General Oceanics Underway pCO_2

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Outline

- Oceanographic Data Facility
- Underway pCO_2 systems
- General Oceanics (GO)
  - Design and options
- UCSD Ship Installations
  - R/V Sally Ride and Revelle
- Data Quality
  - Aux data needs
  - SOCAT

Oceanographic Data Facility

- Specialized services in oceanography since 1972
- Current Team:
  - Chemists (Susan Becker, Melissa Miller, John Ballard)
  - Data analysts (Joseph Gum and Michael Kovatch)
  - Science Advisor (Todd Martz and Jim Swift)
- Nutrients, oxygen, salinity, chlorophyll analysis
- Rosette and CTD sensor setup, calibration, and QC
- GO-SHIP, SOCCOM, UCSD vessel operations, shore analysis, equipment loan, SIO teaching assistance, and PI contracted cruises
- Analytical methods, instrument, and software development

Underway pCO_2 systems

- Measurement of carbon dioxide in surface seawater and atmosphere (Infrared analyzer, GC, or cavity ring down)
  - Ocean and atmosphere gas exchange
  - Significant parameter for global carbon budgets and modeling
- Normally frequent calibration with CO_2 standards
- Many custom built systems over past 30-40 years
- Effort to standardize data quality (ie: SOCAT)
  - Accuracy within 0.2 µatm (air) and 2 µatm (seawater)
- Supporting measurement accuracy crucial
  - Barometric pressure, equilibrator temperature, intake temperature

General Oceanics

- Originally developed by Craig Neill (UW, Bergen, CSIRO)
  - Craig Neill still advises GO engineering decisions
- One of the first commercially available underway pCO_2 systems (2003?)
- Fully automated measurements with option of stand alone operation
  - Particularly useful on ships of opportunity
- NOAA/AOML installation guides and support

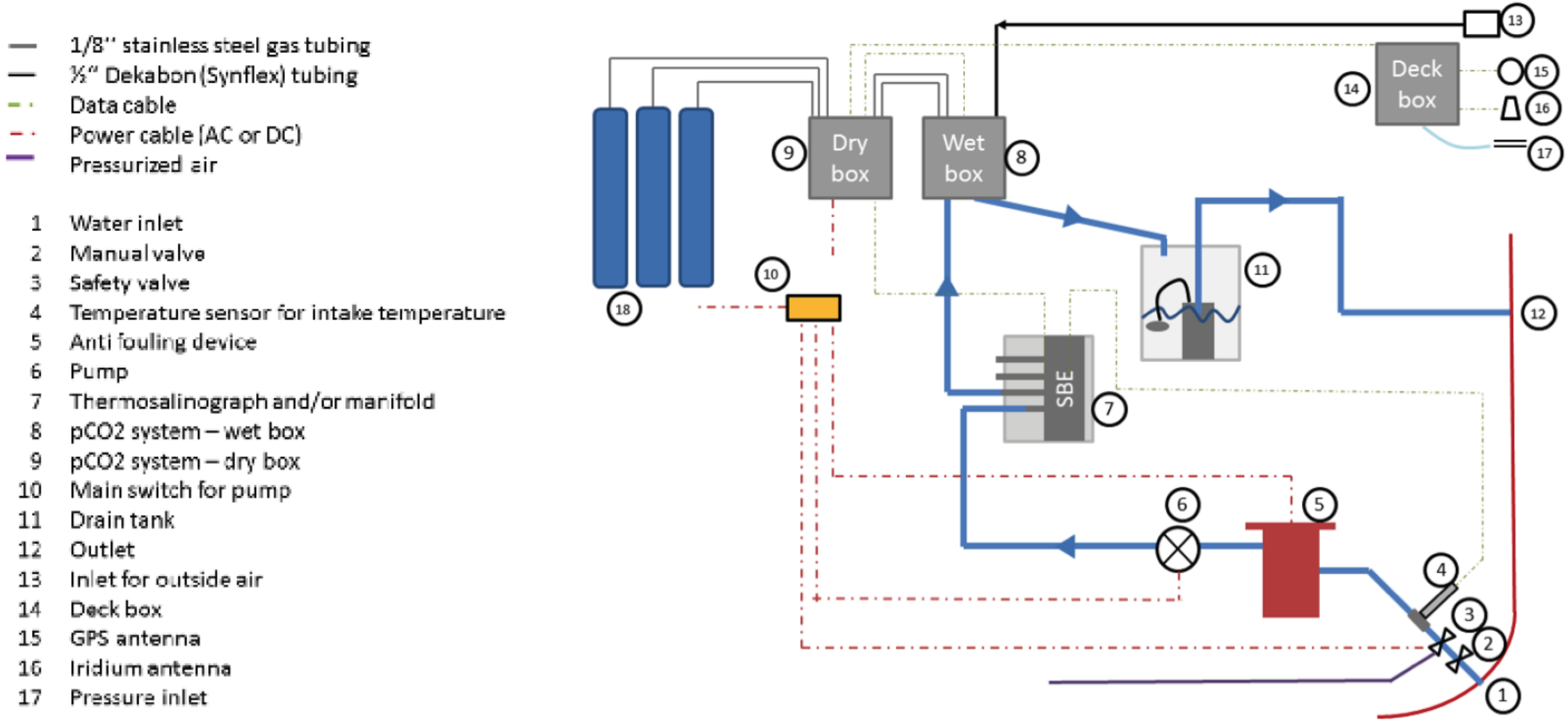
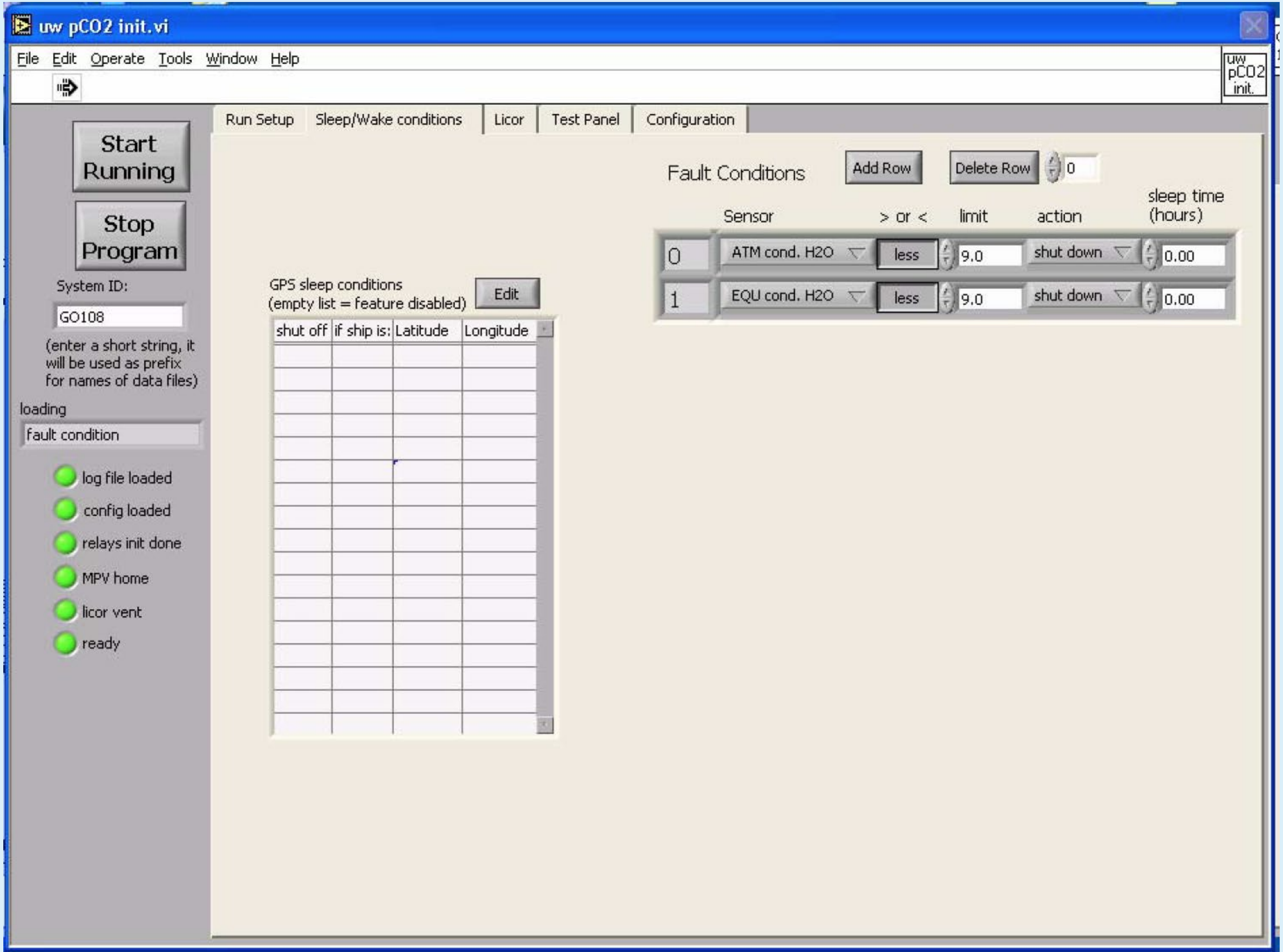


Figure 1. Schematic overview of the full installation of an autonomous underway pCO_2 system.

General Oceanics

- Three main components:
  - Wet Box – Seawater gas exchange
  - Dry Box – CO_2 analyzer, control laptop
  - Deck Box – GPS, barometric pressure, Iridium antenna
- Optional external sensor interface
  - pH, oxygen, temperature, salinity, turbidity, fluorometer
- Labview based control software
  - Serial inputs handled through ethernet switch to laptop
  - GPS based Sleep/Wake conditions
  - Moisture sensors and shut off valve
  - Additional shut off valve control

https://www.generaloceanics.com/pc02-monitoring/


uw pCO2 init.vi
File Edit Operate Tools Window Help
uw pCO2 init.
Run Setup
Sleep/Wake conditions
Licor
Test Panel
Configuration
Start Running
Stop Program
System ID:
GO108
(enter a short string, it will be used as prefix for names of data files)
loading
fault condition
log file loaded
config loaded
relays init done
MPV home
licor vent
ready
GPS sleep conditions (empty list = feature disabled)
Edit
shut off
if ship is:
Latitude
Longitude
Fault Conditions
Add Row
Delete Row
0
Sensor
> or <
limit
action
sleep time (hours)
0
ATM cond. H2O
less
9.0
shut down
0.00
1
EQU cond. H2O
less
9.0
shut down
0.00

Documentation and Support

- Dennis Pierrot, AOML
- Rik Wanninkhov, AOML
- Kevin Sullivan, RSMAS
- Peter Quesada, General Oceanics
- Craig Neill, CSIRO

NOAA Technical Report, OAR-AOML-50
https://doi.org/10.25923/ffz6-0x48

Installation of Autonomous Underway pCO_2 Instruments onboard Ships of Opportunity

Instruction Manual

Model 8050

Automated Flowing pCO_2 Measuring System

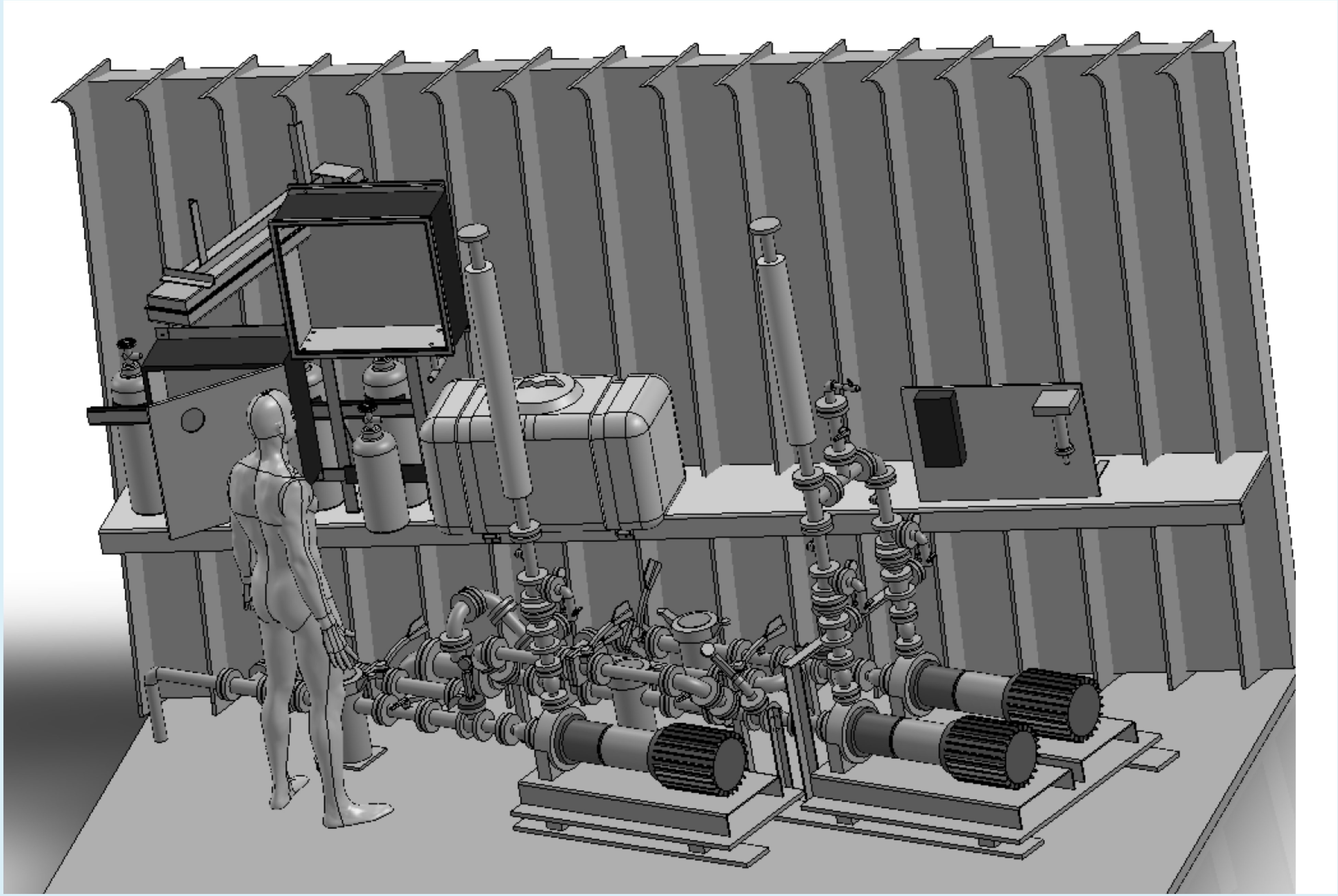
Recommendations for Autonomous Underway pCO_2 Measuring Systems and Data Reduction Routines

Denis Pierrot [a,*], Craig Neill [b], Kevin Sullivan [a], Robert Castle [c], Rik Wanninkhof [c], Heike Lüger [a], Truls Johannessen [b], Are Olsen [b,d,e], Richard A. Feely [f], Catherine E. Cosca [f]

UCSD Installations

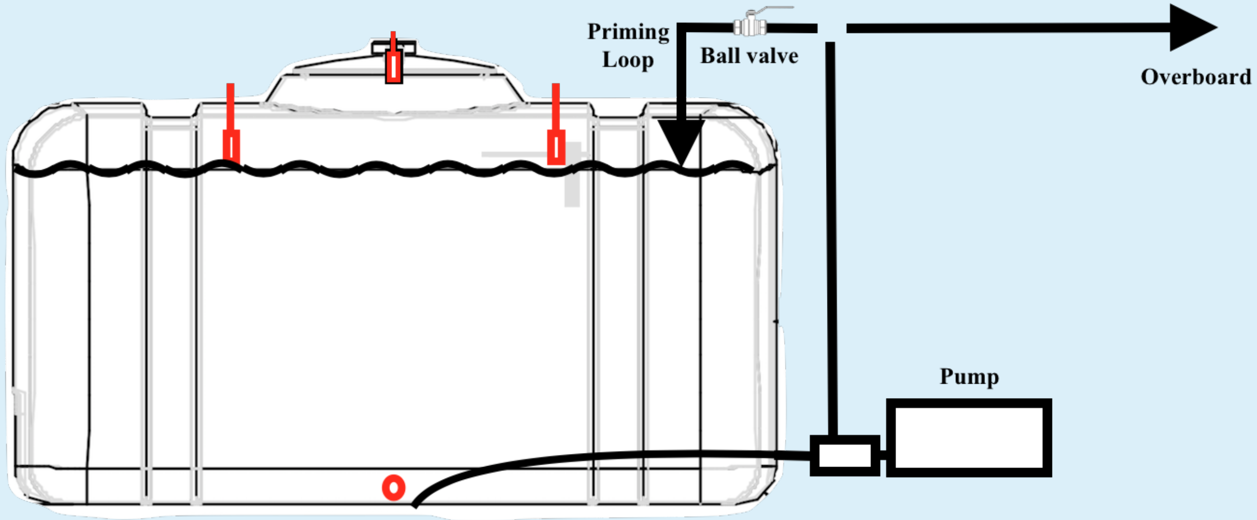
R/V Sally Ride

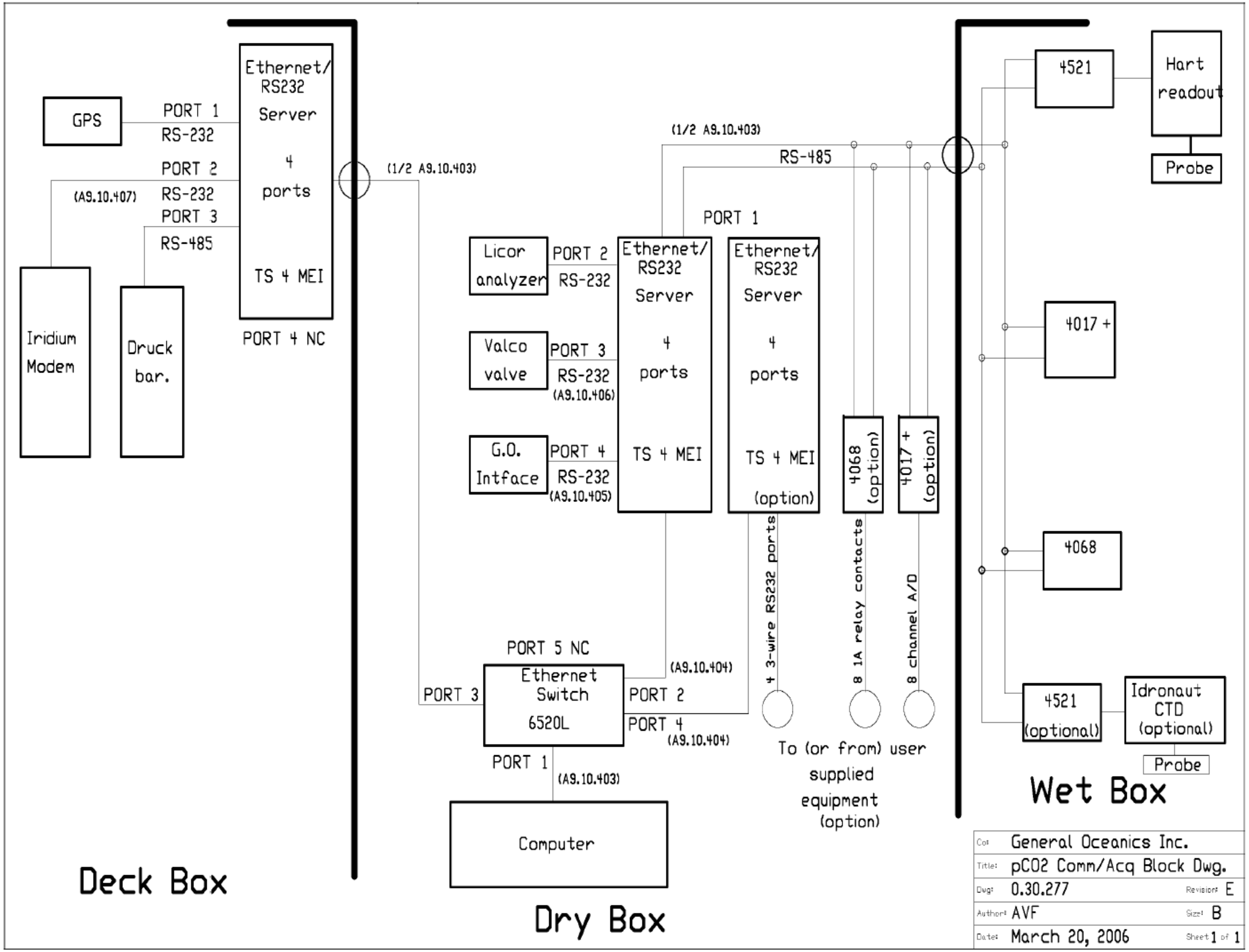
- Target:
  - Final test December 2019
  - Operational early 2020



UCSD Installations
R/V Sally Ride

- Completed and tested February 2019
  - SS 316 plumbing of SW and FW
  - Drain tank system
  - New TSG mount and plumbing
  - Emergency e-actuated shut off valve
  - Gas standards and instrument calibrations





Co:	General Oceanics Inc.
Title:	pCO2 Comm/Acq Block Dwg.
Dwg:	0.30.277 — Revision: E
Author:	AVF — Size: B
Date:	March 20, 2006 — Sheet 1 of 1

UCSD Installations

R/V Sally Ride

- Integration with our network
  - GO ethernet switch routed into network drop (transceiver room)
  - Virtual machine instead of laptop
    - Local remote access for maintenance and QC
  - UDP protocol for inputs
    - GPS, barometric pressure, intake temperature, and TSG
    - Labview updates?
    - GO will accommodate custom communication settings
- FW backflush of plumbing between wet box and underway SW pump
  - Manual ball valves
  - Each port stop?
  - Bleach annually? Test biofouling in plumbing with CO_2 measurements
- Intake temperature - dry dock 2021
  - Requires pipefitter and custom probe mount

UCSD Installations

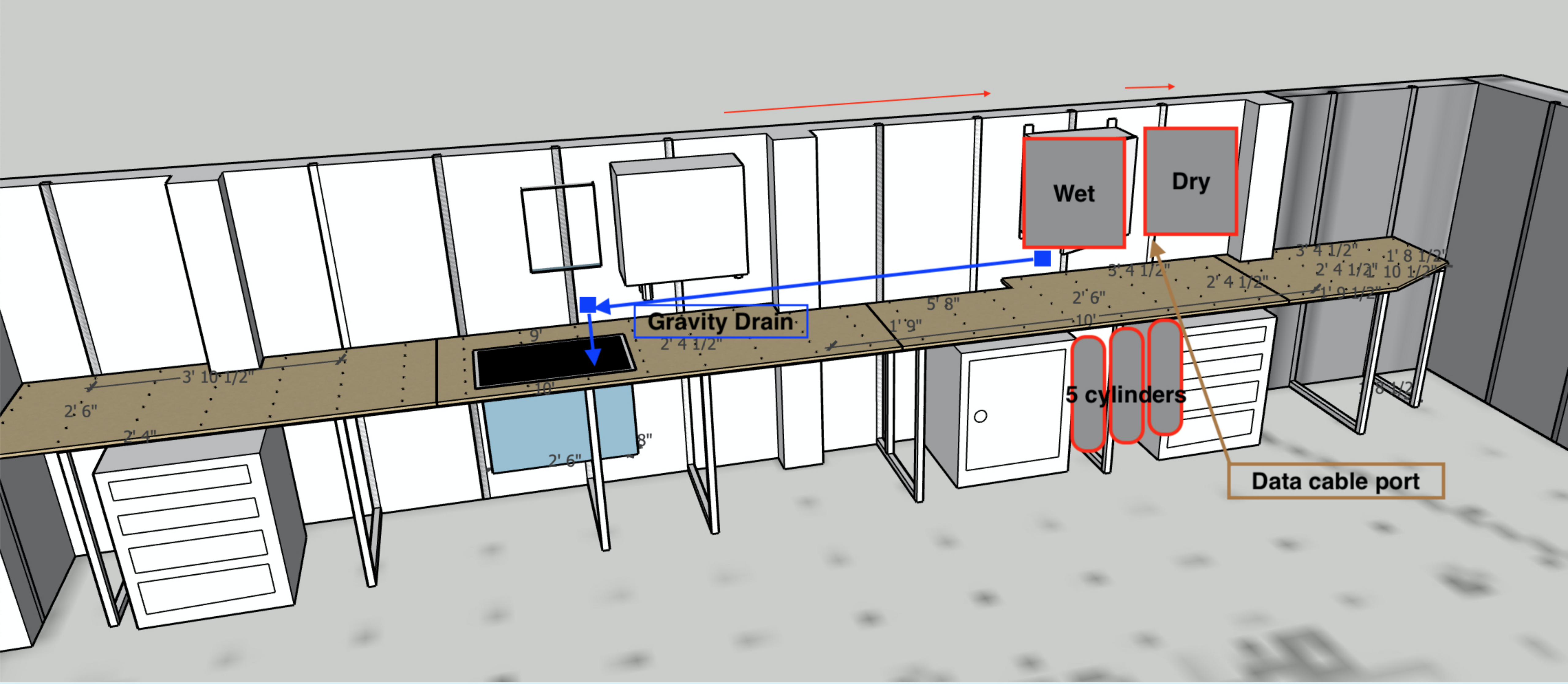
R/V Sally Ride

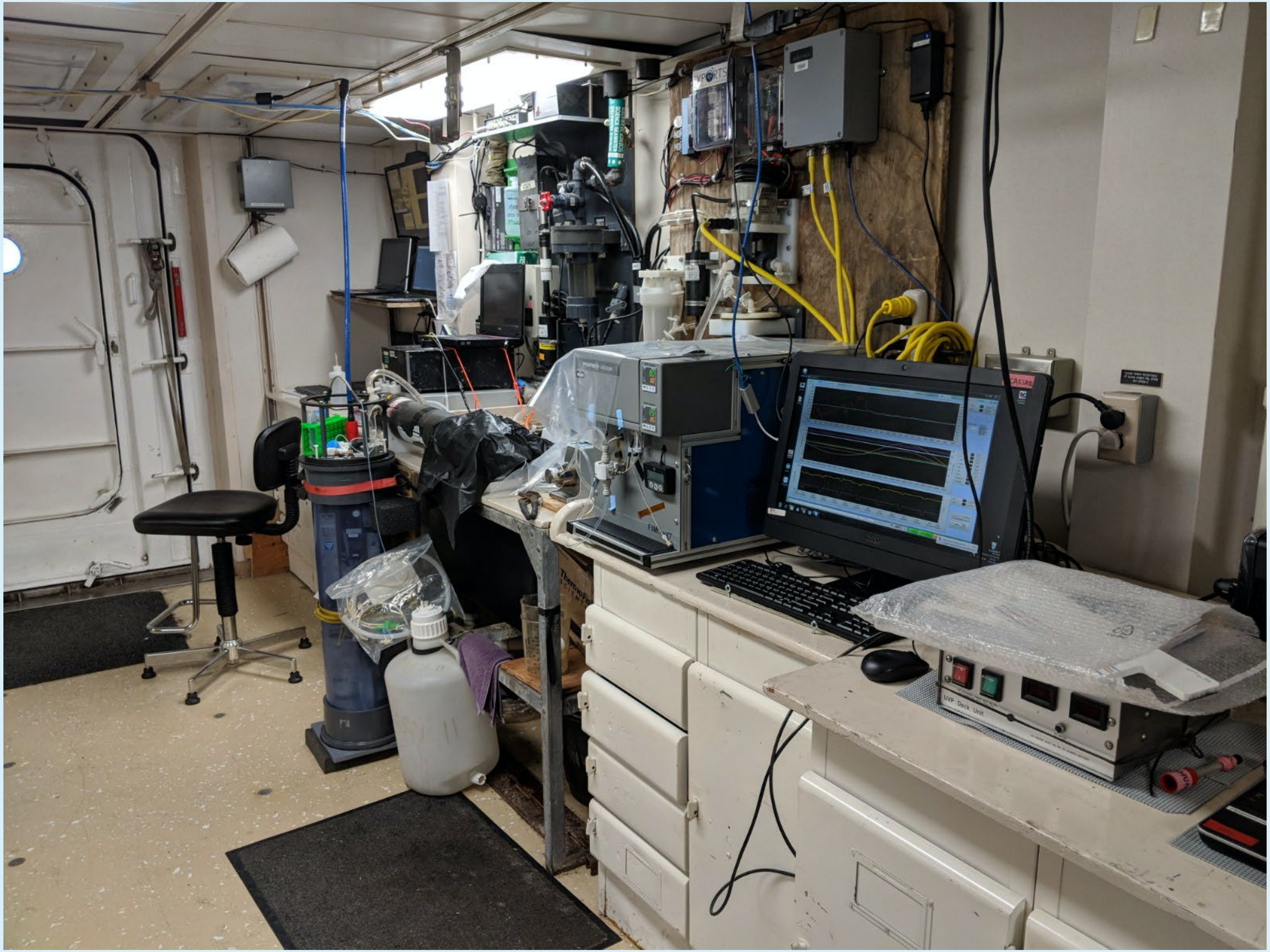
- Heavy vibrations in bow thruster room (bow slap)
  - Dampers on frame and box mounts
  - Are dampers enough?
  - Shortened instrument life or leaks?
- Limit intake temp change
  - Heat exchange SSW pump and bow thruster
  - Insulate plumbing
  - High flow rates with bypass valve
- TSG and GO flow rates displayed in MET
- GO equilibrator temp displayed side by side with TSG
- Discrete sampling valve near wet box

UCSD Installations

R/V Revelle

- Target:
  - Install and test early 2020
  - Operational mid 2020
- Network integration will follow Sally Ride template
- Intake temperature
  - SBE 38
  - Inline installation does not require dry dock
- QC procedure
  - Precedent set by Sally Ride
  - Likely involve a group of interested PIs (ie: Todd Martz)
  - New funding?


Wet
Dry
Gravity Drain
5 cylinders
Data cable port


UVP Deck Unit

Mandatory Hardware

- Intake Temperature
  - closest to opening to sea surface as possible
  - Accuracy 0.05^{o} C required
  - Ideally, ΔT (intake to equilibrator) < 1^{o} C
    - Ex: If $\Delta T = 1^{o}$ C , then 16.8 µatm correction with uncertainty of 0.8 µatm pCO_2
    - General instrument uncertainty ~1 µatm, so total in this scenario ~2 µatm
    - Remember, overall accuracy needed to 2 µatm pCO_2
- Barometric Pressure - accuracy 2 mbar
- At least 3 non-zero WMO traceable standards

Surface Ocean CO_2 Atlas (SOCAT)

- International repository for pCO_2 data (>100 contributors)
- ‘Cookbook’ for data QC flag and SOP criteria
  - QC flags A + B (uncertainty 2 µatm), C + D (5 µatm), E (10 µatm)
  - 7 SOP criteria for flags A + B
- PMEL live access server fo QC software
  - http://access.pmel.noaa.gov/SOCAT

SOCAT Quality Control Cookbook
-For SOCAT version 7-

Siv Lauvset, Kim Currie, Nicolas Metzl, Shin-ichiro Nakaoka, Dorothee Bakker, Kevin Sullivan, Adrienne Sutton, Kevin O'Brien, Are Olsen

QC flag A + B

Seven SOP criteria:

1. The data are based on xCO_2 analysis, not fCO_2 calculated from other carbon parameters, such as pH, alkalinity or dissolved inorganic carbon;
2. Continuous CO_2 measurements have been made, not discrete CO_2 measurements;
3. The detection is based on an equilibrator system and is measured by infrared analysis, or gas chromatography or cavity ring-down spectroscopy;
4. The calibration has included at least two non-zero gas standards, traceable to World Meteorological Organisation (WMO) standards, which bracket the observed range in xCO_2;
5. The equilibrator temperature has been measured to within 0.05 °C accuracy;
6. The intake seawater temperature has been measured to within 0.05 °C accuracy;
7. The absolute equilibrator pressure has been measured to within 2 hPa accuracy. Note that many equilibrator-based instruments only have a differential sensor in the equilibrator itself, and an external pressure sensor (often the LiCor pressure sensor) is used to estimate the absolute pressure (i.e., abs_equ_pressure = diff_equ_pressure + abs_lab_pressure). If this is the case then the absolute equilibrator pressure is a sum of two sensors so the accuracy of both (alternatively the combined accuracy of both) must be documented.

In addition, **warming between in situ and measurement should be <1 °C** as explained above.

QC flag C + D

For an accuracy estimate of better than 5 µatm (C or D) the criteria differ depending on type of instrumentation:

- Shipboard NDIR, gas chromatographs and CRDS systems must have:
  - Two calibration gases, one of which can be a zero gas. The non-zero gas should span nearly the entire range observed in fCO_2 (i.e. the observations cannot be >20% outside the certified standard gas value).
  - Both temperatures must be measured to within 0.2 °C accuracy, and absolute equilibrator pressure has been measured to within 5 hPa accuracy.
  - **The warming between in situ and measurement should be <3°C**.
  - In addition, all other SOP as given above are fulfilled and properly documented in the metadata.
- Alternative sensors need to have:
  - Daily or more frequent *in situ* (i.e. when the instrument is operating in its natural environment) calibration with at least two calibration gases, one of which can be a zero gas. The non-zero gas must span the range observed in fCO_2.
  - A clear and detailed description of the calibration (including the frequency of it) needs to be provided in the metadata.

Questions?

Figure 1 (from Wanninkhof et al., 2013) below shows isopleths of uncertainty in calculated *f*CO_2 ($\Delta f CO_2$) arising from uncertainty in the temperature (T_{equil}) and pressure (P_{equil}) of equilibration, respectively. For equilibrator-based systems, the uncertainty in the *in situ* and measurement temperatures and the measurement pressure needs to be evaluated in order to assess the overall accuracy of *f*CO_2.

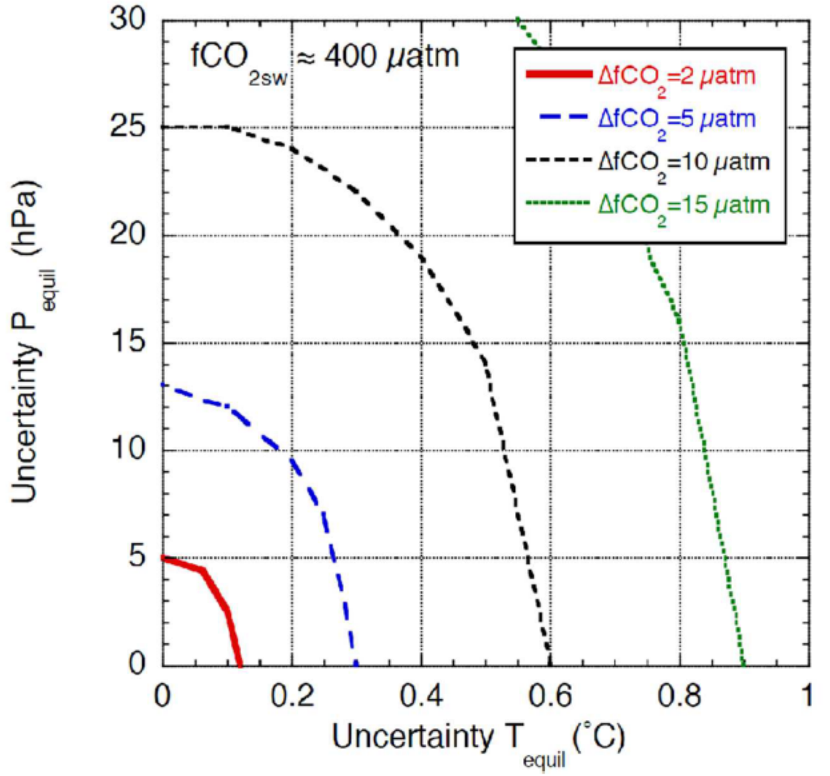


Figure 1. The impact of uncertainties in temperature and pressure on fCO_2 (from Wanninkhof et al., 2013).