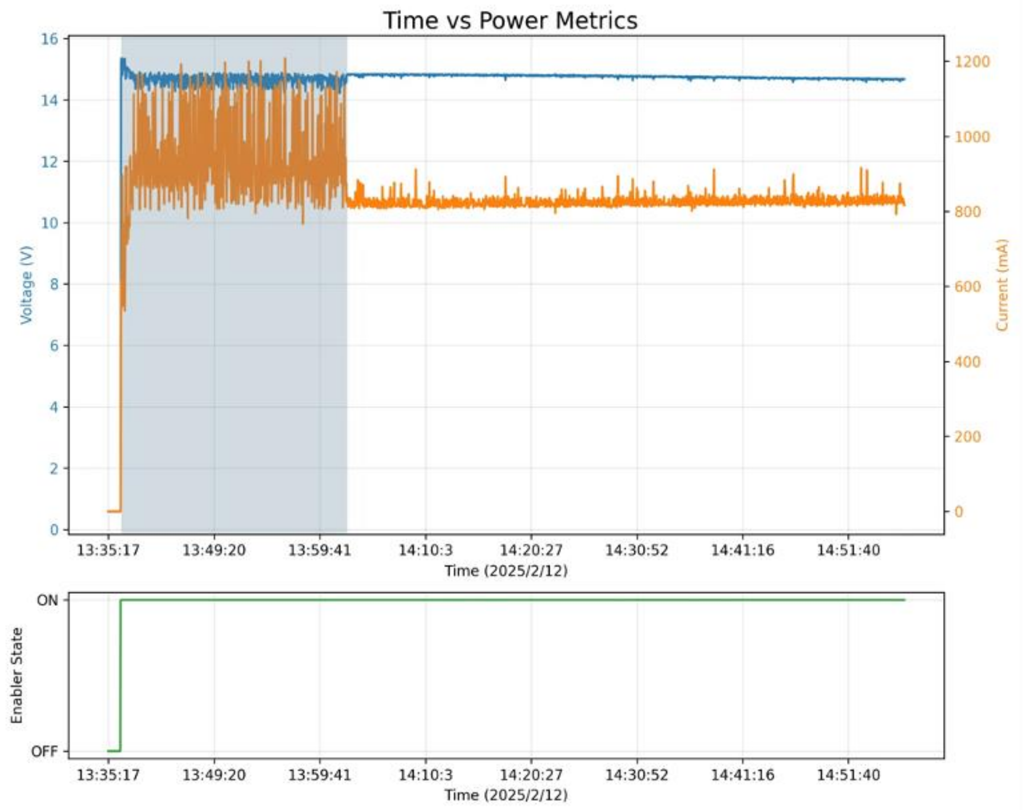


Figure 7 Haul 2 Time vs Power Metrics.

5.4 Haul 2 Findings

From the recorded sensory data, the second haul lasted one hour and twenty minutes, and again this aligns to the timing in the haul data during trials, confirming that power from the latch battery was correctly supplied to the components and that the sensors were operational. However, data logged by the AI system indicates that the camera system, strobe, and AI detection, were functional for only twenty-one minutes. This is further supported by the power metrics highlighted in the shaded area of figure 7. During this period, two fish were detected, both of which met the catch criteria, triggering the gate.

5.5 Haul 3: 13th February at 14:33

As with haul 2, the system required several reboots to become fully operational. The gate was set to default catch position before deployment and upon recovery, there was only one strobe flashing. There was a mixed catch as the latch was set to catch position. The go-pro footage revealed no gate rotation throughout.

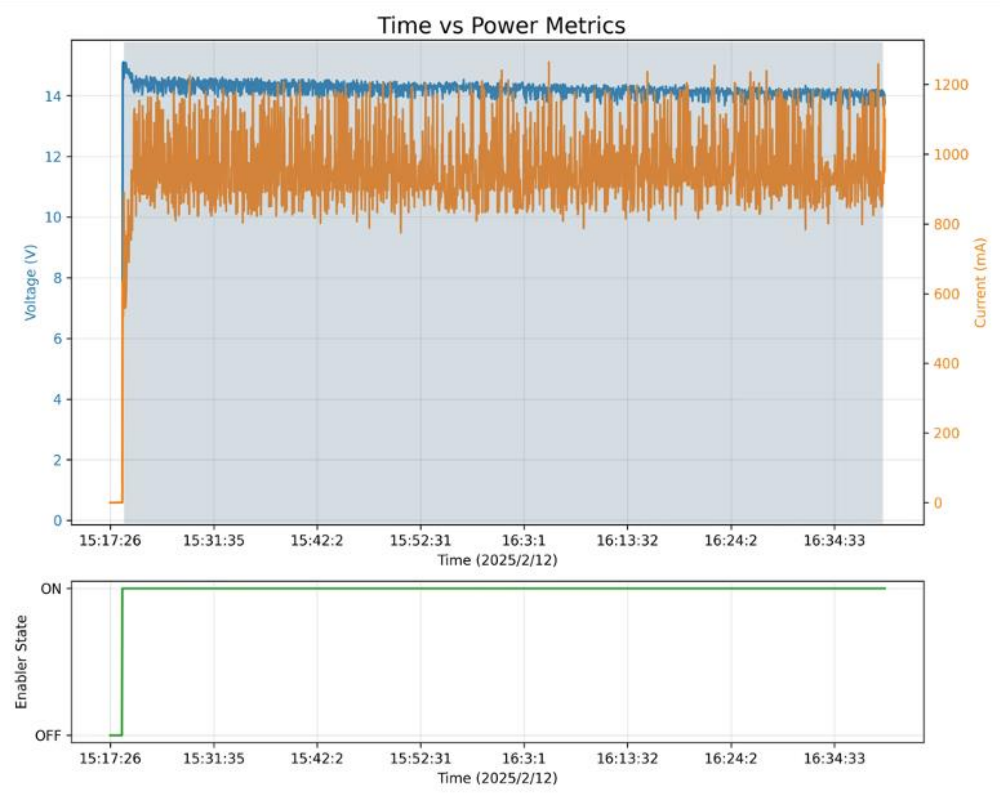


Figure 8 Haul 3 Time vs Power Metrics.

5.6 Haul 3 Findings

From the recorded sensory data, the third haul lasted one hour and twenty-two minutes, aligning with the timing in the haul data during trials. The data logged by the AI system indicates that the camera system, strobe, and AI detection, were functional for one hour and seventeen minutes. This is the first time the entire system was up running for the entire haul without disruption as is shown in figure 8, although only one strobe was working upon recovery. There were 1764 images collected on this haul. During haul 3, six fishes were detected. four was too small, one was too large and only one met the catch criteria, triggering the gate.

5.7 Back at Shetland Lab on 13th February at 18:13

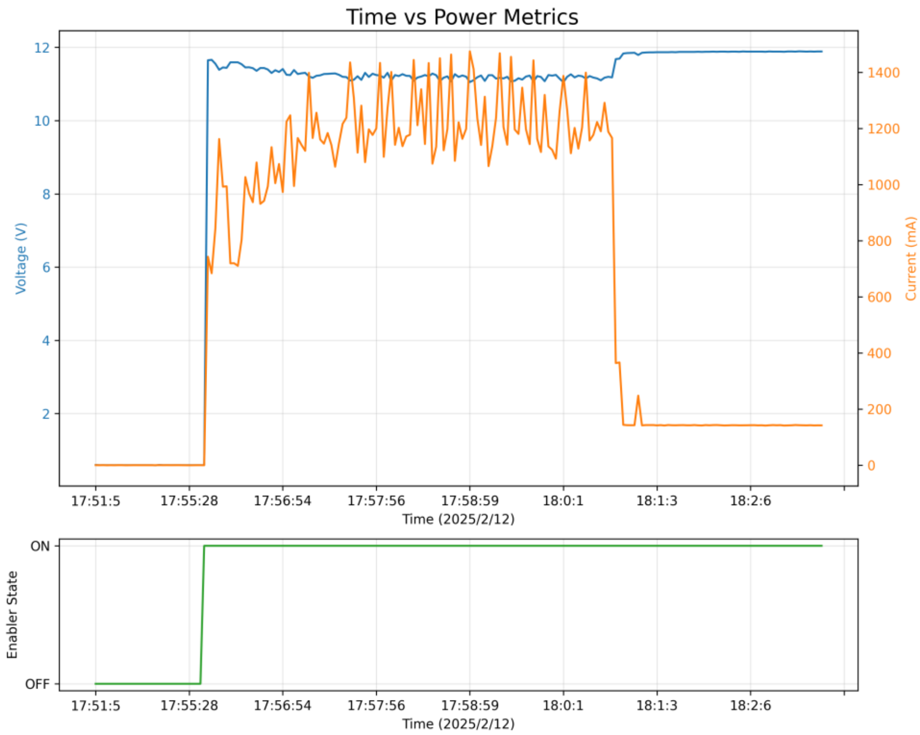


Figure 9 Shetland Lab Time vs Power Metrics.

5.8 Findings back in Lab

Reviewing the sensor data (figure 9) 17:50:52, we believe this was the time when the team attempted to access the camera system after the sea trials. The current draw dropped to 180mA after five minutes, which is abnormally low and consistent with what we observed when the kit was tested with a bench power supply during postmortem. Based on the water droplets observed inside the camera dome and the corrosion on the carrier board, we suspect that water ingress was the cause of this and prior issues when the system struggled to boot up. The water appeared to have accumulated around the M.2 E-Key, and when the system was powered on, it caused a short circuit on the board, leading to a failure of booting up.

5.9 Haul 4 on 14th February at 10:17

Although the strobes were not reliably working, as there was still vessel time available it was decided that a separate torch should be attached to the stereo camera frame to illuminate the camera frame in case strobes were not working. The system is deployed when with the green LED flashing indicating the system had power. Upon recovery, the strobes were not flashing the latch was seen to continuously disengaged and engaged. A review of the GoPro footage show that the gate is rotating between catch and release position.

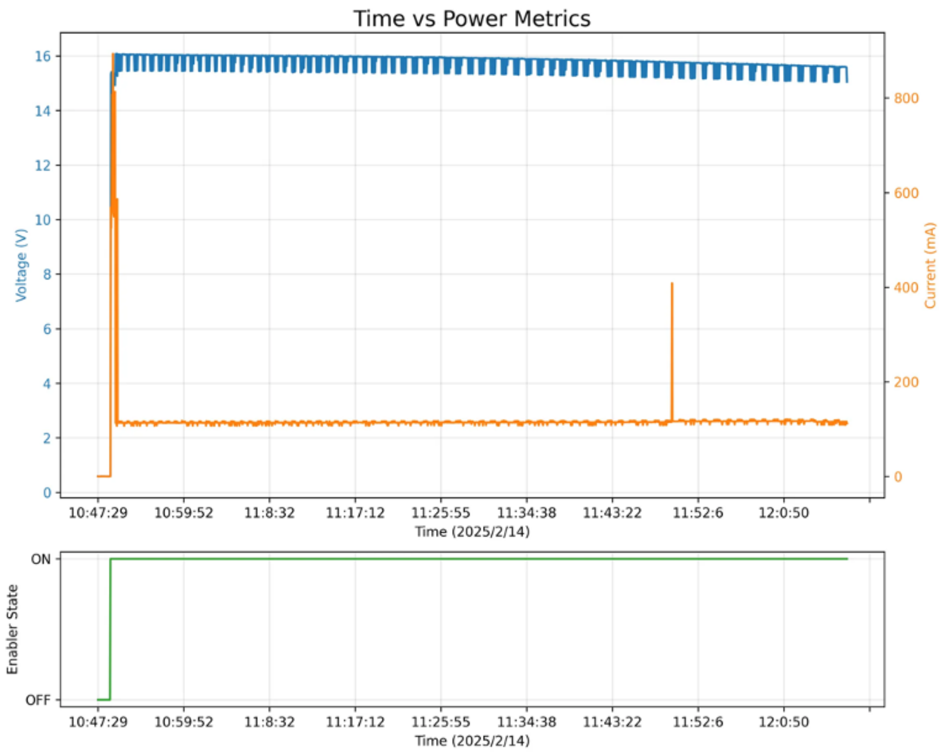


Figure 10 Haul 4 Time vs Power Metrics.

5.10 Haul 4 Findings

The current dropped significantly around 10:50 on 14/02/2025, which we believe marks the moment water began seeping into the latch bottle, causing the system to behave unpredictably. The repeated latch activity observed on the GoPro footage was not triggered by the camera system but in fact was due to shorts within the latch bottle electronics.

5.11 Real Time Clock (RTC)

When the field team tried to access the image data, it was noted that the image folders had unitivitve file naming and the folders were being overwritten. The underlying cause of this was that the system clock was not properly synced after installing the coin battery causing the images overwriting.
In the smartrawl system there are in fact two Real Time Clocks (RTC): The default Tegra Soc is set to rtc1 and the external battery is connected to rtc0. The kernel however is configured to sync time with rtc1, which causes the time to be incorrect at the boot, until it is synced with network time. The RTC was not properly synchronised after installing the coin battery causing the RTC to reset to its default epoch time (January 1, 1970), causing the system to incorrectly interpret the time. As a result, the system used the last recorded time, which was no longer accurate, leading to the generation of folders with the same timestamp. This caused folder overwriting, as the system failed to distinguish between new and previously existing folders based on the time. The failure to synchronize the RTC properly resulted in data loss and operational inconsistencies. The fix was to ensure the RTC was correctly sychronized and confirm this as part of a QC check list.

5.12 Image orientation

On accessing the images collected during the trials, it was found that all the images were upside down. It was confirmed that the camera had been mounted in the correct orientation in the frame and therefore the issue existed in software. The system has stereo cameras one of which, for space reasons, is mounted upside down to the other and there is code to flip the image from the one camera that is upside down. This line of code had infact been applied to the camera that was in the correct orientation resulting in both images being upside down. This was resolved by setting the image flip method to the other camera and adding an image orientation check to the QC checklist.

6. Repairs

The tables below detail the repairs carried out:

6.1 Camera System 1: Smartrawl System

Action	**Owner**	**Completed**
Strobe-camera sync	Hsing-Yu	March 10, 2025
Save Images prior to AI processing	Sean Katagiri	March 12, 2025
Fix RTC	Sean Katagiri, Hsing-Yu	March 14, 2025
Fix Upside Down Image	Joshua Roe, Sean Katagiri	March 16, 2025
Attach Jetson to the housing	Hsing-Yu	March 19, 2025
Dome refit	Joshua Roe, Hsing-Yu	March 21, 2025
Hardware Service	Joshua Roe	March 21, 2025
Vacuum Test (Camera System 1)	Joshua Roe	March 21, 2025
Blank / Cap the Vacuum Test Port	Joshua Roe	March 21, 2025
QA Check (Camera System 1 - Smartrawl)	Joshua Roe, Hsing-Yu	March 25, 2025
Test and verify RTC fix	Sean Katagiri, Rosie Ashworth	March 25, 2025
Test and verify Image orientation	Rosie Ashworth	March 25, 2025
Image quality / exposure settings check with Rosie	Sean Katagiri, Rosie Ashworth	March 25, 2025
Save Images Full Pipeline Testing	Sean Katagiri, Rosie Ashworth	March 25, 2025
Wet test in oceans lab	Rosie Ashworth, Joshua Roe, Hsing-Yu, Sean Katagiri, Chris Moorhead	March 26, 2025
Software Backup	Sean Katagiri,	March 28, 2025

6.2 Camera System 2: Data Collection Only

Action	**Owner**	**Completed**
Refit Odriod Board	Hsing-Yu	March 10, 2025
Close up housing	Hsing-Yu	March 21, 2025
QA Check (Camera System 2 - Image Capture Only)	Joshua Roe	March 25, 2025

6.3 AI Module

Action	**Owner**	**Completed**

Share docker file and shared folder with Chris	Joshua Roe	March 10, 2025
Endurance testing (continuous loop)	Chris Moorhead, Joshua Roe, Sean, Hsing-Yu,	March 16, 2025
Enable GPU	Chris Moorhead	Incomplete
U Limit fix	Chris Moorhead	March 21, 2025
Test for Image Crash (evidenced from Shetland Trials)	Chris Moorhead	March 21, 2025
Endurance testing (system level with NR team)	Chris Moorhead, Hsing-Yu, Joshua Roe	March 25, 2025
Test for AI crash (image runds)	Chris Moorhead	March 28, 2025

6.4 Latch Bottle

Action	**Owner**	**Completed**
Remake the circuit	Hsing-Yu	March 10, 2025
3D print part	Hsing-Yu	March 10, 2025
Test protection module	Hsing-Yu	March 10, 2025
3D print battery cover	Hsing-Yu	March 10, 2025
Deep clean the bottle	Joshua Roe	March 11, 2025
Order Blue Robotics parts	David Morrison	March 13, 2025
Add LED Power on Status	Hsing-Yu	March 17, 2025
Add LED Low Power Status	Hsing-Yu	March 17, 2025
Move Fuse Before Switch	Hsing-Yu	March 17, 2025
Secure Arduino board	Hsing-Yu	March 17, 2025
Test with ROS command	Hsing-Yu	March 18, 2025
Battery life testing - part of output from Endurance Test	Hsing-Yu	March 19, 2025
Fit the connectors to Latch Bottle	Joshua Roe, Hsing-Yu	March 25, 2025
QA Check	Joshua Roe	March 25, 2025

6.5 Software

Several modifications have been made to:

- Fix issues highlighted by results and logs from 2025 Shetland trials
- Add functionalities found to be useful based on learnings from 2025 Shetland trials

The following sections will outline these changes and their effect on the system.

6.6 AI Module

Change 1 - rostrawl.py

```
def SyncCallback(self, cam_0_msg, cam_1_msg):
    cv_image_0 = self.bridge.imgmsg_to_cv2(cam_0_msg, desired_encoding='bgr8')
    cv_image_1 = self.bridge.imgmsg_to_cv2(cam_1_msg, desired_encoding='bgr8')
    cv_image_1 = cv2.rotate(cv_image_1.copy(), cv2.ROTATE_180)
    if SCALING_FACTOR != 1:
        cv_image_0 = cv2.resize(cv_image_0, (0,0), fx=SCALING_FACTOR, fy=SCALING_FACTOR)
        cv_image_1 = cv2.resize(cv_image_1, (0,0), fx=SCALING_FACTOR, fy=SCALING_FACTOR)
    if len(self.camera_buffer) < 1:
        self.camera_buffer.append([np.array(cv_image_0),np.array(cv_image_1)])
        self.get_logger().info("got image, adding to buffer. New buffer size=%d" % len(self.camera_buffer))
    else:
        self.get_logger().debug("got image but not adding to queue because queue size greater than 1. Current queue size = %d" % len(self.camera_buffer))
```

The above screenshot shows 2 changes made:

- Replacement of two non-synchronised image callbacks with a single synchronised callback function
    - Previously the system made assumptions that images received were synchronised, and simply adding the stereo pair to the processing queue when a left image and right image was available in the callback. This created a potential for an offset to exist between a left image being received and the right image being received to be pushed to the processing queue
    - The new callback checks the message headers to ensure that the callback is only activated upon a left/right pair with timestamps within a tolerance is received. (Tolerance is set at 0.1 seconds). This ensures all stereo pairs that are pushed to the ai processing queue are synchronised within 0.1 seconds.
- Reduction of the camera buffer size to 1
    - Due to the current AI module being unable to keep up with the 2Hz image input, there is a significant delay between the image being captured and the gate decision being made. To minimise the effect of this delay, the camera buffer size has been reduced to 1 to ensure that the AI module is processing the latest available image as opposed to an image that was captured between 2-10 seconds before the time the gate decision was made.

Change 2 – sizing_module.py

This file received a major update, received from Chris Moorhead in March, as well as minor amendments to integrate the ROS interface as this was not included in the updated file. The changes are as follows:

- QUEUE_LIMIT reduced to 1

```
QUEUE_LIMIT = 1 # Number of items that can be loaded into the pipeline at once. Not all may be active in the same process.
```

    - This is to apply the same thought process as the reduction of the camera buffer size. This results in the processing buffer size to be reduced to 1, ensuring the system is not holding on to outdated image data.
- Addition of image retrieval in **image_capture** function

```
left_im = camera_buffer[0][0].copy()
right_im = camera_buffer[0][1].copy()
camera_buffer.pop()
```

    - This code block has been added for both the **time_test** and non-**time_test** conditions in **image_capture** (note this has not been added to the **sim** condition. This code block simply retrieves the image data from the camera buffer to the **left_im** and **right_im** variables, which are used to add the images to the processing buffer. The data in the camera buffer is then cleared to allow for new image to be added by rostrawl.py.
- Addition of relevant shared variables and process initialisations

```
ros_output_message = dynamic_shared.Value('s', "")
camera_buffer = dynamic_shared.list()
```

```
image_subscriber = Process(target=subscriber_child_process_target, args=(["/cam_0/image_raw", "/cam_1/image_raw"], camera_buffer))
ai_output_publisher = Process(target=publisher_child_process_target, args=("ai_output_publisher", ros_output_message))
```

    - These code blocks are simply re-adding the shared variables and processes required to enable the interface between the AI module and ROS nodes.

    - Several functions and their respective calls have been updated to incorporate these shared variables. (namely **image_capture**, **dual_detection**, **size_processing**)

6.7 ROS nodes

Change 1 – Addition of a camera stream heartbeat monitor

- Addition of **run_cameras.sh**
    - This script allows for dynamic launching of the camera drivers from code. The use of this script will be outlined below
- Addition of **start_cameras.py**
    - This is a new node whose responsibility is to start the camera driver on boot, as well as ensuring both left/right camera streams are publishing properly.
    - The check is done by using a synchronised callback which checks the timestamps of the two cameras are within 0.05 seconds' difference.
    - If the callback does not get triggered for over 1 second, the driver process is killed by relaunching the camera driver by calling the **run_cameras.sh** script.
    - This was implemented to rule out the camera driver becoming the cause of data not being collected during the trawl in future trials.
- New node added to **full_setup.launch.py**
    - The new heartbeat monitor node is added to the main launch file to ensure it is launched alongside all other nodes on boot

Change 2 – status_check.py

- Addition of image saving capability
    - The node now has a synchronised subscriber which will retrieve the image data for the stereo pair and save to disk under “results/raw_images” in the sambashare directory.
    - Images are separated into “left” and “right” folders
    - Images are named with a leading index number **(NOT RELATED TO AI MODULE INDEXING)**, followed by year month day, followed by hour minute seconds, followed by milliseconds. E.g. 00011_D250327-T111108_578451.jpg
- Addition of 2Hz timer to manually trigger the strobes
    - The node will now trigger the strobes at 2Hz, which in turn triggers the cameras to capture an image at 2Hz. These images are then saved by the saving capability outlined above.

Change 3 – control.py

- Addition of capability to read parameters from a file accessible by scientists
    - The gate behaviour can now be edited via editing “config/gate_params.csv” in the sambashare directory
    - “CONFIDENCE_THRESH” - any value between 0-1 to indicate what confidence level is required of the output from the ai module to trigger the gate latch. The default value is 0.6 which equates to 60% confidence.
    - “CATCH_DELAY” - number of seconds the gate should be kept in the “catch” position before being put back in "release" position. Default value is 5.
    - “GATE_DELAY” - number of seconds after the last “catch and release” before the gate can be rotated into the “catch” position again. This is to give time for the gate to go through the full latch release and catch safely before processing another request. Default value is 2.5. We do not recommend setting the value lower than the default value.

Change 4 – Image acquisition

- System has been changed to acquire and save images at 2Hz regardless of AI performance

- Based on this change, images are saved at 2Hz while the AI module runs at ~0.5 Hz
- One shortfall of this change is that the IDs of the images saved under "results/raw_images" and the IDs associated with detections will not match up due to differing processing speeds.
- Future work will be to find a way to synchronise the IDs to ease the process of matching AI detections with raw images

Change 5 – start_ai.py

- Addition of capability to enable/disable AI module visualisation by scientists
  - There is now a file in "config/ai_params.csv" in the sambashare directory
  - "vis_on" - controls whether the AI module saves its visualisations under the "results/vis" folder or not. Set to "TRUE" for AI module to save images, "FALSE" for no image saving by the AI module
  - This is done using differently named bash scripts in the "code" folder. (run_smartrawl-ai.sh vs run_smartrawl-ai_no_vis.sh)

Change 6 – sensor monitoring and logging

All sensors have been migrated from the microcontroller (ESP32) to the single-board computer (Jetson Orin Nano). This transition enables sensory data to be accessed via the sambashare directory (under "results/sensor") to avoid opening camera housing. Each sensor type has its own dedicated node in ROS2: one for the IMU, one for the pressure sensor (including pressure, depth, and temperature), and one for the power monitoring module (which tracks bus voltage, shunt voltage, and current). In the control.py script, an additional callback has been implemented to collect data from all sensors at a frequency of 2Hz and save the information into a text file in the directory mentioned.

7. Tank Testing

In order to test the fixed system and the pipeline from image aquisation, detection, AI processing, gate logic to latch engaging the Smartrawl system under went tank testing (26.03.2025 and 27.03.2025). Tank testing allowed for the camera parameters to be tested, ensuring exposure and gain setting were sufficient to illuminate fish and clear colours.

A colour card and model of haddock and cod were placed in the stereo camera field of view.

System set up: The control.csv file controls the species and size requirements of the Smartrawl system which can be pre programmed by the fisher for desired catch. For testing, all species and Minimum Conservation Reference Size (MCRS) was set for each species as seen below.

Control.csv:

type	size
haddock	30
whiting	27
saithe	35
cod	35
hake	27
flatfish	27
prawn	8.5
monkfish	0

Camera parameters were also set to the following:

param_name	value
gain_auto	Off
gain	0
exposure_auto	Off
exposure_time	600

7.1 Tank set up:

Tank testing occurred in the Ocean System Lab (OSL) at Heriot-Watt University on March 26th and 27th 2025. The set up aimed to mimic trawl extension conditions, with a background blue tarpaulin placed opposite the camera and model fish moving across field of view. A large tarpaulin was placed over the tank to reduce light levels. See set up below.

Figure 11 – Tank testing set up with a dark blue tarpulin postioned opposite the stereo camera to simulate background tarpulin in trawl extension. Model fish positioned opposite camera field of view.

7.2 Results post tank testing:

Tank testing demonstrated fuctioning of the pipeline through image aquistion to latch enaging when a the model cod and haddock were placed in the field of view. Clear results displayed the AI outputs, Latch decisons, raw images and visualiation from the AI model. Despite the pipeline working well, results displayed mis classifcation of species and sizing.

Figure 12 shows a screenshot of the AI output file, incidating species identification, size and confidence score. Haddock (35cm)and cod (42cm) fish models were solely used during testing. AI output shows identifcation of monkfish, whiting and flatfish instead.

```
11-17-57 > ['monkfish', '24.508', '0.4599170982837677']
11-17-59 > ['None', '0', '0']
11-18-02 > ['None', '0', '0']
11-18-05 > ['monkfish', '0', '0.48782867193222046']
11-18-07 > ['None', '0', '0']
11-18-09 > ['None', '0', '0']
11-18-12 > ['None', '0', '0']
11-18-14 > ['monkfish', '0', '0.5006933808326721']
11-18-17 > ['flatfish', '0', '0.4890684187412262']
11-18-19 > ['whiting', '35.6', '0.4995046854019165']
11-18-22 > ['None', '0', '0']
11-18-25 > ['None', '0', '0']
11-18-27 > ['None', '0', '0']
11-18-30 > ['monkfish', '0', '0.450558602809906']
11-18-33 > ['None', '0', '0']
11-18-36 > ['None', '0', '0']
11-18-39 > ['None', '0', '0']
11-18-41 > ['None', '0', '0']
11-18-43 > ['monkfish', '0', '0.5096837282180786']
```

Figure 12 – Screenshot from AI output, from left to right (showing time stamp, species identified, length (cm), confidence threshold.

Moreover, below showcasese the latch output file of the disisions made post AI processing. The latch will only be triggered if the species, size and confidence threshold is above 60% - 'catch' . When latch decisions are ' Confidence too low' or 'Size too small' or 'Species not wanted' the latch is not triggered.

```
11-20-50 > Confidence too low
11-20-53 > Confidence too low
11-20-56 > Size too small
11-20-58 > Catch
11-21-06 > Catch
11-21-13 > Confidence too low
11-21-15 > Species not wanted
11-21-19 > Confidence too low
11-21-21 > Species not wanted
11-21-24 > Species not wanted
11-21-27 > Species not wanted
11-21-29 > Confidence too low
```

Figure 13 – Signals to latch output, latch triggered once correct species, size and confidence is detected outputting 'catch' which signals to release latch allowing for gate to rotate a quarter turn into the catch position.

Another folder in the results displays the raw images from the left and right camera. Below shoes images captured by the left camera of the colour card and a haddock. Image quality is clear, with all colours seen on the colour card.

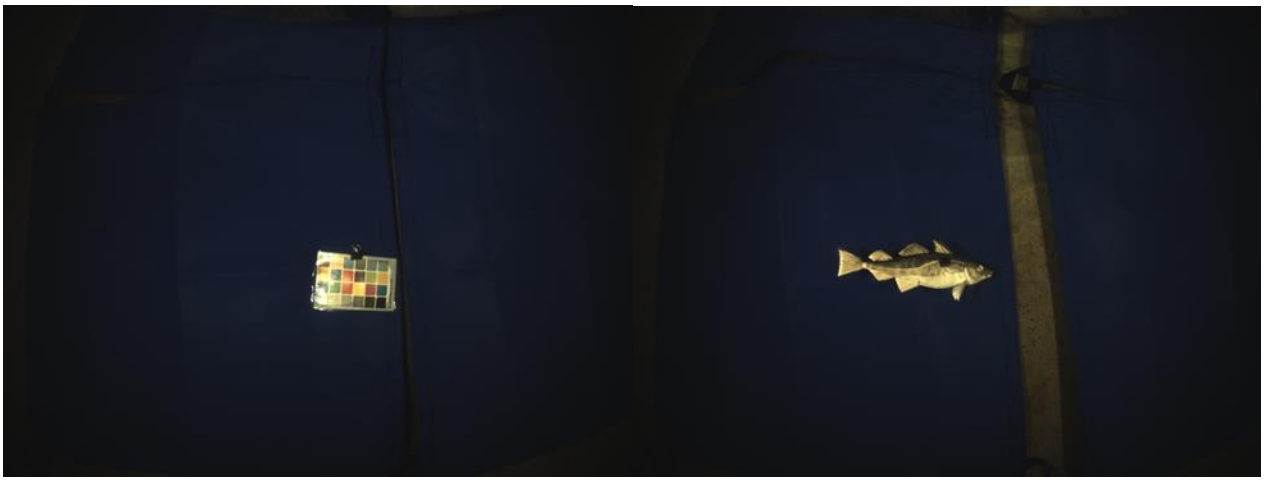


Figure 14 – Image from left camera of colour card used to check camera parameters and of a model haddock fish.

In order to see the processed visualisation from the AI, the vis toggle was turned on. This will not be turned on during at sea testing as this double saves images and increased processing time. However, for tank trials this allowed to clearly see detection and if species classification and sizing was correct. Below the cod is identified but the sizing is incorrect as the model cod is 42cm. And the haddock was not detected.

Figure 15 – Paired image of annotated fish, both haddock and cod are in frame – AI model has correctly identified cod, of a high confidence and length of 31cm.

8. Gate

The original gate (gate V1) had too much play in the bushing it was rotating on, which we swapped out for marine bearing for a smoother spin in Phase 5. The centre column was made up of multiple parts bottled down the centre to hold in place. This had to be finely adjusted to hold things tight enough to not loosen off but not too tight it restricts the ease of the gate spinning. This has been addressed in the new design, shown in figure 16

8.1 Gate V2

Figure 16: Revised gate design (Gate V2)

The following modification have been made:

- Redesign the centre column, making it more rigid – 40mm tube. This in turn will lead to the increase of size of the central spinning cone assembly.
- Increased size of marine bearings – from 20mm to 40mm, this will increase the rigidity and increase lifespan of the gate.
- Added holes in end plates to make lashing gate to trawl net easier.
- Addressed the buoyancy issue by adding polyurethane expanding foam into the dead zones behind the green plastic panels.
- Relocated the latch bottle
- New lifting points & shackles onto the gate to ease moving it around and deploying at sea have been added.
- Relocated the latch bottle for easier access to remove batteries for charging. This also made adding buoyancy foam easier, shown in figure 17.

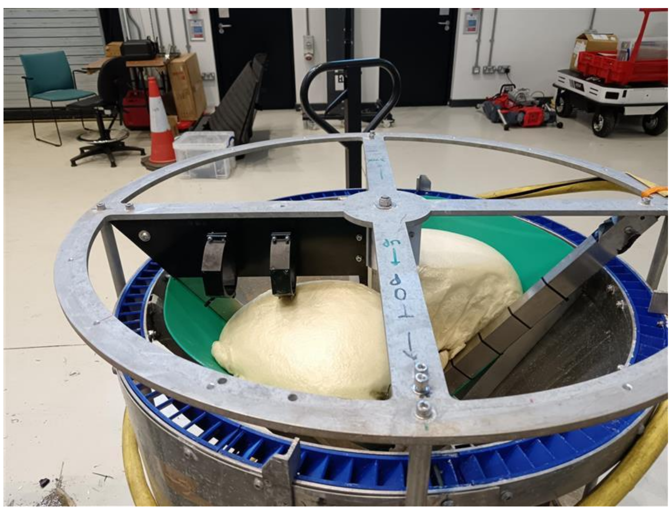


Figure 17: (Gate V2) latch bottle relocation & buoyancy foam

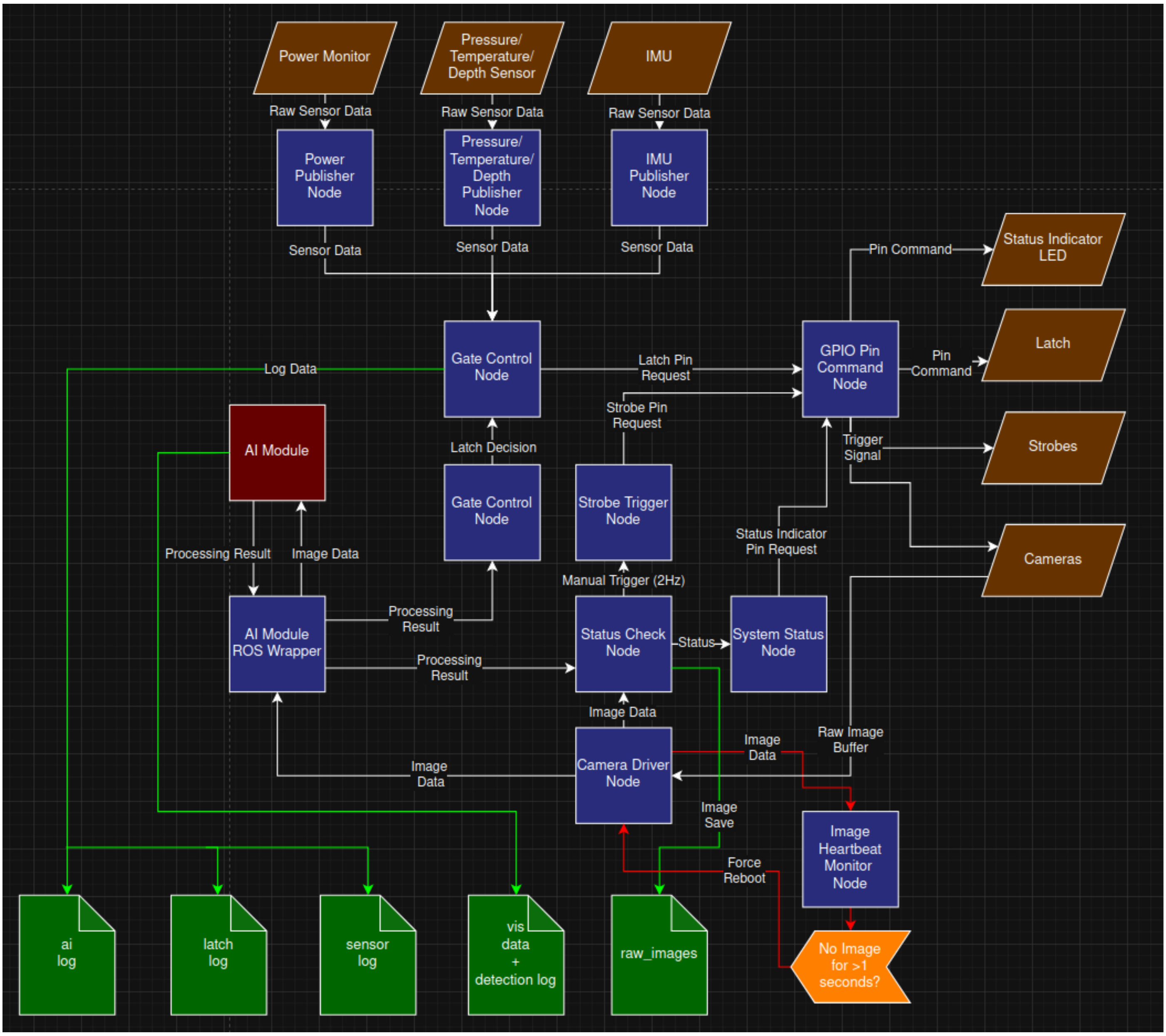
9. Fabrication Quotes

The following companies have contacted awaiting finished quotes.

Ocean Kinetics Ltd Port Business Park Gremista Lerwick Shetland ZE1 0TW UK	www.oceankinetics.co.uk Tel: +44 (0)1595 696 777 (main switchboard) Tel: +44 (0)1595 697 900 (shop) / 696 777 Fax: +44 (0)1595 697 040 Email: **info@oceankinetics.co.uk**
Almond Engineering Ltd 3a Fleming Rd, Kirkton Campus, Livingston Village, Livingston EH54 7BN	https://almond.co.uk/ John Gilmour <jgilmour@almond.co.uk> Director of Sales & Estimating Tel: 01506 410880 M: 07833518787
Fifab 29 Rutherford Rd, Glenrothes KY6 2RT UK	https://fifab.com sales@fifab.co.uk +44 (0) 1592 776 700

10. Appendix

10.1 Appendix 1 – Overview of software node structure



10.2 Appendix 2 – Bill of Materials Smartrawl - Gate V2

Smartrawl - Gate V2		
Description	**Qty**	**Purchase Link**
Gate		
M8 x 65 Socket button Screw (316 Stainless - A4)	10	https://www.accu.co.uk/socket-button-screws/8383-SSB-M8-65-A4
M8 x 60 Socket button Screw (316 Stainless - A4)	10	https://www.accu.co.uk/socket-button-screws/8382-SSB-M8-60-A4
M8 x 35 Socket button Screw (316 Stainless - A4)	4	https://www.accu.co.uk/socket-button-screws/8377-SSB-M8-35-A4
M8 x 16 Socket button Screws (316 Stainless - A4)	2	
M8 Nylocks (316 Stainless - A4)	26	https://www.accu.co.uk/hexagon-nylon-locking-nuts/7961-HNN-M8-A4
M8 Washers (316 Stainless - A4)	8	https://www.accu.co.uk/metric-flat-washers/72523-HPW-M8-A4
M6 x 25 Socket Cap Screw (316 Stainless - A4)	8	https://www.accu.co.uk/metric-cap-head-screws/3131-SSC-M6-25-A4
Lugs		
M5 x 20 Philips Countersunk Screws (316 Stainless - A4)	8	https://www.accu.co.uk/phillips-countersunk-screws/66106-SIK-M5-20-A4
M5 Nylocks (316 Stainless - A4)	8	https://www.accu.co.uk/hexagon-nylon-locking-nuts/7959-HNN-M5-A4
Bearings		
Bearings (68 x 40 x 15mm - S316-6008-2PES) (316 Stainless - A4)	2	https://www.smbbearings.com/products/316-stainless-steel-bearings.html
		https://simplybearings.co.uk/shop/Bearings-Deep-Groove-Ball-Bearings/c3_11/index.html?selection=Stainless+Steel+Ball+Bearings
Outside Bars		
M8 x 25 Socket Cap Screw (316 Stainless - A4)	8	https://www.accu.co.uk/metric-cap-head-screws/4039-SSCF-M8-25-A4
M8 Washers (316 Stainless - A4)	8	https://www.accu.co.uk/metric-flat-washers/72523-HPW-M8-A4
Central Threaded Rod		
M12 x 10000mm Threaded Rod (316 Stainless - A4)	1	https://www.accu.co.uk/metric-threaded-bars/14740-HTB-M12-1000-A4
M12 Nylocks (316 Stainless - A4)	2	https://www.accu.co.uk/hexagon-nylon-locking-nuts/652940-HNN-M12-A4-80
M12 Washers (316 Stainless - A4)	2	https://www.accu.co.uk/metric-flat-washers/415486-HPW-M12-V1-A4

Lifting Brackets		
M8 x 16 Socket Cap Screw (316 Stainless - A4)	2	https://www.accu.co.uk/metric-cap-head-screws/4035-SSCF-M8-16-A4
Latch		
M8 x 50 Socket Cap Screw (316 Stainless - A4)	2	https://www.accu.co.uk/metric-cap-head-screws/4044-SSCF-M8-50-A4
M8 x 30 Socket Cap Screw (316 Stainless - A4)	1	https://www.accu.co.uk/metric-cap-head-screws/3157-SSC-M8-30-A4
M8 Nylocks (316 Stainless - A4)	3	https://www.accu.co.uk/hexagon-nylon-locking-nuts/7961-HNN-M8-A4
M8 Washers (316 Stainless - A4)	4	https://www.accu.co.uk/metric-flat-washers/72523-HPW-M8-A4
M5 x 20 Socket Cap Screw (316 Stainless - A4)	2	https://www.accu.co.uk/metric-cap-head-screws/4009-SSCF-M5-20-A4
M5 x 12 Socket Cap Screw (316 Stainless - A4)	4	https://www.accu.co.uk/metric-cap-head-screws/4005-SSCF-M5-12-A4
M4 x 25 Socket Cap Screw (316 Stainless - A4)	1	https://www.accu.co.uk/metric-cap-head-screws/3095-SSC-M4-25-A4
M4 Nylocks (316 Stainless - A4)	1	https://www.accu.co.uk/hexagon-nylon-locking-nuts/7958-HNN-M4-A4
M3 x 25 Socket Cap Screw (316 Stainless - A4)	1	https://www.accu.co.uk/metric-cap-head-screws/3070-SSC-M3-25-A4
M3 Nylocks (316 Stainless - A4)	1	https://www.accu.co.uk/hexagon-nylon-locking-nuts/7957-HNN-M3-A4
M3 Washers (316 Stainless - A4)	1	https://www.accu.co.uk/metric-flat-washers/72508-HPW-M3-A4
Heat inserts (2 off) needed, from pack of 50	1	https://www.amazon.co.uk/gp/product/B0D9QDNK1G/
Coil/solenoid	1	https://www.bensonsolenoids.co.uk/wp-content/uploads/2023/02/BLM5-Latching-Solenoid-Datasheet.pdf https://bensonsolenoids.co.uk/dc-latching-solenoids/
Shackles		
8mm Safety D Shackles	2	https://www.s3i.co.uk/EDshackle.php?pid=2666
Expanding Foam (buoyancy)		
Polycraft LD40 Expanding Polyurethane Foam - Hard/Rigid - 1 Litre Kit	1	https://amzn.eu/d/5fmlt8f

10.3 Appendix 3 – Drawing List

Smartrawl - Gate V2 Drawing List					
Part	**Qty**	**Design**	**Drawing**	**Complete**	**Extra**
End Ring (top)	1 off	☑			
Bottom (1m dia)	1 off	☑	☑	☑	
Centre column (40mm od - 950 long)	1 off	☑	☑	☑	
Outside Rods (20mm tie bars)	4 off	☑	☑	☑	
Column spacer (bottom)	1 off	☑	☑	☑	
Bottom Ring (1m dia) Assembly	1 off	☑	☑	☑	
Centre spinning cone					
Top ring (30mm bar)	1 off	☑	☑	☑	
Bottom Outer ring	1 off	☑	☑	☑	
Side panels	2 off	☑	☑	☑	
Lower Ring	1 off	☑	☑	☑	
Bearing column	1 off	☑	☑	☑	
central cone frame	1 off	☑	☑	☑	
4 legged support	1 off	☑	☑	☑	
4 Legged Support Bracket (3d printed)	4 off	☑	☑	☑	.STL
Interchangeable fins (3d printed)	10 off	☑	☑	☑	.STL
Lugs	4 off	☑	☑	☑	
Lifting Bracket	2 off	☑	☑	☑	
Centre Cone Assembly		☑	☑	☑	
Drilling jigs for assembly (3d printed)		☑			.STL
BOM				☑	
Latch					
Hook	1 off	☑	☑	☑	
Hook pad	1 off	☑	☑	☑	
Hook & pad (assembly)	1 off	☑	☑	☑	
Pivot	1 off	☑	☑	☑	
Link	1 off	☑	☑	☑	
Mounting bracket (3D Printed)	1 off	☑	☑	☑	.STL
Heat inserts (2 off a pack of 50)	1 off	https://www.amazon.co.uk/gp/product/B0D9QDNK1G/			
Coil/solenoid		https://www.bensonsolenoids.co.uk/wp-content/uploads/2023/02/BLM5-Latching-Solenoid-Datasheet.pdf			
Latch Assembly			☑	☑	
Latch bottle mounting plate	1 off	☑	☑	☑	
Smartrawl foam anchor (3D Printed)	4 off		☑	☑	.STL

Complete Assembly V2	1 off	☑	☑	☑	

10.4 Appendix 4 – 3D Print files list (for scale model)

Smartrawl - 3D printed 1/4 Scale Model		
Part	**Qty**	**.STL**
End Ring (top) v1	1 off	☑
End Ring (bottom) v2	1 off	☑
Centre cone (fixed) v6	1 off	☑
Centre cone (fixed) Spacer v1	1 off	☑
Centre cone v24	1 off	☑
4 legged panel centre v1	1 off	☑
Top ring v13	1 off	☑
1/4 panels v12	2 off	☑
50mm long spacer (3.2 x 5mm) v1	20 off	☑
45mm long spacer (3.2 x 5mm) v1	4 off	☑
250 wide x 200 high net* v1	2 off	☑
Above nets 3d printed, using 2 walls, 30% rectangular infill and no top & bottom layers		
Hardware		**Amazon links**
M5 x 300mm threaded rod, cut to 250mm (1 off)	1 off	https://amzn.eu/d/c0xRTdb
M5 nyloc nuts (2 off)	1 off pack	https://amzn.eu/d/fxCcf4G
M3 x 300mm threaded rod, cut to 250mm (4 off)	1 off pack	https://amzn.eu/d/9tH3JO0
M3 nyloc nuts	8 off	https://amzn.eu/d/8BA9J7I
M2.5 x 12 mm long (12 off) M2.5 nuts (12 off)	1 off pack	https://amzn.eu/d/fJtTXm4
Bearings - 10 x 5 x 4mm (3 off)	1 off pack	https://amzn.eu/d/df8e2xE
Selection of small cables ties to mount the nets	N/A	As required

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