RV *Investigator* Voyage Plan

Voyage #:	**IN2017_V02**		
Voyage title:	SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasmania		
Mobilisation:	Hobart, Wednesday-Thursday, 15-16 March 2017		
Depart:	Hobart, Friday 17 March 2017 ~ 08:00, to allow procedural tests in Adventure or Storm Bay that day and arrival at SOTS by midnight on Saturday 18 March for a deep CTD before beginning mooring deployments at first light on Sunday 19 March.		
Return:	Hobart, Wednesday, 29 March 2017 (targeting 16:00)		
Demobilisation:	Hobart, Thursday, 30 March 2017		
Voyage Manager:	Max McGuire	Contact details:	Max.mcguire@csiro.au 0477 397 439
Chief Scientist:	Co-chiefs: Thomas W Trull (CSIRO/ACE CRC) Eric Schulz (BOM)		
Affiliation:	CSIRO / ACE CRC BOM	Contact:	Tom.Trull@csiro.au E.Schulz@bom.gov.au
Supplementary Projects			
Principal Investigators:	Mark Rayner		
Project name:	International Nutrient Intercalibration Exercise		
Affiliation:	CSIRO	Contact:	Mark.Rayner@csiro.au
Principal Investigators:	Eric Woehler		
Project name:	Spatial and Temporal Variability in the Distribution and Abundance of Seabirds		
Affiliation:	Birdlife Australia UTAS	Contact:	Eric.Woehler@utas.edu.au
Piggy-Back Projects			
Principal Investigators:	Philip Boyd		
Project name:	Trace Element Cycling		
Affiliation:	UTAS	Contact:	Philip.Boyd@utas.edu.au
Principal Investigators:	Rudy Kloser		
Project name:	Acoustic estimates of zooplankton and fish distributions		
Affiliation:	CSIRO	Contact:	Rudy.Kloser@csiro.au

Scientific objectives

SOTS

The Southern Ocean has a predominant role in the movement of heat and carbon dioxide into the ocean interior moderating Earth's average surface climate. SOTS uses a set of three automated moorings to measure these processes under extreme conditions, where they are most intense and have been least studied. The atmosphere-ocean exchanges occur on many timescales, from daily insolation cycles to ocean basin decadal oscillations and thus high frequency observations sustained over many years are required. The current context of anthropogenic forcing of rapid climate change adds urgency to the work.

SOTS will also support two efforts that aim to advance understanding of the controls on two aspects of biological processes that contribute to the control of carbon dioxide uptake– trace metal limitation and zooplankton grazing, as described in the Piggy-Back Projects section.

Supplementary Project: Nutrients

This project will centre on the investigation of seawater nutrient analysis, specifically looking at the differences in results obtained by a series of international groups. The analysis of seawater nutrients is completed all over the world, conducted with many different instruments and methodologies. This voyage will assist in the furthering of knowledge on the analysis as well as allowing different groups to highlight differences between attained results. With close collaboration between potentially 5 scientific parties, the science of seawater nutrient analysis can be improved or refined upon.

Many aspects of this analysis will be studied, spanning from the collection of water to the final data processing. This international collaboration is beneficial for all involved, allowing all teams to advance their analysis techniques. The impact of this voyage will be the improved knowledge of nutrient analysis techniques, potentially meaning future data will be of higher accuracy and precision, lowering the uncertainty associated with analysis of samples.

Supplementary Project: Seabirds

The project seeks to quantify the distribution and abundance of seabirds at sea around Australia using standardised seabird survey protocols. One or two dedicated observers will collect real-time data on seabirds observed within 300m transect during daylight hours while the vessel is underway. Incidental observations will be collected while the vessel is stationary (eg CTD stations) or while the vessel is deploying/recovering moorings. The data collected will be compatible with previous seabird at sea surveys conducted around Australia and farther south, allowing for analyses and assessments to be extended by the current surveys. The distribution of seabirds at sea is strongly linked with oceanographic features such as convergences that concentrate prey at densities that allow for efficient foraging by seabirds. Our surveys on the voyage will link with oceanographic investigations to identify the types and strengths of oceanographic features at which we observe different species of seabirds that utilise different methods of feeding (surface seizing, diving etc). No dedicated ship time is required for the seabird surveys. Surveys are conducted by observers while the vessel is underway during daylight hours.

Voyage objectives

SOTS

The primary objective is to first deploy a new set of SOTS moorings (SAZ-19 and SOFS-6) and then recover the existing SOTS moorings (FluxPulse-1 lower section, and SAZ-18). Additional work will obtain ancillary information on atmospheric and oceanographic conditions using CTD casts, underway measurements, the Triaxus towed body, and autonomous profiling “Bio-Argo” floats.

Each of the SOTS moorings delivers to specific aspects of the atmosphere-ocean exchanges, with some redundancy:

- the SAZ sediment trap mooring collects samples to quantify the transfer of carbon and other nutrients to the ocean interior by sinking particles, and investigate their ecological controls.
- the Southern Ocean Flux Station (SOFS) measures meteorological properties and ocean properties important to air-sea exchanges, ocean stratification, waves, and currents.
- the (now superceded) Pulse biogeochemistry mooring focused on processes important to biological CO_2 consumption, including net community production from oxygen measurements and nitrate depletion, biomass concentrations from bio-optics and bio-acoustics, and collection of water samples for nutrient and plankton quantification.
- the FluxPulse mooring combines some elements of Pulse onto the SOFS platform to create a combined mooring, and was deployed for the first time in 2016, but broke into two sections. The top section has been recovered. The bottom section remains to be recovered. This combined mooring was intended to meet financial constraints. In 2017 we will use the simpler SOFS design, while redesigning FluxPulse for relaunch in 2018.

Supplementary Project: Nutrients

Key Voyage Objectives

1. Identify any differences in nutrient analysis accuracy and precision between scientific groups.
2. Assess different techniques of nutrient sampling, investigate areas of improvement.
3. Compare the different workflows for data processing between the groups.
4. Use and implications of international standard ‘Reference Material for Nutrients in Seawater’, produced by Kanso Co Ltd.

The exact location of CTD casts does not concern our project. Bottom casts are all that is needed.

10 CTDs are proposed, this includes 2 CTDs in conjunction with Tom Trull. It would be highly beneficial for this project to use the 36 bottle rosette, this allows the teams to collect much more water for analysis. This is vital, as the overall number of CTDs is rather low. CTDs are planned to operate at 0100 daily, this should hopefully be recovered before moorings work at first light.

CTD plan example

Date	CTD	CSIRO Hydro sampling	NIWA sampling	Group X sampling	Group Y sampling	Tom Trull sampling
19/03/17	1	X				
20/03/17	2	X	X	X	X	
21/03/17	3	X				X
22/03/17	4	X	X	X	X	
23/03/17	5	X				
24/03/17	6	X	X	X	X	
25/03/17	7	X				X
26/03/17	8	X	X	X	X	
27/03/17	9	X				
28/03/17	10	X				

A water budget is not necessary while using the 12L Niskins, all of hydrochemistry sampling will not use more than 3L per bottle. Nutrient sampling completed by other groups should not be more than 2L per group, as only small (<50mL) samples are collected.

Sampling of water from the CTD will be done on every CTD by hydrochemistry, this will include salinity, dissolved oxygen and nutrients (number of replicates as required for each group). The nutrients will sampled into Sarstedt 30mL tubes (62.543.001). The majority of the bottles fired will occur below the salinity minimum, within the Antarctic bottom water. This is to minimise any fluctuations in water collected by the Niskins, such that samples are completely homogenous throughout nutrient sample collection. This approach will help characterise each groups results, aiding in the investigation of Key Objective 1. By comparing the different results attained, the accuracy and precision of each team can be assessed.

To address Key Objective 2, other scientific parties will be given the chance to sample on CTDs which will be analysed to determine if there is any differences between the sampling techniques. It would be best if all groups could analyse the samples, so that statistical analysis of sampling methods can be achieved. This however depends on the scientific group’s instrumentation capabilities as well as voyage time constraints.

We plan to hold a few workshops where each team will have a chance to discuss and demonstrate how the data is processed through their method. These workshops will help meet Key Objective 3 and allow the different groups to gain an understanding of potentially alternate processing workflows. This can provide each group with an insight on the quality and robustness of the processing methods, translating to future improvements within each groups preferred method.

The workshops will also serve as a platform for the groups to teach and share knowledge of the different instrumentation used. It will be beneficial for all involved to gain an extra understanding of the alternative instruments for nutrient analysis. Hopefully scientific personnel involved will be able to take away key information that can be applied to future nutrient analysis.

In order to track the results produced by each group CSIRO Hydrochemistry will be providing Reference Material for Nutrients in Seawater (RMNS) to each group. This is a commercially produced standard material of a known concentration. By running this with each run, utilising RMNS from the same batch results of each team can be easily compared and checked for accuracy. However, it is a Key Objective to investigate the implications of utilising this commercially produced standard. It is of interest to learn how other groups use and treat these standards, as well as interpretation of the results. Extending from this, in order to further characterise and track results a Bulk Quality Control (BQC) will be made and distributed between participants. The BQC will consist of water collected below the salinity minimum, filtered through a 10μm filter and then poisoned with Mercuric Chloride (CONC?). This will serve as a secondary standard which will be used for intra-run result tracking. It will also provide additional data for analysis, boosting the statistical power of the investigations.

Supplementary Project: Seabirds

The observations on this voyage will complement existing data from the survey area collected between 1980 and 2005. These earlier data were collected from Antarctic Division research and resupply voyages. The early data were collected between Tasmania and the Antarctic, and the spatial and temporal overlap between current voyage and previous efforts allow integration of the data sets. Seabird observations will commence in the Derwent River and continue while the vessel is underway and during daylight hours. At least one student will be on the seabird team, allowing for their training in seabird observation protocols. Incidental observations of marine mammals, marine debris and kelp masses at sea will be recorded consistent with previous surveys.

Priority-ranked list of tasks to achieve the overall objectives

SOTS

1. Deploy SOFS-6 meteorology mooring
2. Deploy SAZ-19 sediment trap mooring
3. Recover SAZ-18 sediment trap mooring
4. Do CTDs (2 casts to 2250m) at the SOTS site, including collecting samples for nutrients, oxygen, dissolved inorganic carbon, alkalinity, and particulate matter analyses. (Note: this work may be achieved on a CTD cast carried out for the Supplementary Project: International Nutrient Intercalibration).
5. Carry out underway air and water sampling and sensor measurements, including bio-acoustics.
6. Tow MacArtney Triaxus one or more nights while at SOTS site.
7. Possibly deploy 1-2 autonomous profiling floats at the SOTS site, subject to availability
8. Tow CPR to SOTS site
9. Carry out tasks for the two Piggy-Back Projects that are closely aligned with SOTS:

Kloser Acoustic zooplankton and fish Piggy-Back Project:

i. With a vessel stationary, deploy PLAOS acoustic-optical profiling device to 1000m depth, 3 times per night for up to 5 nights. Each cast takes ~1 hour. Protocols have been developed for the PLAOS operations on previous trials and operational voyages. The deployments need to commence at night at least 1 hour after sunset and finish at least 1 hours before sunrise. If time permits deploy the PLAOS during the day for 1 -2 casts to characterise the vertical flux of organisms to assist with zooplankton grazing experiments.

ii. Operate the ships underway bio-acoustic sensors during the voyage to characterise the epipelagic and mesopelagic scattering. Trials of broadband acoustics from the vessels transducers will also be done on an opportunistic basis. Work in conjunction with SIT and GSM staff and attempt to identify the cause of high background noise levels on multiple frequencies of bioacoustics transducer. There will also be investigation into minimising interference on voyage critical acoustic equipment.

iii. Within time and weather constraints trial a new broadband acoustic system WBAT by attaching it to the CTD for casts that go to 1000 m. The method of attachment and deployment protocols will follow those developed during the 2015 RV Investigator voyage.

Boyd Trace Element Cycling Piggy-Back Project

i. Deploy Trace Metal Rosette three times to 1500m depth
ii. Deploy In-situ pumps twice to 1500m depth and twice to 500 m depth
iii. Deploy and Recover free-drifting RESPIRE/TMtrap device once for 3 days
iv. Potentially deploy trace element clean intake fish for underway iron sampling
v. Opportunistically deploy IMAS zooplankton net in the upper 50 m to collect particles
vi. Opportunistically deploy the CTD in the upper 200 m to collect particles at 1-2 depths

Rayner International Nutrient Intercalibration:

1. Carry out a deep CTD (4500m) every night while at the SOTS site
2. Sample every bottle for salinity, nutrients, oxygen
3. Compare nutrient analytical results

Woehler Seabirds

1. Carry out seabird observations throughout the voyage during daylight hours (no impact on ship operations)

Operational Risk Management

SOTS

Mooring operations will follow the stern A-frame deployment methods used during IN2016_v02, but with the modifications recommended by that voyage party (Appendix 1). The general mooring protocols are in the ship's Safety Management System (SMS), and these along with updated CSIRO Mooring Deployment Procedures will be reviewed with the crew and MNF.

Triaxus deployments will be as per MNF operational procedures.

Rayner International Nutrient Intercalibration Supplementary Project

Operations are limited to the use of the CTD and laboratories and standard MNF operating procedures will be followed.

Woehler Seabirds Supplementary Project

Access to observational posts will be at the discretion of the Master and subject to existing protocols.

Boyd Trace Element Cycling Piggy-back Project:

Operations will include deployment of the CTD, Trace Metal Rosette, in-situ pumps , free-drifting sediment traps, a zooplankton net, and potentially a trace-element clean water intake fish towed at ~3 m depth on the starboard side. All of these activities have been performed successfully on *Investigator* before and the existing standard safety protocols will be followed.

Kloser Acoustic Zooplankton Piggy-back Project

Operations will involve the deployment of the PLAOS system, as performed on RV Investigator previously. The existing standard safety protocols will be followed. We also plan to attach the WBAT acoustic system to the CTD and deploy to 1000 m as was done on RV Investigator in 2015.

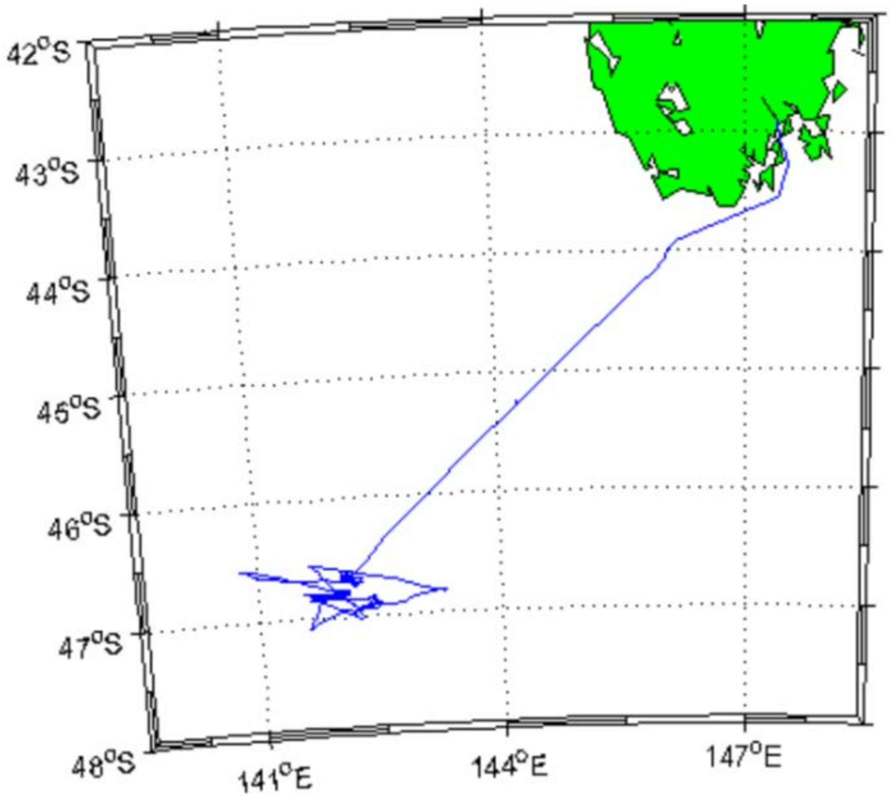
Overall activity plan including details for first 24 hours of voyage

(approximate timings, subject to weather and operational revision)

15 - 16	Mar	Mobilise: 1. SOTS: Load CSIRO winch and mooring containers (Sedtrap and Half-Height) and other mooring gear (SOFS-6 large float, anchors) to main trawl deck. Spool moorings to winches. 2. BOYD: Load trace element lab vans (old white clean van, TMR Rosette and deck box) 3. KLOSER load PLAOS to shelter shed 4. SOTS/BOYD/KLOSER/RAYNER Load lab equipment and begin internal labs setup 5. SOTS: Load Triaxus
17	Mar	0800: Depart In Adventure or Storm Bay (depending on weather and CTD test cast requirements of Rayner Nutrient Supplementary Project), test CTD, trace metal rosette (TMR), in-situ-pump (ISP), Triaxus and mooring deck procedures, possibly including practice recovery of a mock mooring. [CTD water will be available to Rayner and Boyd projects for tests] 1400: Begin transit to SOTS
18	Mar	Transit to SOTS towing CPR, doing underway sensor observations
19	Mar	Arrive SOTS site: 0000 0000-0500 Rayner Nutrients 1: CTD cast to bottom 0600-1800 SOTS: deploy SOFS-6 mooring 1800-2400 Kloser Acoustics 1: PLAOS casts
20	Mar	0000-0600 Kloser Acoustics 2: PLAOS casts 0600-1800 SOTS: spool on SAZ Mooring –deck ops only 0600-1000 Boyd Trace Elements 1: TMR cast to 1500m 1000-1400 Boyd Trace Elements 1: In-situ-pump cast to 1500m 1400-1800 SOTS: Deploy RESPIRE trap for Boyd Trace Elements* if time permits, otherwise 23 Mar 1800-2400 SOTS: mooring triangulation, sensor observations near SOFS-6, possible shallow CTD for Boyd.
21	Mar	0000-0500 Rayner Nutrients 2: CTD cast to bottom 0600-1800 SOTS: deploy SAZ-19 mooring, possible daytime PLAOS cast if time permits 1800-2400 Kloser Acoustics 3: PLAOS casts
22	Mar	0000-0500 Rayner Nutrients 3: CTD cast to bottom 0600-1800 SOTS: recover SAZ-18 mooring 1800-2400 SOTS spool-off SAZ-18 mooring – deck ops only, sensor observations near SOFS-6
23	Mar	0000-0500 Rayner Nutrients 4: CTD cast to bottom 0600-1800 SOTS spool-off SAZ-18 mooring – deck ops only 0600-1000 Boyd Trace Elements 2: TMR cast to 1500m 1000-1400 Boyd Trace Elements 2: In-situ-pump cast to 1500m 1400-1800 SOTS: Recovery RESPIRE trap for Boyd Trace Elements* or deploy if not done on 20 Mar 1800-2400 Kloser Acoustics 4: PLAOS casts

24	Mar	0000-0500 Rayner Nutrients 5: CTD cast to bottom 0600-1800 SOTS: attempt recovery of FluxPulse-1 mooring lower section 1800-2400 Kloser Acoustics 5: PLAOS casts
25	Mar	0000-0600 Kloser Acoustics 6: PLAOS casts 0600-1200 Rayner Nutrients 6: CTD cast to bottom 1200-1600 Boyd Trace Elements 3: In-situ-pump cast to 500m 1600-2000 SOTS: mooring triangulation, sensor observations near SOFS-6 2000-2400 Kloser Acoustics 7: PLAOS casts
26	Mar	0000-0500 Rayner Nutrients 7: CTD cast to bottom 0600-2400 Triaxus tow
27	Mar	0000-0500 Rayner Nutrients 8: CTD cast to bottom 0600-1200 SOTS: Recover RESPIRE trap for Boyd Trace Elements 1200-1500 Boyd Trace Elements 4: TMR cast to 1500m 1500-1900 Boyd Trace Elements 4: In-situ-pump cast to 500m 1900 begin transit to Hobart towing Triaxus
28	Mar	0000-0500 Rayner Nutrients 9: CTD cast to bottom Continue transit to Hobart, potentially towing Triaxus for a portion of transit
29	Mar	Arrive Hobart - 16:00 target time
30	Mar	Demobilisation

Voyage track example



Waypoints and stations

(Time estimates are at 10 knots)

	Decimal Latitude	Decimal Longitude	Distance (nm)	Total Distance (nm)	Steaming time (hrs)	Total Steam (hrs)
Hobart	42.87	147.35				
Storm Bay	43.33	147.350	27.62	27.62	2.76	2.76
SOTS	46.80	141.884	311.50	339.12	31.15	33.91
Hobart	42.87	147.35	352.44	748.98	35.24	69.15

Current Mooring Locations

Mooring	Latitude	Longitude	Depth
FluxPulse-1 anchor triangulation FluxPulse-1 release position*[1]	46° 46.635'S 46.77725 °S	141° 59.573'E 141.99289 °E	4658m 850m
SAZ-18 anchor triangulation	46° 47.017'S 46.78361 °S	141° 50.536'E 141.84226 °E	4582m

*[1] float position estimated by *RV Aurora Australis*

WARNING the damaged FluxPulse-1 lower mooring section could potentially surface at any time. The Ship should stay 3 miles away from the release position. Acoustic communication with this broken mooring will be attempted on an opportunistic basis.

New Mooring Target Locations

Mooring	Latitude	Longitude	Depth
SOFS-6 original site, now superceded SOFS-6 new site*[2]	46° 38.643 'S 46.64405 °S 46° 0.665 'S 47.01109 °S	142° 3.435 'E 142.05725 °E 142° 12.810 'E 142.21350 °E	4550m 4550m
SAZ-19	46° 49.824'S 46.83040 °S	141° 38.981'E 141.64968 °E	4600m

*[2] use new site because FluxPulse-1 lower section not recovered by *RV Aurora Australis*

Piggy-back projects

Piggy-Back Project 1.

Phillip Boyd, University of Tasmania, Trace Element Cycling

Scientific Objectives: Iron and other trace element availability has a strong controlling role on Southern Ocean productivity/particle export and thus biologically mediated CO2 uptake. The scientific objective is to determine the inventories of these elements and the processes that control their availability, cycling and export out of surface waters.

Voyage Objectives: To measure profiles of trace element dissolved and particulate concentrations, their stable isotopes and to examine the processes that produce and recycle them. This work was trialled successfully during IN2016_v02 SOTS/Eddy/Capricorn voyage and will be expanded in a dedicated project during IN2018_V02. The work during IN2017_v02 will in combination with those efforts deliver observations from 3 successive years and thus contribute to defining the stability versus interannual variability in trace element levels at the SOTS site.

Piggy-Back Project 2.

Rudy Kloser, CSIRO, Acoustic Zooplankton and Fish Distributions

Scientific Objectives: The small crustaceans, squids, fishes and gelatinous organisms that make up micronekton are a key biological component of the worlds' oceans many making nightly migrations from mesopelagic 200-1000 m depths to the surface epipelagic 0-200m depths. Understanding their diversity, distribution, biomass and energetic needs is key to further understanding the carbon cycle and linking primary production to top predators.

Voyage Objectives: The voyage objective is to map the top 1000m of the water column for these organisms at the SOTS site using the PLAOS acoustic optical system. Commonly nets, optic and acoustic samplers are used to determine the taxonomy, size, biomass, trophic linkage and energetics of zooplankton and micronekton. Each of these sampling methods have bias and uncertainty that need to be quantified prior to attributing changes within and between regions. In particular for the gelatinous community that covers a wide range of taxonomic and energetic groups that are difficult to sample with nets. To improve vessel mounted acoustic and net sampling methods of macro-zooplankton and micronekton a new profiling multi-frequency acoustic optical system has been developed with the ultimate aim of it being used as a remote sampling tool. On this voyage we will be testing the next phase of a profiling lagrangian acoustic and optical probe (PLAOS) to sample these organisms to depths of 1000 m. These tests will involve detailed sampling of the repeatability of the measurements when varying lighting, using new broadband acoustic sensors and a new buoyancy engine to enable the system to do repeat profiles. A new broadband sounder system will be trialled on the CTD to test if this could provide similar measurements to the more complex PLAOS system. Development of this methodology and technology will significantly advance our knowledge of micronekton biomass and distribution and provide the necessary structure and function understanding for the development of carbon and ecosystem models of the open ocean linking to the ACE CRC carbon program as well as the MESOPP ecosystem program.

Work in conjunction with SIT and GSM staff and attempt to identify the cause of high background noise levels on multiple frequencies of bioacoustics transducer. There will also be investigation into minimising interference on voyage critical acoustic equipment.

Investigator equipment (MNF)

SOTS

Trawl Deck Equipment and Support

- Install CSIRO mooring winch on mid-line forward on deck.
- Stern-ramp cover ("dance-floor") without overhanging lip on aft surface installed with gap protectors and mounts for user-supplied Bulls Horns fairlead.
- A-frame utility winches.
- Tagging line cleat attachment points fitted.
- 2 container slots free for installation of user-supplied containers and deck clear for installation of a third half-height container on starboard aft quarter

O2 Deck Equipment and Support

- Install Investigator net drum winch on Mezzanine with spooler-rail installed aft of it, as the best location as discussed with MNF and ASP for this voyage.

CTD Equipment and Support

- 36-bottle CTD-rosette with 10L Niskin bottles and MNF-O_2, MNF-PAR, MNF-transmissometer, MNF-fluorometer sensors mounted.
- Lowered ADCP with all heads working and logging
- CTD voltage inputs calibrated to correctly log sensor inputs
- MNF supplied hydrochemists to carry out oxygen sensor calibrations on land and analyses at sea (priority), as well as salinity and nutrient analyses. SOTS and Boyd Piggy-Back each require ~150 oxygen, salinity, and nutrient analyses.
- WOCE/Go-Ship compliant CTD data processing and output files to be provided, including error estimates for oxygen and nutrient parameters

TRIAXUS Equipment and Support

- Triaxus towed body and towed body winch, equipped with:
  - MNF supplied electronics, data display and logging, and piloting support
  - MNF dual CTs with oxygen electrodes
  - MNF-LOPC
  - user-supplied SUNA, PAR, and FIRE sensors

Underway Equipment and Support

- Multibeam/Multifrequency bio-acoustic system, with MNF supplied electronics, computing, and operational support
- Working and logging underway echosounder with bottom detection and real-time display
- Working and logging underway ADCP, with real-time display
- Working and logging underway thermosalinograph and fluorometer and real-time display
- Working hull mounted 12 kHz transducer for use with acoustic release deck unit

- Working drop keel for bioacoustics, thermosalinograph and ADCP data gathering deployed to >4m.
- Working and logging meteorological instruments including ISAR SST radiometer

Boyd Trace Element Cycling Piggyback Project

CTD, Triaxus, and Underway equipment and support needs are covered by the SOTS request above.

- Support for, including deployment winch for, MNF in-situ pumps, MNF TM rosette, MNF TM Clean (wet) laboratory container, (and user-supplied trace metal CTD rosette).
- Hydrochemistry support: Boyd requires ~ 150 oxygen, salinity, and nutrient analyses.
- Use of controlled temperature cabinets in Dry Clean Laboratory

Kloser Acoustic Zooplankton and Fish Distributions Piggyback Project

- Support for PLAOS device, including storage in the Shelter Shed and deployment from the hydraulic boom.
- Support to place a broadband device on the CTD
- Support to investigate why the RV Investigator has high noise on its bioacoustics sensors

User Equipment

SOTS

For Installation on Trawl Deck (see deck loading plan)

- Bullhorn mooring fairlead to be mounted on ship stern – ***this will mean that great care will be needed to avoid it for Triaxus deployments and recoveries***.
- CSIRO mooring winch - requires hydraulic leads to power supply installed in shelter-shed
- MNF mooring winch for SOFS-6 deployment and FluxPulse-1 recovery
- 1xhalf-height open-top containers to hold mooring equipment
- Full height container for storing and working on sediment traps, – requires monophase 240V 15 amp power supply. This container will also house the in-situ pumps for use during Boyd component.
- SOFS/FluxPulse float and recovery cradle
- (potentially) Recovered FluxPulse-1 damper and UBE 3-float pack
- (potentially) Recovered FluxPulse-1 RAS instrument package
- 2 mooring anchor stacks – 3 to be combined into SOFS-6 anchor, plus single stack for SAZ anchor
- ~6 cage pallets of mooring equipment
- Handheld and deck mounted pneumatic line throwers (“grappling gun”)
- Video cameras installed on trawl deck

For Installation in Shelter Shed

- Power Supply for CSIRO Mooring Winch
- TRIAXUS
- Pallet of mooring gear

For Installation in Ops room

- acoustic release deck unit to be mounted in the Ops room (and spare unit stored)

For Installation in Underway Lab

- pCO2 system (already onboard), Trull pigment filtration system in sink.

For installation in the General Purpose (Dry Clean) Laboratory, forward inboard bench

- Trull particle filtration system, also requires use of laminar flow bench in this lab

For installation on the Triaxus towed body

- SUNA nitrate sensor
- FIRE fluorescence induction and relaxation sensor (maximum depth 200m)

<u>**Boyd Trace Element Cycling PiggyBack Project**</u>

For installation in Dirty Wet Lab

- Free-drifting sediment traps

For Installation in Underway Lab

- Underway optics package including fluorometers and transmissometer

For installation in the General Purpose (Wet Clean) Laboratory

- Filtration system

For installation in the General Purpose (Dry Clean) Laboratory

- Particle aggregation device and roller tables

For installation in the Controlled Temperature Laboratory

- small volume (< 20 L) Incubation bags

PLAOS system to be installed in the Shelter Shed and deployed from the hydraulic boom
Requires adequate rope on the coring winch – modifications to the side for a pulley and an emergency acoustic release with be deployed over the side. A location beacon will be attached to PLAOS and this needs to be synchronised with the vessels position keeping system

A broadband acoustic device will be attached to the CTD as developed during the 2015 RV Investigator voyage.

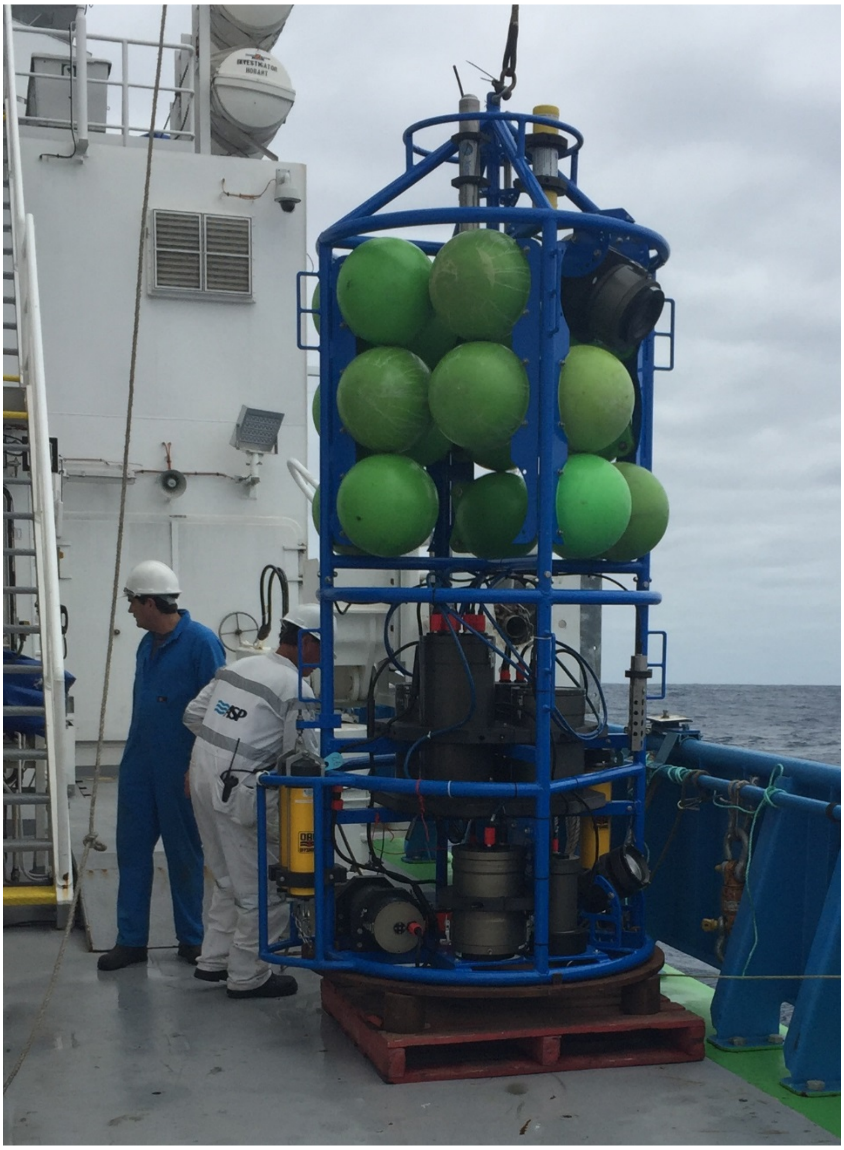


Figure: photo of Kloser PLAOS

Special Requests

Please see above *Investigator* Equipment and User Equipment lists for installation support needs.

Permits

SOTS

- Collection of seawater and sediment trap samples for return to Hobart under ACE CRC Quarantine permit #IP15013655.
- Mooring locations and buoy marking details will be provided to AMSA for notice to mariners.

Boyd Piggyback

Collection of seawater and sediment trap samples for return to Hobart under IMAS Quarantine permit #IP0001035393

Personnel List

1.	Max McGuire	MNF	Voyage Manager
2.	Aaron Tyndall	MNF	MNF SIT support
3.	Ben Baldwinson	MNF	MNF SIT support
4.	Steven Van Graas	MNF	DAP computing support
5.	Francis Chui	MNF	DAP computing support
6.	Frances Cooke	MNF	GSM support
7.	Cassie Schwanger	MNF	Hydrochemist
8.	Christine Rees	MNF	Hydrochemist
9.	Will Ponsonby	MNF	MNF SIT support
10.	Tom Trull	CSIRO-ACE	SOTS: Chief Scientist
11.	Eric Schulz	BOM	SOTS: Co-Chief Scientist, Dogger
12.	Peter Jansen	ACE-CSIRO	SOTS: Managing Engineer
13.	Jamie Derrick	CSIRO	SOTS: Mooring Technical Supervisor
14.	Gary Curtis	CSIRO	SOTS: Mooring deck work
15.	Darren Moore	CSIRO	SOTS: Mooring deck work
16.	Makito Yokota	JAMSTEC	SOTS: mooring engineer observer
17.	Rudy Kloser	CSIRO	PiggyBack-Kloser
18.	Tim Ryan	CSIRO	PiggyBack-Kloser
19.	Jeff Cordell	CSIRO	PiggyBack-Kloser
20.	Haris Kunnath	CSIRO	PiggyBack-Kloser
21.	Arti Verma	Curtin Univ	PiggyBack-Kloser
22.	Emma Cavan	UTAS	PiggyBack-Boyd:
23.	Mathieu Bressac	UTAS	PiggyBack-Boyd:
24.	Manu Laurenceau-Cornec	ACE-UTAS	PiggyBack-Boyd:
25.	Xiaoyu Chan	ANU	PiggyBack-Boyd:
26.	Eric Woehler	UTas	Seabirds
27.	Tracey-Ann Hooley	Mus. Victoria	Seabirds
28.	Cloe Cummings	UTas	Seabirds
29.	Mark Rayner	CSIRO	International Nutrient Inter Calibration
30.	Kendall Sherrin	CSIRO	International Nutrient Inter Calibration
31.	Graham Marshall	Global FIA	International Nutrient Inter Calibration
32.	Mariko Hatta	Uni of Hawaii	International Nutrient Inter Calibration
33.	Greg Olsen	NIWA	International Nutrient Inter Calibration
34.	Tae Rho	KIOST	International Nutrient Inter Calibration
35.	Purena Son	KIOST	International Nutrient Inter Calibration
36.	Hangoo Kang	KIOST	International Nutrient Inter Calibration
37.	Jun Sun	Chin. Acad. Sci.	International Nutrient Inter Calibration
38.	Guicheng Zhang	Chin. Acad. Sci.	International Nutrient Inter Calibration

Signature

Your name	Thomas W Trull
Title	Chief Scientist
Signature	Thomas W. Trull
Date:	27 February 2017

List of additional figures and documents

1. IN2016_V02 Report on Pulse Mooring Entanglement
2. Deck Plan
3. Mooring diagrams
4. Mooring Procedures will be provided separately - as updates of those provided previously to MNF (for IN2015_v01 and IN2016_v02) that are now part of ship management system (
   - SOFS/FluxPulse Mooring Deployment/Recovery Procedures –updated in Feb 2017, to be reviewed with ASP
   - SAZ Mooring Deployment/Recovery Procedure
   - UTAS drifting trap Deployment/Recovery Procedure
5. In-situ pump deployment procedure (as listed below):

Mclane pump deployment and retrieval

Deployment

1. Couple pumps top computer, program and insert new batteries (if necessary)
2. Spool hydrowire through block and attached weights (~100 kg)
3. Deploy weight by paying out ~50 m of wire
4. Move wire close to side of vessel
5. Attach lower Mclane pump clamp to hydrowire (see figures below)
6. Lift Mclane pump (~50 kg) and locate lower pin through eye on pump – requires three people
7. Secure upper clamp on pump – third person job while 1 and 2 hold pump, attach safety line
8. Attach pressure sensor (RBR logger) to hydrowire – determines the pump depth – and CTD (tbc)
9. Move hyrdowire away from vessel and then lower to desired depth – need monitor amount of wire out
10. Repeat from step 3 for next 4 pumps at chosen depths

Retrieval

1. Spool hydrowire
2. Once pump is at deck level move hydrowire close to vessel
3. Undo upper clamp – persons 1 and 2 hold pump while the third person undoes clamp
4. Lift pump off lower clamp
5. Remove lower clamp

IN2016_V02 Report on Pulse Mooring Entanglement with Recommendations for Mooring Operations (to be reviewed with crew)

N2016_v02 Pulse-11 Mooring Entanglement Summary
25 March 2016

The entanglement occurred on Sunday 20th March. Three discussions of the incident were held. These were on the bridge, on 21, 23, and 25 March. Participants included the Master, Chief Engineer, Chief Mate, Chief IR, Voyage Manager, Chief Scientist, Science Project Manager, Science Technical Supervisor and Science Mooring Specialists at each meeting. The IRs who had been deck during the incident and the deputy-Chief Scientist participated at the first two meetings.

This document provides a summary of the outcomes of these discussions, in four sections:

1. Summary of factors contributing to the entanglement
2. Procedural recommendations to reduce the potential for future entanglements
3. Engineering recommendations to reduce the potential for future entanglements
4. Statement regarding priorities and responsibilities during operations.

This document was written by Chief Scientist Tom Trull, with inputs and review by all participants.

Background:
The Pulse-11 mooring is an s-tether with a small surface float (Figure 1). Because the surface float is attached with elastic bungees that cannot be used to lift the subsurface components, the mooring is normally retrieved from the bottom end by grappling the lowest float pack next to the acoustic releases, after this pack surfaces, typically ~40 minutes after the acoustic signal is sent to free the mooring from its anchor. If the mooring surfaces as expected and is strung out by the wind and seas, then it is expected to lie on the surface as shown in Figure 2.

1. <u>Summary of the events leading up to the entanglement</u>

It is considered that there were several contributing factors to the entanglement:

a) The mooring did not surface as expected.

- Specifically the lowest float pack was not visible on the surface. Acoustic communication identified it as a constant 1000m away, the length of the line from it to the next lowest float pack. Based on this the supposition was made that some or all of the floats on the lowest float pack had imploded and thus the acoustic releases and this length of the mooring line were dangling vertically down below the rest of the floating mooring at a depth of 1000m. This implosion of a deep float pack had occurred twice previously with SOTS moorings and thus the supposition was consistent with the data in hand and the Science team's experience which was conveyed to the Bridge Team. All other float packs were visible and the mooring was strung out nicely in a line at this time. On this basis the decision to approach the second from bottom float pack was made.
- Importantly, after the entanglement the deepest float pack surfaced (with 4 of its 8 glass floats imploded). While the acoustic ranging data and intact recovery of the 1000m line to this deepest pack indicates that it was not involved in the entanglement, and did not surface under the ship, this could have happened and emphasizes that surfacing of a mooring in an unexpected state is an indication of heightened risk that must be carefully evaluated.

b) The ship needed to move close to the mooring to grapple it.

- Owing to the failure of the large deck mounted pneumatic grappling gun, the smaller shoulder fired pneumatic grappling gun was used. This required the ship to approach close to the mooring. This operation of closing on the floats and the risk associated was determined by the information available.

c) Initial grappling can change the mooring geometry in the sea, increasing the risk of getting it under the ship.

- The mooring was initially grappled from the starboard quarter and the line brought to the stern to begin recovery using the winch. This was the ideal situation, but unfortunately the grapple line parted and contact with the mooring was lost. During this time the mooring line was possibly pulled in a bight towards the ship.

d) The ship did not go around after the initial grappling failed

- Moving away might have allowed recognition of the possible changed geometry of the mooring, especially the ship position relative to the entire mooring array rather than just the nearest float pack, though the visible float packs were aligned for the approach. The ship was under control at all times and the second approach was based on unchanged information, again with the visible float packs aligned for the approach in order to grapple again (Figure 3). This was a considered action, and did not necessarily contribute to the entanglement, but nonetheless it is considered a contributing factor because the opportunity to further examine the mooring for the possibility of new hazards was missed. Whilst there was dialogue between Science and Ops with regards to" going around", this question was not directed to the Bridge. The Bridge, furthermore, did not advise Science and Deck that the ship was not going around.

e) The mooring line between grappled float pack and the rest of the mooring had a large loop.

- This loop is shown in Figure 4. Its presence was not expected, and must probably formed during surfacing of the mooring. The presence of this large bundle of loops is considered to be a key contributing factor to the multiple entanglement on the Ship's propeller, which was then compounded by other factors.

2. <u>Procedural recommendations to reduce the potential for entanglements</u>

a) Mooring work presents significant hazards to the ship.

- Accordingly, the Master and Officer of the Watch should be on the Bridge during mooring operations. In addition, the Master should also establish a "damage control" team who will have responsibility for evaluation of and recovery from any entanglement. This team will prepare tools such as cameras, ROVs, cutting implements on poles, etc. ahead of the mooring operation, and will establish a location and process for getting and evaluating information to lead recovery.

b) Rehearsals of operations are advantageous

c) Diagrams showing expected mooring geometry on the surface of the sea should be provided

- These should indicate expected spacings between floating elements, and detail identifying marks (and/or include photos of the float packs). The expected layout should be discussed with the bridge and deck parties during the toolbox meeting.

d) Approach and retreat plans for the ship movements during the grappling operation should be discussed during the Toolbox meeting so that the bridge, deck, and ops room teams all understand it and any deviations from the agreed plan should be challenged.

e) The mooring should only be released when the Officer of the watch, Chief Scientist, Chief IR, and Technical Supervisor are ready to observe it's arrival on the surface.

f) After release of the mooring the Officer of the watch, Chief Scientist, Chief IR, and Technical Supervisor should evaluate its layout on the sea relative to the expected layout. This effort should be as quantitative as possible in terms of estimated float pack spacings and should include information on the position of the surface float from GPS and the releases from acoustic ranging. In doing this, it may be useful to move the ship along the mooring to check component spacing. A plan view drawing of its layout should be made and possible locations of hazards such as floating line loops identified.
g) The mooring layout should be marked on a navigational screen that can be used to monitor the ship position relative to the mooring during the approach. This information should be updated using the mooring GPS and acoustic ranging position estimates. With the equipment available the ability to track non-radar reported objects in relative or true motion is not possible.
h) Consider use of the Fast Rescue Craft if conditions allow
i) Grappling should be from as far away as possible.
j) "Grapple fired", "mooring grappled" and "grapple lost, go around" should be radioed to the bridge
k) After grappling the ship should be moved into a position such as to tow the mooring from directly astern and cause its components to move away from the ship, before the mooring is brought closer to the ship.
l) If the grappling moves the mooring and then fails, this be defined as an "equipment failure" (along with near miss incidents, incidents, major weather changes and man overboard) and the ship should move away from danger and all concerned parties reconsider the possibility of important changes in the mooring layout before proceeding.

3. Engineering recommendations to reduce the potential for entanglements

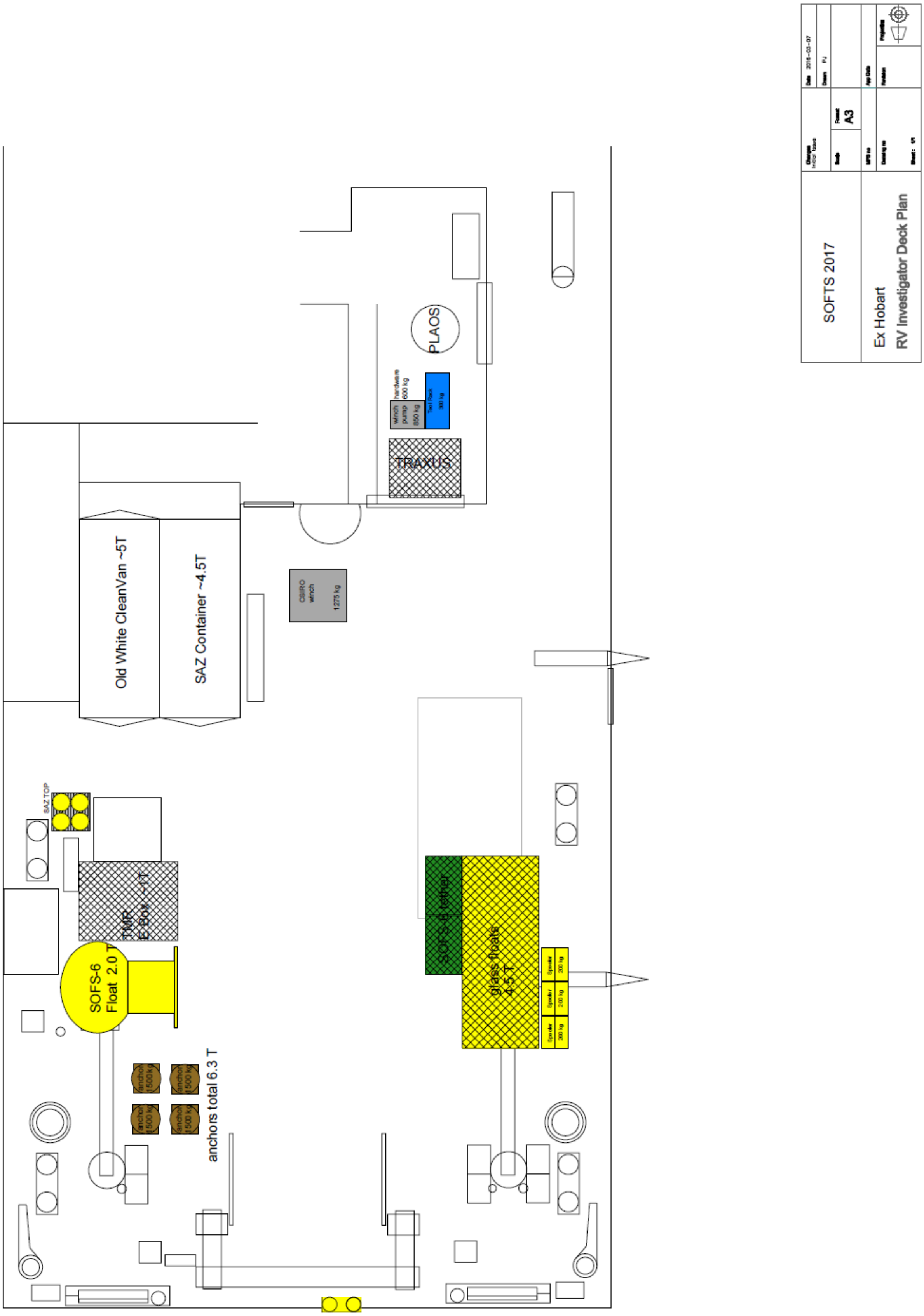
a) It is important to be able to distinguish the mooring components. More identifying marks or distinguishing colours are needed for floats and lines.
b) A powerful grappling gun capable of reaching the mooring at a distance of at least half the longest length of line between floats, and of sending a line capable of slowly towing the mooring is warranted
c) The grappling gun should be able to fire multiple successive grapples.
d) Grapples with gates to improve their retention on to the mooring, and without sharp edges that might cut lines, should be used

4. Statement regarding priorities and responsibilities during operations.

a) At all times the priority of the voyage is safety of the vessel and participants.
b) Science operations must operate within this mandate. Coordination of the science mooring program is led by the Chief Scientist, Project Manager, and Technical Supervisor, with oversight from the Voyage Manager.
c) If circumstances change such that operations other than the science operation are affected, then transition to another leadership process is needed, and this transition and leadership needs to be identified in advance. Examples include damage to ship equipment, or the vessel itself, changes in environmental conditions, injury or health of people on board. In relation to the entanglement of the mooring with the rear of the ship, identification of a "damage control team" would be appropriate. A leader with appropriate expertise should be identified, as well as those with specialist expertise.
d) The leader of this "damage control" effort needs to have the others report to him/her and should not be pulled into involvement in "hands-on" remedial actions.
e) Those not involved in this team need to be quickly cleared from the area of operations to minimise distractions and to allow the team to function effectively.

f) Decisions of the “damage control” team need to be made without rushing and with time for full consultation of the appropriate specialists and if available a scribe be delegated.
g) The priority for the damage control team is integrity of the ship and not the science equipment.
h) If any Party is in doubt of actions of another Question and Response
i) CCTV Cameras are to be such that critical operations are being recorded and the cameras not moved on their axis by any Party. Prior to Operation all camera lenses to be cleaned.

This document will be used for further determinations if required.


SOFTS 2017
Ex Hobart
RV Investigator Deck Plan
A3
PLAOS
TRAXUS
winch pump 850 kg
hardware 600 kg
Old White CleanVan ~5T
SAZ Container ~4.5T
CSIRO winch 1275 kg
SAZ TOP
TMP E-Box ~1T
SOFS-6 Float 2.0 T
SOFS-6 tether
glass floats 4.5T
anchors total 6.3 T

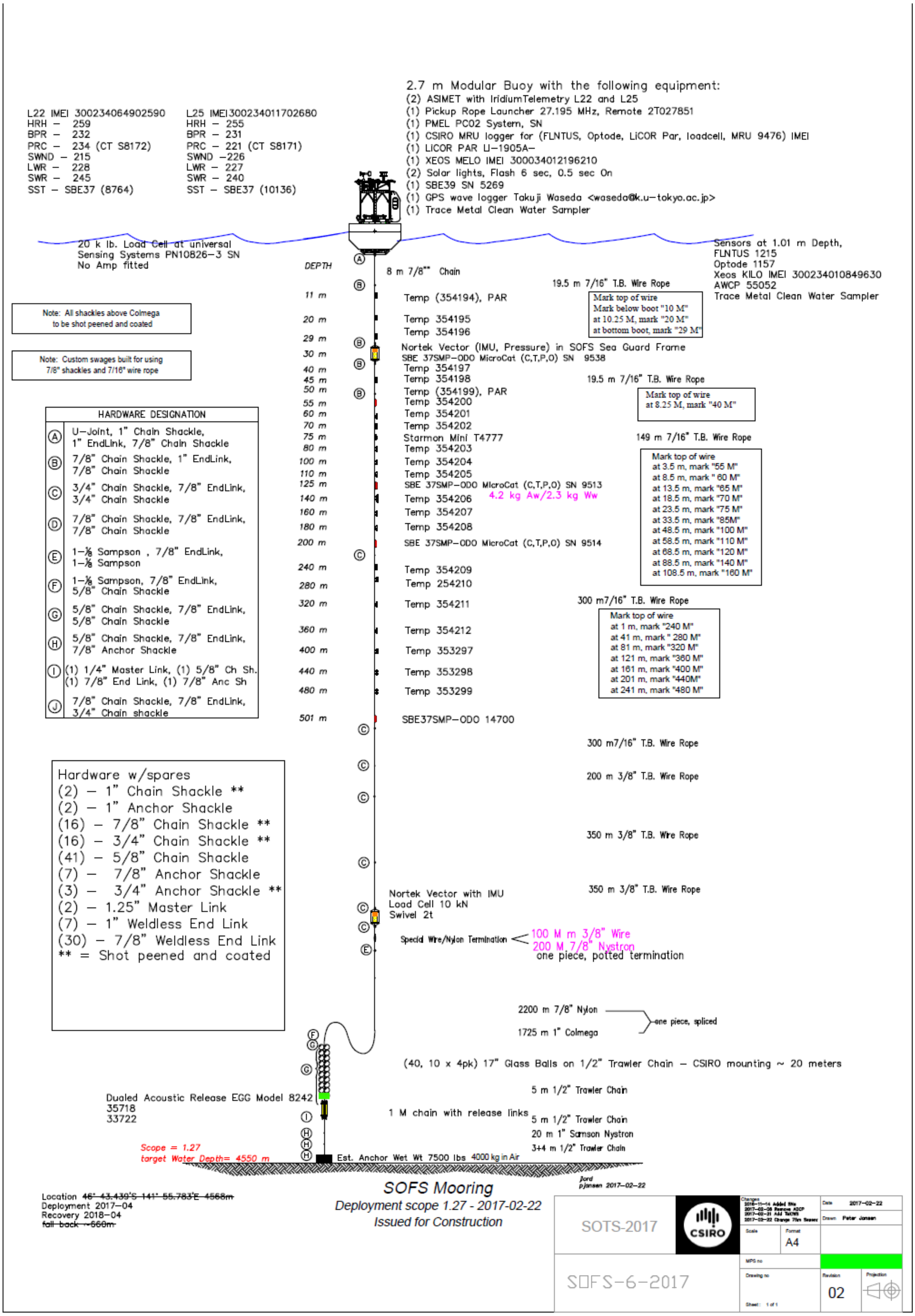
INV2017_V02 Mooring Diagrams

Deployments:

1. SOFS-6 build
2. SOFS-6 2-step deployment plans: first drogue and top float, then deep section and anchor
3. SAZ-19 build (single step anchor last deployment)

Recoveries

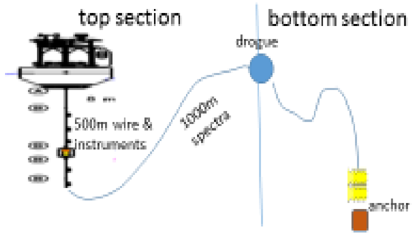
4. SAZ-18 build (top end mooring mast pickup recovery)

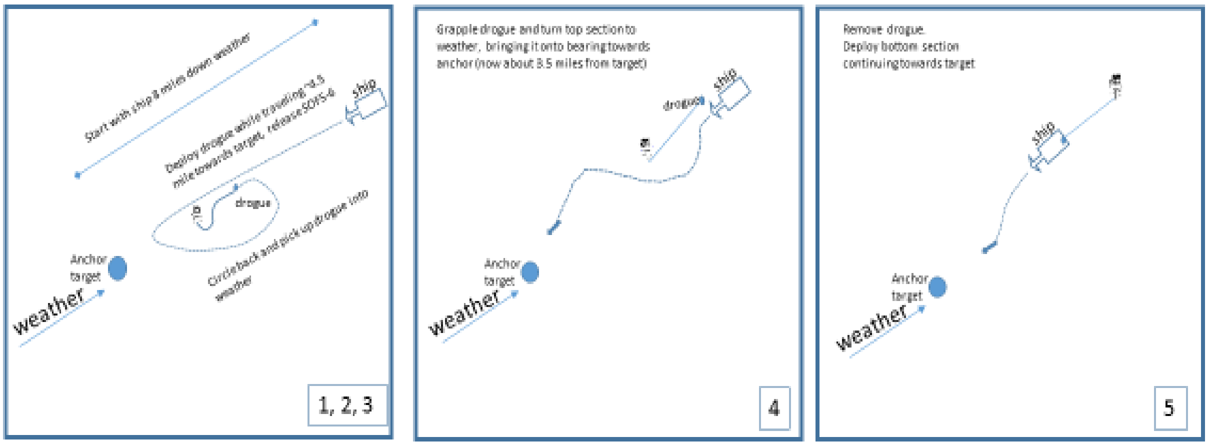


1. SOFS-6 build (to be deployed)

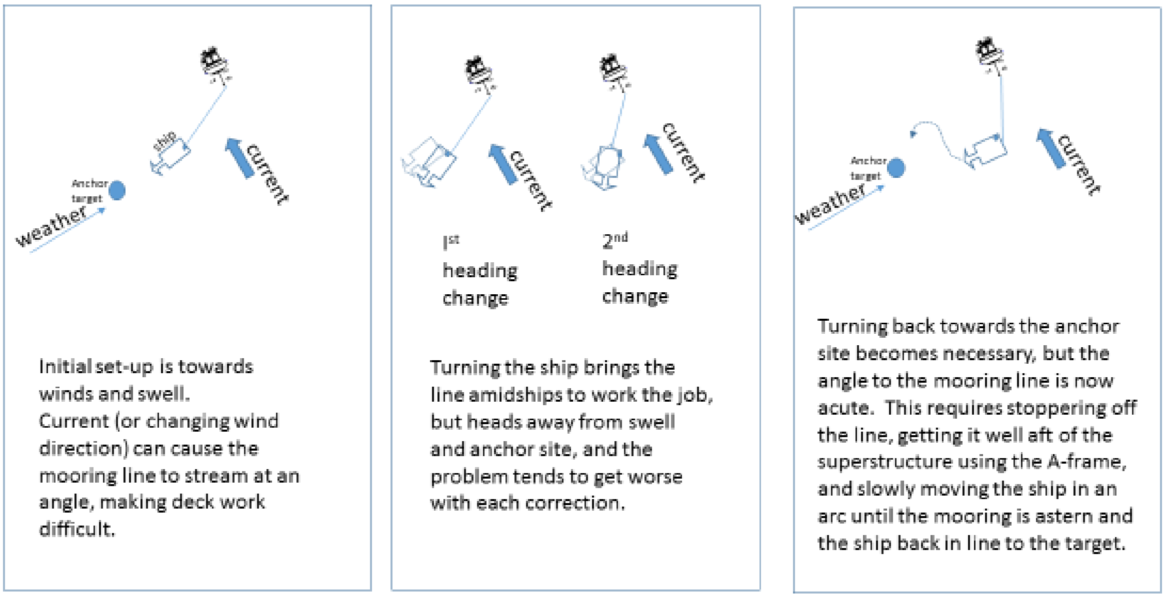
SOFS-6 deployment sequence

1. Start 8 miles down weather from anchor target; all deployment stages at 1-1.5 knots thru water
2. Deploy drogue,1000m spectra, and top 500m wire section with instruments
3. Deploy SOFS-6 tower, return and recover drogue and 1000m spectra
4. Tow slowly in arc to windward until mooring is laid out behind ship, remove drogue
5. Deploy remaining bottom section of mooring, finishing with anchor near target

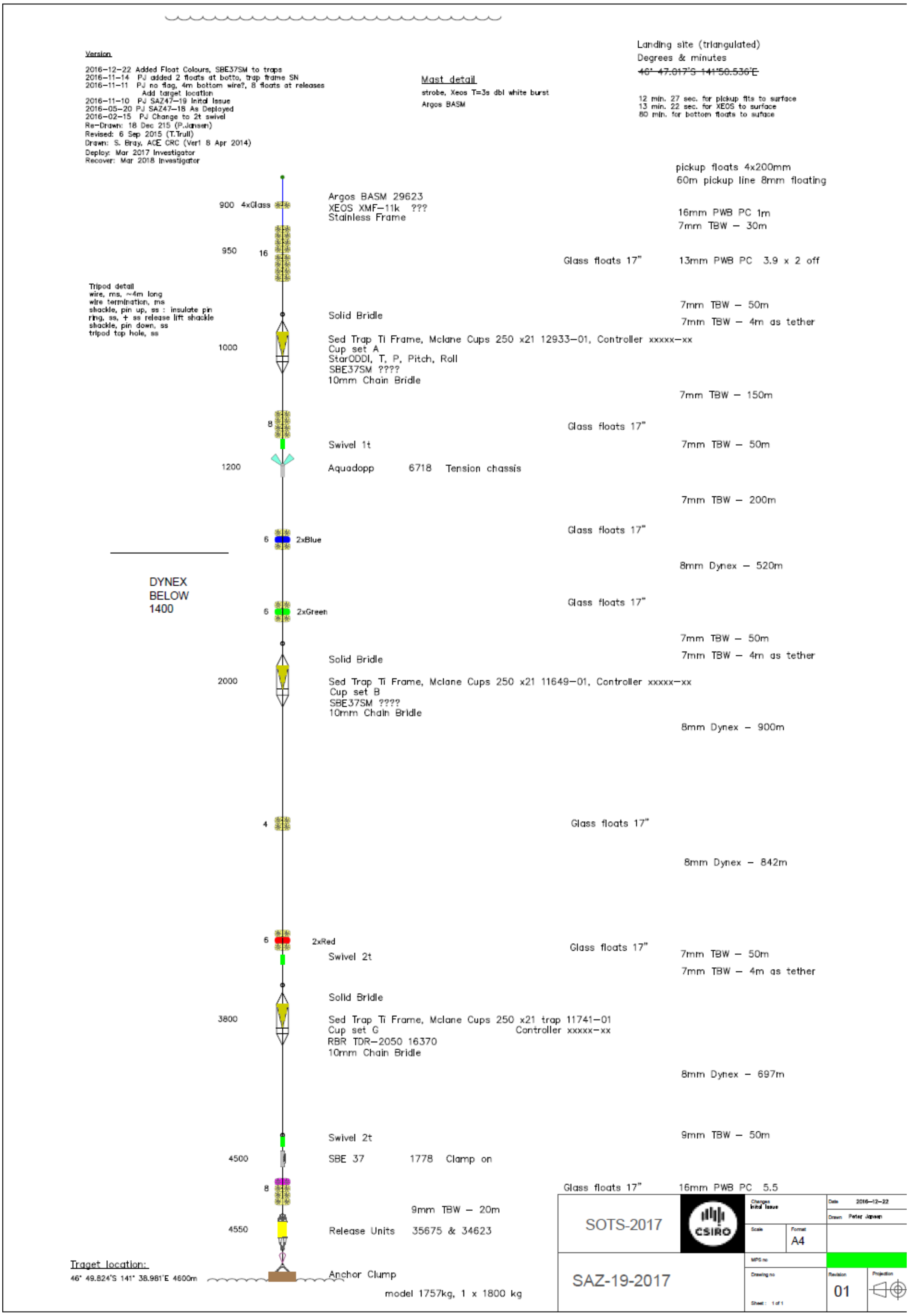




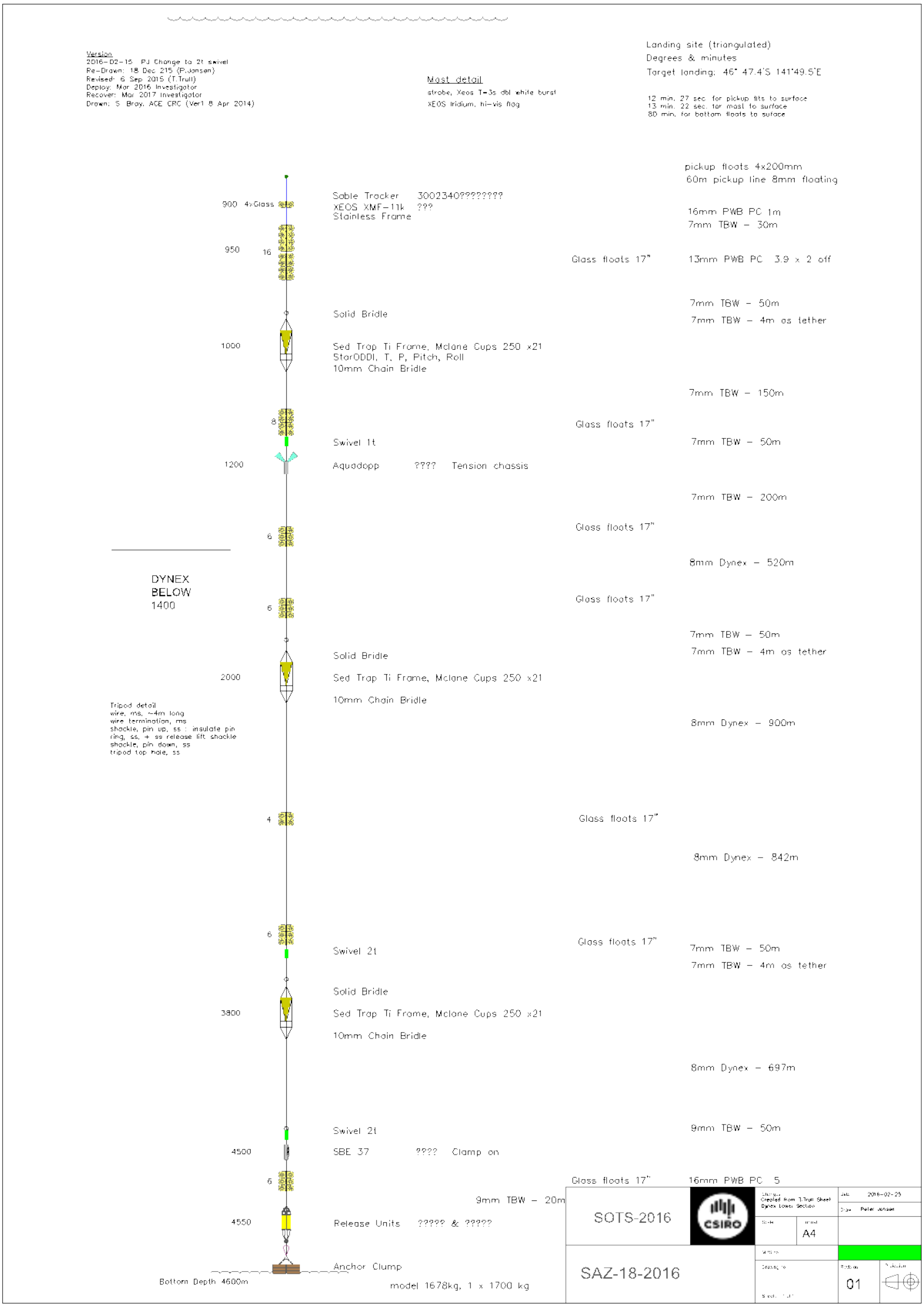
SOFS-6 deployment: keeping the mooring line mid-ships – short term heading changes followed by stoppered tows



2. SOFS-6 2-step deployment plans



3. SAZ-19 build (to be deployed)



4. SAZ-18 build (to be recovered)

Scientific equipment and facilities provided by the Marine National Facility

Some equipment items on the list may not be available at the time of sailing. Applicants will be notified directly of any changes.

Indicate what equipment and facilities you require from the Marine National Facility by placing an **X** in the relevant box.

(i) Standard laboratories and facilities

Name	Essential	Desirable
Constant Temperature Lab	X	
Underway Seawater Analysis Laboratory	X	
GP Wet Lab (dirty)	X	
GP Wet Lab (Clean)	X	
GP Dry Lab (Clean)	X	
Sheltered Science Area	X	
Observation deck 07 level	X	
Ultra-Low Temperature Freezer	X	

(ii) Specialised laboratory and facilities

May require additional support

Name	Essential	Desirable
Modular Trace Metal Laboratories (Old white TM van; TMR DeckBox)	X	

(iii) Standard laboratory and sampling equipment

Name	Essential	Desirable
CTD - Seabird 911 with 36 Bottle Rosette	X – preferred by Rayner Nutrient Supplementary Project	
Milli -Q System	X	
Laboratory Incubators	X	
Dissecting Microscopes	X	

(iv) Specialised laboratory and sampling equipment

May require additional support

Name	Essential	Desirable
TRIAXUS – Underway Profiling CTD		X
Continuous Plankton Recorder (CPR)		X
Trace Metal Rosette and Bottles	X	
Trace- metal in-situ pumps	X	
Stern Ramp (Trull - NEEDS TO BE COVERED WITH DANCE FLOOR)	X	

(v) Underway systems

Acoustic Underway Systems

Name	Essential	Desirable
75kHz ADCP	X	
Multi Beam echo sounder EM122 12kHz (100m to full ocean depth)	X	
Multi Beam echo sounder EM710 70-100kHz (0-1000m approx.)	X	
Scientific Echo Sounders EK60 (6 bands, 18kHz-333kHz)	X	
Trace metal clean seawater supply		X

Underway Seawater Instrumentation

Name	Essential	Desirable
Thermosalinograph	X	
Fluorometer	X	
Optode	X	
PCO2	X	