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Canadian Scientific Submersible Facility, 2021 – 2022

2021, In review

Operations

The year 2021 started with many unknowns, under the Covid cloud, with no vaccines insight, significant delays at shipping terminals and virtually empty airports like something out of an apocalyptic movie.

It was early February, midmorning, and we found ourselves standing in the deserted departure area at the Vancouver International Airport. It was something that we'd never witnessed before in over 35 years of flying. I've taken off at 01:00 a.m. on a red-eye to Vegas, and I've landed at 3:00 a.m. on a return flight from the Far East; and never experienced this scene - nobody at a desk, no one cleaning, the shops all closed.

We knew all of the people at the airport that day. Eight of us were on our way to Wellington, New Zealand, with a 14-day mandatory quarantine awaiting us at the other end.

We had one member experience a "close contact" during the flight, but after 14 days in isolation, we all exited the hotel on time. Unfortunately, despite those two weeks, our equipment was still on a ship enduring its own version of quarantine. When we initially shipped the system, we had a seven-week buffer, and it was looking like it would take eight weeks due to delays at Long Beach, CA. Fortunately, the ship arrived a little earlier than planned, mobilization went smoothly, and the RV Tangaroa set sail about a week after our release from quarantine.

A few months after returning from New Zealand, a few ROPOS team members travelled to Quebec City to join the Canadian Coast Guard Ship Amundsen, to operate a new ROV (the Comanche) managed by Laval University. After completing some pre-mission trials, we worked for a month off the Labrador Coast and as far North as Pond Inlet on Baffin Island. What a great trip we had, seeing that part of the world for the first time and also managing to produce some of the best ROV diving that this group has experienced. We look forward to working with this group and their ROV again in the future.

A function of the challenges that Covid brought to the shipping industry in 2021, our equipment spent almost four months in a backlot in New Zealand. We ultimately decided to ship the system to Korea, given its advantageous position for trans Pacific shipments. Serendipitously as the equipment was loading in Wellington, we received a contract with our established clients from KORDI/KIOST to work on their new research vessel RV ISABU in the Indian Ocean.

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The team was sent to Korea in a staggered way to ensure the mobilization on the RV ISABU went smoothly, with the bulk of the team being on-site at the end of September. To enter Korea, we had to be double vaxxed, and thankfully we were, as we encountered Covid on this trip. Needless to say, more challenges ensued, and after a 3-week transit from Korea to the Indian Ocean, we began 4-weeks of operations SW of the Maldives and Diego Garcia. At the end of November, the RV Isabu went into Port Louis, Mauritius, to demobilize ROPOS. A day later, the ISABU was gone, and the RV Pelagia tied up to begin the mobilization of ROPOS for a month at sea with BGR. The last crew member returned home on January 7, after leaving on September 23. It was cold at home.

Instruments

We delivered the Remote Ocean Coring System (ROCS) drill to BGR in December 2020, and a year later, we successfully used it on the seafloor!! From the get-go, the expedition was viewed as an opportunity to learn how to drill with an ROV. After some initial adjustments, we succeeded at recovering samples from several different types of substrate. If you would like some more information about this tool and its applications, please see Page 8.

In the 3rd quarter of 2021, we delivered an Autonomous Temperature Acquisition Probe (ATAP) to BGR in Germany and then deployed it for the first time in December on several dives. It worked well, providing temperature measurements up to 60 cm below the seafloor, through an optical communication link. In addition, the probe revealed temperature gradients close to venting sites never before measured or anticipated. If you want some more information about the ATAP, there is a detailed description on Page 10.

2022, Looking forward

Operations

2022 is already shaping up to be a busy year, made more challenging by the continued slowdown in the world of international shipping. At CSSF, we are making plans to clone essential operating equipment and exploring how to move parts of the system by air to reduce the impacts of the shipping crisis.

The schedule in 2022 includes:

- Working with KIOST (Korea) again for two months in the April to June timeframe on the RV ISABU.

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- We are supporting OOI operations off the West Coast of Oregon in August and September.
- Then rounding out the year back in the Indian Ocean, working for BGR on the RV Pelagia.

Instruments

We plan to produce our first Remote In-situ Fluid Sampler (RIFS) this year. RIFS supports the acquisition of eight (8) discrete hot fluid samples and one (1) hot "gas-tight" sample. Please see Page 12 for more details about RIFS.

Operations 2021, Expedition Summaries

NSF/GNS Expedition – RV Tangaroa, March 6 – 26, 2021

In February 2021, 9 members of the CSSF team travelled from Victoria, Halifax and St. Johns to Wellington, New Zealand, to participate in an NSF/GNS funded expedition on board the NIWA research vessel *Tangaroa*. To meet New Zealand's COVID requirements for entry into the country
the team was quarantined for 14 days in a hotel in Wellington in advance of proceeding to the ship.

The expedition was part of a multi-year study focused on the Hikurangi subduction zone offshore the North Island of New Zealand. The purpose of this work is to advance scientific understanding of the causes and consequences of slow-slip events and large earthquakes at the Hikurangi subduction zone, ultimately contributing to the improved understanding of hazards posed by the subduction zone.

ROPOS spent 3 weeks recovering numerous instruments deployed in 2019 and downloading data from several fixed systems on the seafloor. In addition, the ROV team was tasked to find 5 lost instrument packages that were no longer communicating with operators at the surface.

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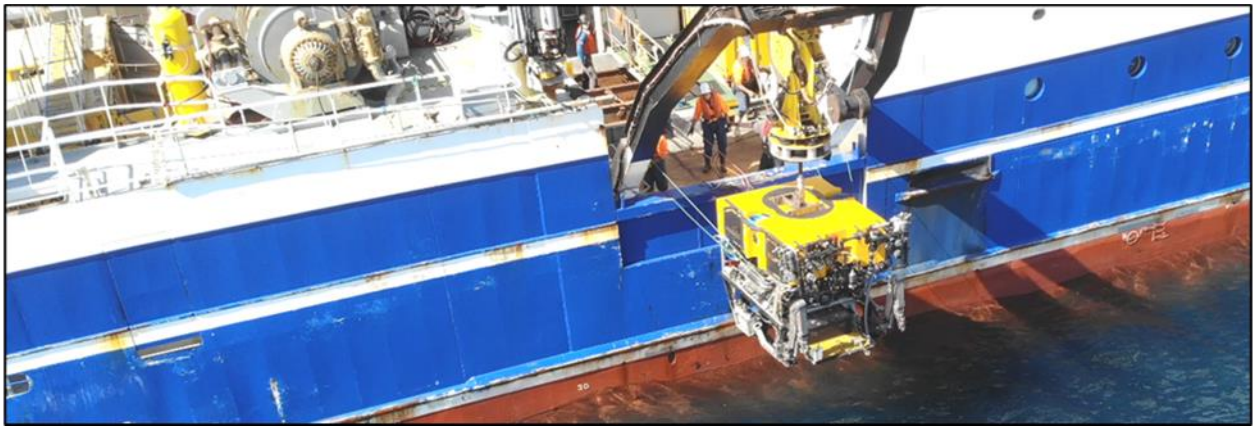

Dr. Evan Solomon from the University of Washington deployed 16 osmotic samplers by ROV in 2019 at multiple locations offshore from the Northern and Southern ends of the North Island. Deployment depths ranged from a few hundred meters, to over 3,000 m. All these samplers were recovered without incident with the exception of two units, which were lost at the surface during recovery of the ROV in rough weather. Fortunately, the schedule allowed for a search and recovery dive at the same location later in the trip, during which time the lost packages were located and recovered safely.

During the expedition ROPOS visited two IODP drill holes outfitted with CORK observatories. The CORKs host a data logger and pressure sensor package at the wellhead connected to hydraulic lines conveying fluids to the sensors from hundreds of meters down the bore hole. These sensors measure changes in pore pressure/volumetric strain down the borehole, which are used to measure changes in crustal strain during offshore slow-slip events. ROPOS connected an underwater mate-able connector to each CORK and successfully downloaded over two years of data from each logger for Dr. Laura Wallace at GNS. Of particular interest was data recorded following a magnitude 7+ earthquake that fortuitously occurred only a week before the voyage left port, as well as a large slow-slip event that occurred beneath the CORKs in 2019. ROPOS also connected to two BPRs (bottom pressure recorders) at two other locations and downloaded two years' worth of data from each.

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The final objective was to visit 5 separate sites to investigate why instrument systems deployed at the surface 2 years prior were no longer communicating. These ocean bottom pressure recorders were outfitted with flotation and an acoustic release system with drop weights, and were deployed at the surface and geo-located using a triangulation procedure. ROPOS managed to locate the original positions of 4 of these systems; 1 location still had an instrument on site which was recovered, and at the other 3 sites only a drop weight could be found, indicating the packages released the weight prematurely, and drifted off. The 5th site was not visited due to poor weather.

The expedition had a few extra days at the end for some exploring, so a day was spent on Bennett Knoll, East of the central coast of the North Island, and another was spent diving in Cook Strait to investigate a major active fault (the Boo Boo Fault), and finally the last few days were spent offshore the Northeastern South Island. This final leg of the journey was focused on exploring for methane seep habitats on Kekerengu Bank. Acoustic surveys from prior voyages in the area had
indicated the possibility of methane bubbles in the water column. These efforts were fruitful, with expansive, dynamic methane seep habitats found across the bank. These discoveries have expanded the researcher's knowledge of biological and geological processes offshore of New Zealand and have contributed to several on-going projects in the region.

By the numbers:

- 18 Operational Days (March 8 – 25).
- 23 ROV Dives.
- 176 Hours, ROV in the water.
- 43+ Hours, longest dive.
- 1,778 Digital still images.
- 17 Instrument systems recovered.
- 8 Years of CORK and BPR data downloaded.
- 20 Push cores collected using the manipulators.
- 2 Gas Tight Samples taken.
- 27 Geological samples collected in rock boxes.
- 54+ Biological samples collected in bio-boxes, suction sampler canisters.

KIOST Expedition – RV Isabu, October 11 – November 29, 2021

The CSSF team implemented a staggered travel plan to Korea to ensure expertise was available for the integration of ROPOS on the RV Isabu at appropriate times. The bulk of the team arrived in later September and coalesced in Busan, a large port city at the Southern extent of the Peninsula.

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A number of factors impacted the departure of this expedition including challenges with shipping, COVID infection and weather. Ultimately, once a typhoon near Taiwan moved on, the RV Isabu was able to leave the KIOST pier on October 11.

Due to the risk that a COVID outbreak posed to the success of the expedition, the management at KIOST determined the safest approach would be to have the entire expedition crew on board for the two and a half weeklong transit from Korea to the Indian Ocean. For the CSSF team, this time was well spent maintaining and configuring the ROPOS system for the upcoming operations. Concerns around piracy in the Strait of Malacca saw the ship transformed into what looked like a floating prison with razor wire encircling the vessel at the lowest points. The ship crew also included security personnel with special training in piracy. Once clear of the Strait of Malacca the RV Isabu headed West towards the first science sites, just SW of the Maldives.

Leg 1

The first scientific leg of the expedition was focused on biological investigations of the hydrothermal vents in the previously discovered Onnuri Field, and the exploration of four other sites in the region with potential for hydrothermal activity. The operational mode was 12 hours of ROV time per 24-hour period, and dive activities included visual inspection and mapping of hydrothermal vents, biological and environmental sampling (benthic animals, plankton, bacterial mats, seawater, plume water, sediments) and geological sampling (chimney/rock fragments). To compliment the environmental sampling, several instruments were integrated with ROPOS, including Methane and CO_2 instruments, an Oxidation-Reduction Probe (ORP) and a second CTD with additional sensors including pH.

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By the numbers:

- 12 days on site and 11 dives, totally 117 hours of dive time.
- 3 new active vents discovered at the study area on the Central Indian Ridge.
- 2,500+ pictures taken for generating a photo-mosaic of the Onnuri vent field.
- 50+ push cores of sediment taken.
- 500+ biological samples collected.
- 20+ rocks and geological samples collected.

Leg 2

The second leg of the expedition started with a crew change in Port Louis, Mauritius. The KIOST "biologists" from Leg 1 departed, with the KIOST "geologists" taking their place. In addition, 2 more CSSF personnel joined the RV Isabu so dive operations could expand from 12 hours a day to a full 24/7 mode. The ship left Port Louis in the early morning of November 17 and was back on site at Cheoeum ("first time") Vent Field in the early hours of November 20.

This leg of the expedition was focused on the visual inspection and sampling of geological and other materials in and around existing and/or anticipated vent sites. The primary mode undertaken during this leg was for the ROV to follow predetermined survey lines based on previous studies that looked for signs of vent water in the water column, and sulphides in sediments and rocks. In addition to visual surveys, the chemical sensors (CH_4, CO_2, ORP) mounted on the ROV were monitored for indications of plume water. A large number of rock and chimney samples were collected during this leg, and some biological and environmental sampling also took place at specific sites.

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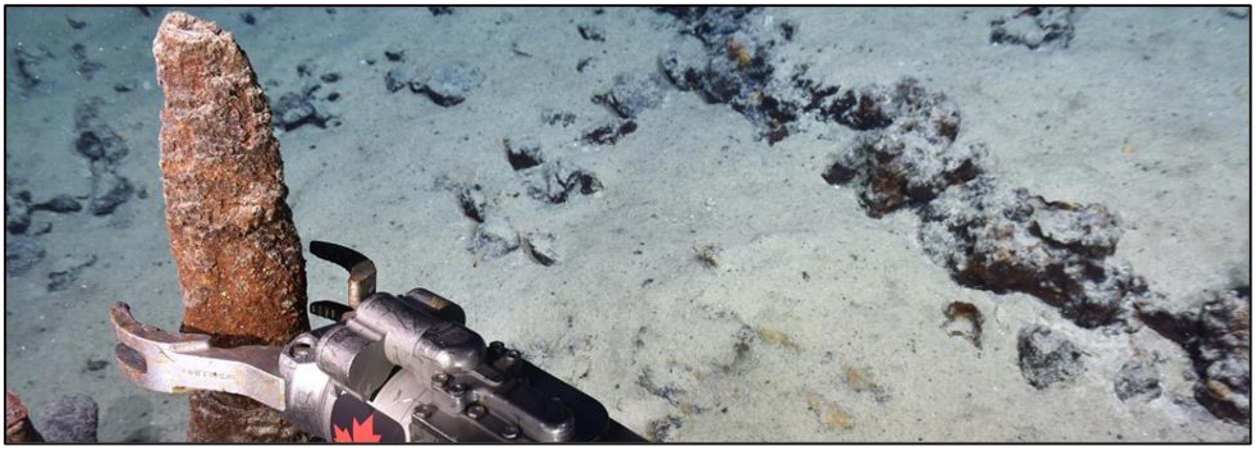

By the numbers:

- 7 days on site and 6 dives, totally 114 hours of dive time.
- 4 active and inactive hydrothermal vent sites investigated along the Central Indian Ridge.
- 27 push cores of sediment taken.
- 50+ rocks and geological samples collected.
- 30+ biological samples collected.

BGR Expedition – RV Pelagia, December 1 – 31, 2021

The final expedition in 2021 was another month in the Indian Ocean with BGR Germany.

(summary required)

Instrument Developments in 2020/2021

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Remotely Operated Core Sampler, Multi-Core (ROCS II)

The ROCS II is a 4,000 m rated seabed coring tool specifically designed for integration with a remotely operated vehicle (ROV). The ROCS II is operated and controlled through a customized hydraulic valve pack. The motor is coupled to a 2-speed gear box for torque/speed control which affords the operator flexibility when adjusting to more difficult drilling conditions. An integrated magazine supports up to four core tubes per dive, and each tube can be configured differently to allow for the sampling of different substrates.

General Specifications

Operating depth	4,000 m
ROCS II weight in air (with empty core tubes)	440 kg
ROCS II weight in water (with empty core tubes)	320 kg
Overall dimensions	1,626 mm W x 508 mm D x 2,210 mm H
Drilling orientation	Vertical
Maximum number of core tubes	4
Core diameter	75 mm
Core length	1,000 mm
Maximum drill pushing force (coring)	100 kg
Maximum drill pulling force (core breaking)	4,536 kg
Nominal Core recovery percentage	84% basalt, 53% unconsolidated material
Fail safe	Core detent release system

To integrate the ROCS II with an ROV, a certain amount of customization by the ROV operators is required. A method for attaching the drill to the ROV needs to be determined, and locations for the hydraulic valve pack and other auxiliary components need to be made available. The mounting of a variable speed thruster above the drill head is recommended for providing the required force on the drill bit, and a method for stabilizing the ROV during coring on uneven ground is also advisable. In addition, multiple cameras and lights are required to observe and record the drilling operation. Additional ROCS II features include:

- A variety of customized parts for the core tubes, including barrels with liners for consolidated rock, extended nose barrels with liners for unconsolidated rock/consolidated sediment, and Shelby push cores for softer sediments.
- A breakaway fitting connecting the core barrel to the drill head which acts as an emergency release for the ROV if the core barrel gets stuck, or in the event the ROV or ship lose power and/or control.

- Software for the display of all sensor data in real-time and for the control of all hydraulic functions. The GUI also displays errors and warnings based on threshold settings.
- A custom core extraction system .
- Optional spares packages, from basic, to comprehensive.

The ROCS II mounted to the ROPOS ROV.

The ROCS II free-standing on its deck plate.

The ROCS II core barrels.

The ROCS II hydraulic valve pack.

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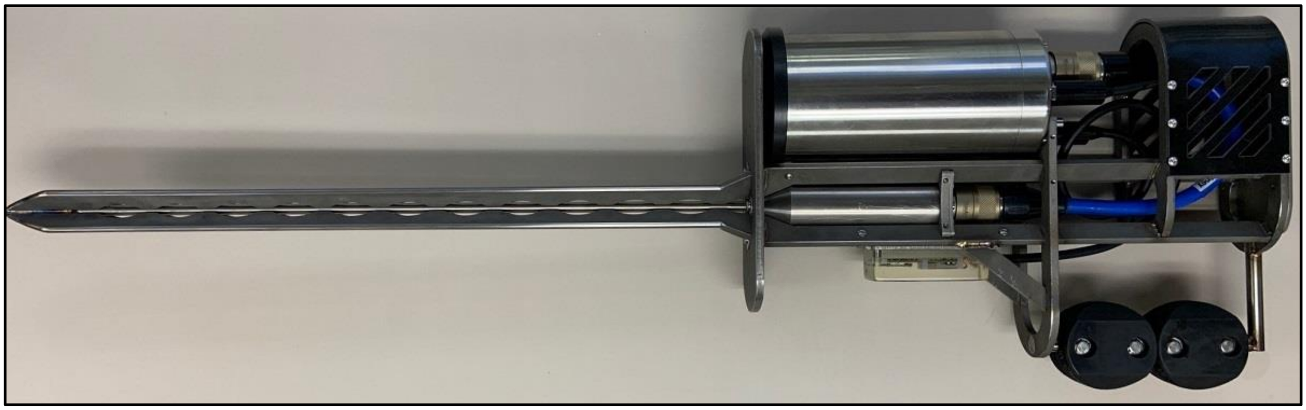


Autonomous Temperature Acquisition Probe (ATAP)

The ATAP is a battery-powered 5,000 m rated temperature measurement instrument system. The data from the ATAP provides insight into the extent of hydrothermal activity beneath the seafloor.

The system supports a multi-thermistor probe, designed to measure temperature in seafloor sediments. The system is capable of both real-time data acquisition and internal logging. When the ATAP is submerged, wireless communication via an optical modem pair is used for real-time data monitoring, re-configuring the instrument, and for downloading data during the deployment.

ATAP features include:

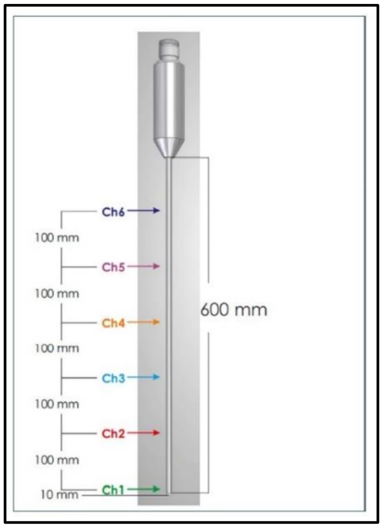
- A 60 cm long titanium probe with 6 PT-1000 thermistors, separated by 10 cm, enclosed in a protective framework made of titanium. The thermistors have a range of 0 ^{o}C to 200 ^{o}C, and an accuracy of +/- 0.1 ^{o}C

- A titanium 1-atm housing containing a data logger, thermistor interface electronics, a communication interface, and a battery power supply.

- The point-to-point optical interface allows a remote user to stop/start logging, upload data files, and configure and calibrate the thermistors on the seafloor. One optical transceiver is mounted to the probe, and the other is integrated with an ROV.

- The wireless communication interface simplifies the deployment of the probe by ROV operators as there are no cables to manage. The ATAP can also be left in-situ to log data while the ROV conducts other tasks.

- A bench top control box for providing a direct connection to the ATAP when it is out of water is included.



The 60 cm long ATAP probe and the relative position of the 6 thermistors along its length.

The ATAP uses a pair of Hydromea Luma optical modems for underwater communication.

Included is a benchtop control box for communicating with the ATAP out of the water.

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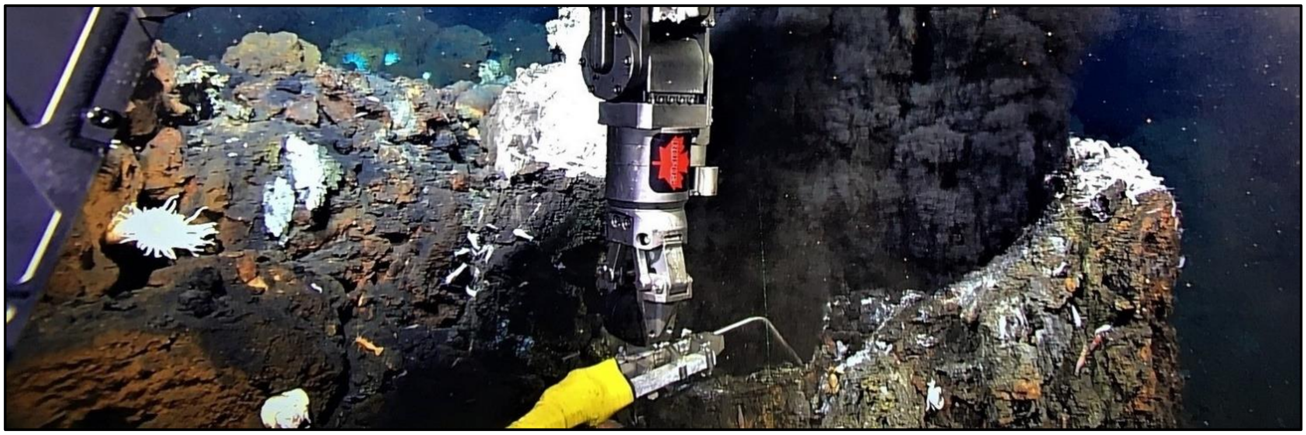

Remote In-situ Fluid Sampler (RIFS)

The RIFS is a high temperature fluid sampling system capable of capturing multiple discrete samples during a single dive. The RIFS is a self-contained unit requiring only one connection for serial communications and power. The system has been designed to work with any ROV, with minimal integration effort. Features include:

- A depth rating of 4,000 m.
- 8 inert sample bottles, readily accessible for installing and removing, before and after the dive.
- Inert plumbing, including tubing, pipes, connectors, valves, etc., upstream of the bottles.
- Individual valves at each bottle for controlling the flow of fluid into each bottle.
- A water pump with the capacity to draw water at 3-4 L per minute at temperatures up to 400 °C at the intake nozzle, which is then cooled to ~ 100 °C by the time it reaches the sample bottles (assuming an ambient water temperature of ~ 2 °C).
- An oil-filled electric motor for driving the water pump (7 A at 24 Vdc). Suction at the intake nozzle is created using an Eductor, which keeps the hot, acidic vent fluid away from the water pump's moving parts.
- A diversion mechanism to reverse the flow in the plumbing section between the intake nozzle and the sample bottles to clear away any remaining fluid from the previous sample and/or other material/detritus that is resident in the upstream lines.

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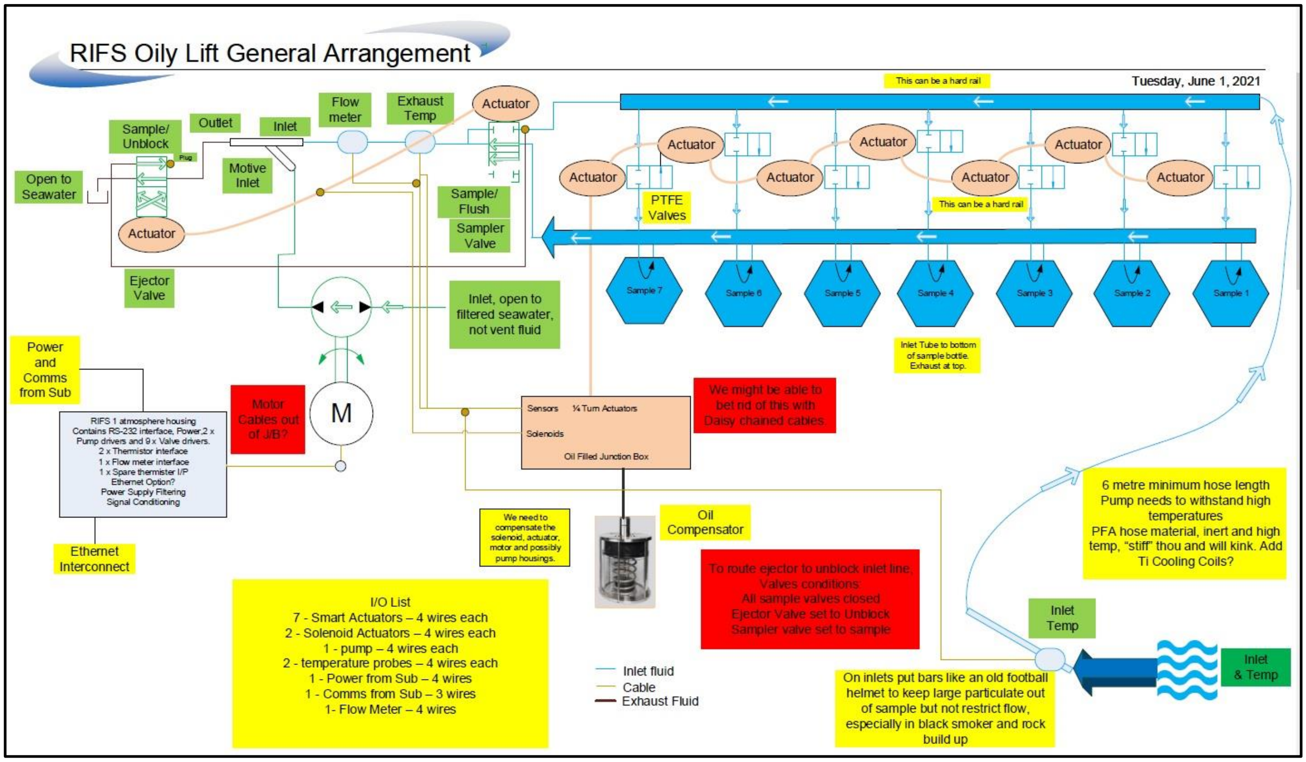
- A 1-atm titanium housing to enclose all PCBs for control, power conditioning and protection.

- Two integrated temperature probes; one at the intake nozzle, and the second just downstream of the bottles for characterizing and tracking the vent fluid in the system.

- A software application with a GUI for the control and the monitoring of the RIFS system.



The system diagram for the RIFS which includes all the major components of the system and their relative positions.