



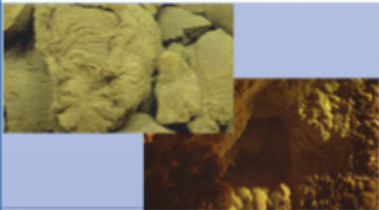
Using Science Operations Tools and Methods from NASA
for Remote Presence Ocean Exploration on Earth:
E/V Nautilus Cruise NA108



SUBSEA: Systematic Underwater Biogeochemical Science and Exploration Analog

What is SUBSEA?

Natural Sciences Research



Characterize novel deep sea environments on our own planet.

Broaden our understanding of the potential habitability of other Ocean Worlds.

Social Sciences Research

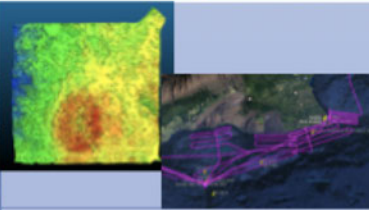


Characterize the tele-presence mission architecture used for science and exploration in the ocean in relation to NASA space mission analogs

Develop methods for productively and safely conducting science-driven Low Latency (time delay) telerobotics in deep space environments

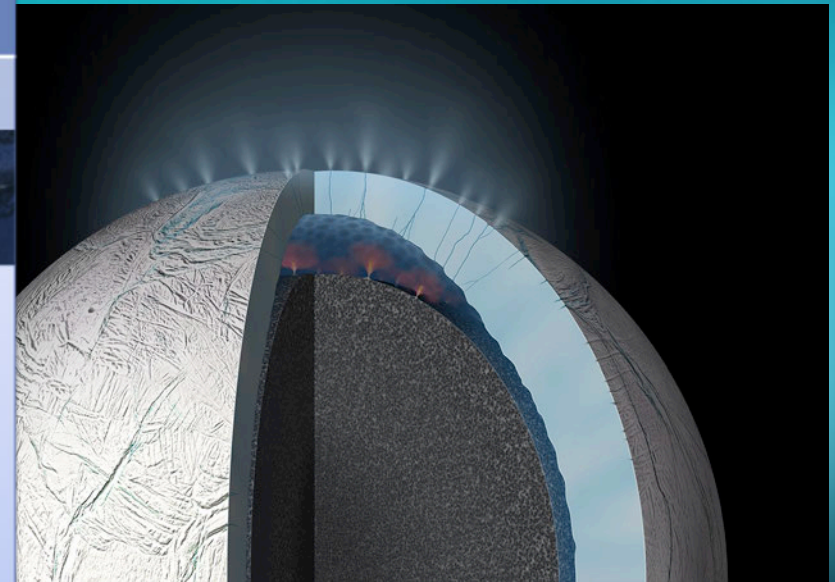
Identify specific capabilities for distributed science teams conducting telerobotic work

Technology Development



Use NASA developed information technologies to support integration and visualization of data products relevant to science-driven LLT telerobotics.

xGDS will provide human/robotic software functionality relevant to future human exploration of deep space.



Credits: NASA JPL/Caltech

What is SUBSEA?

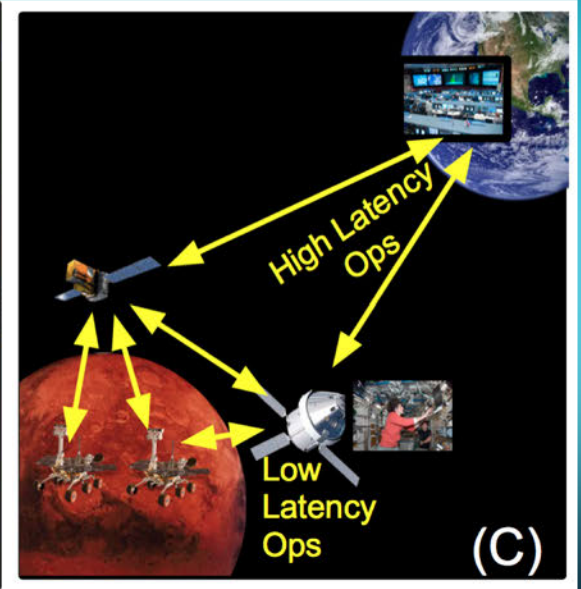
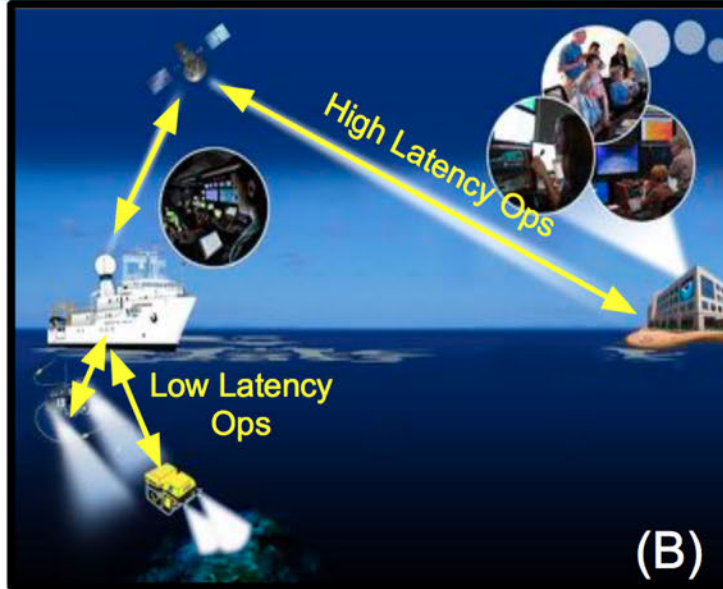
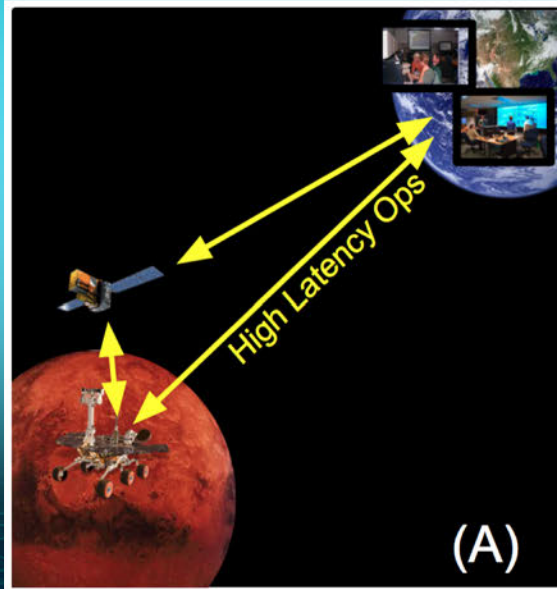




Photo Credit: OET

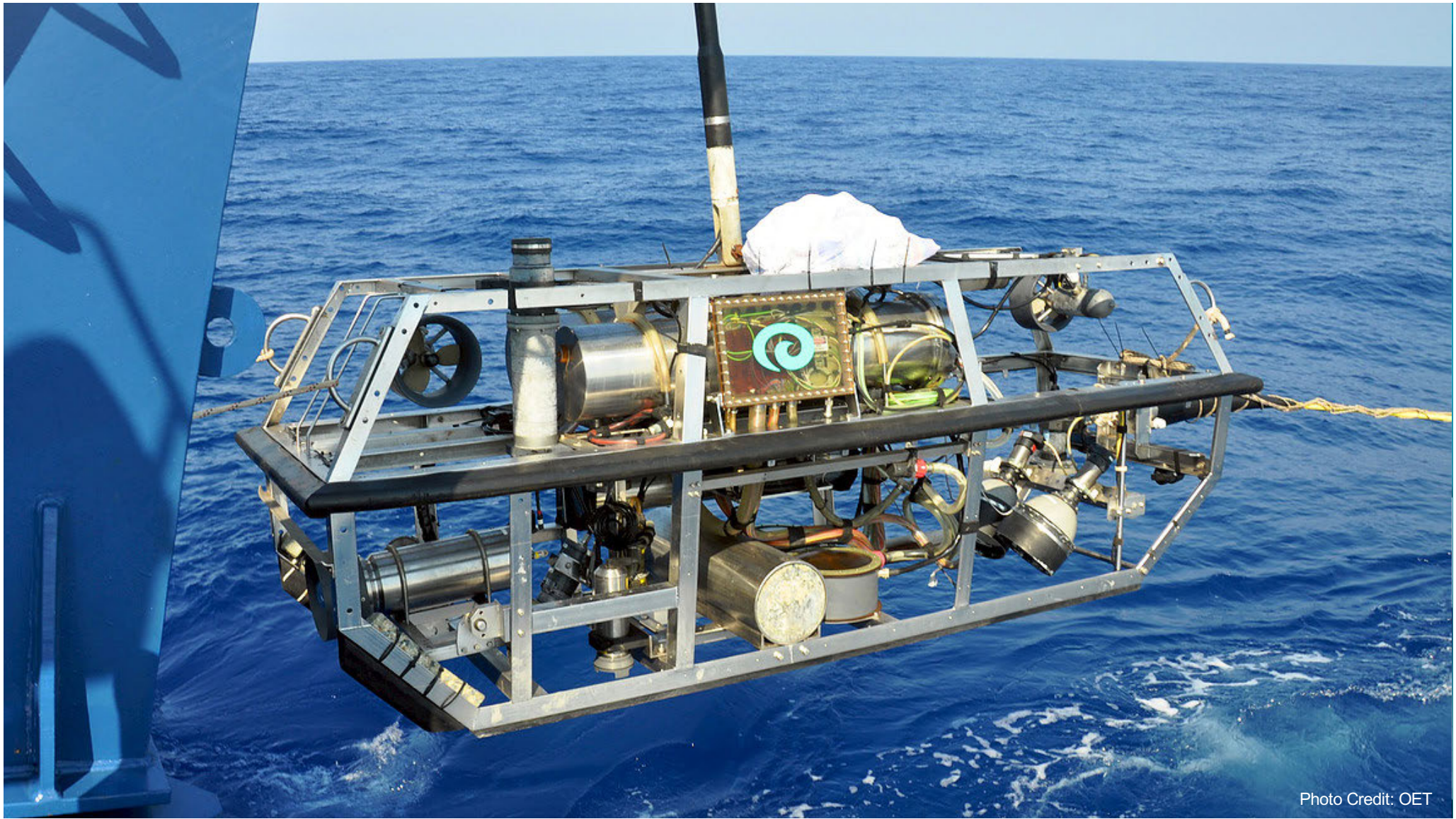


Photo Credit: OET

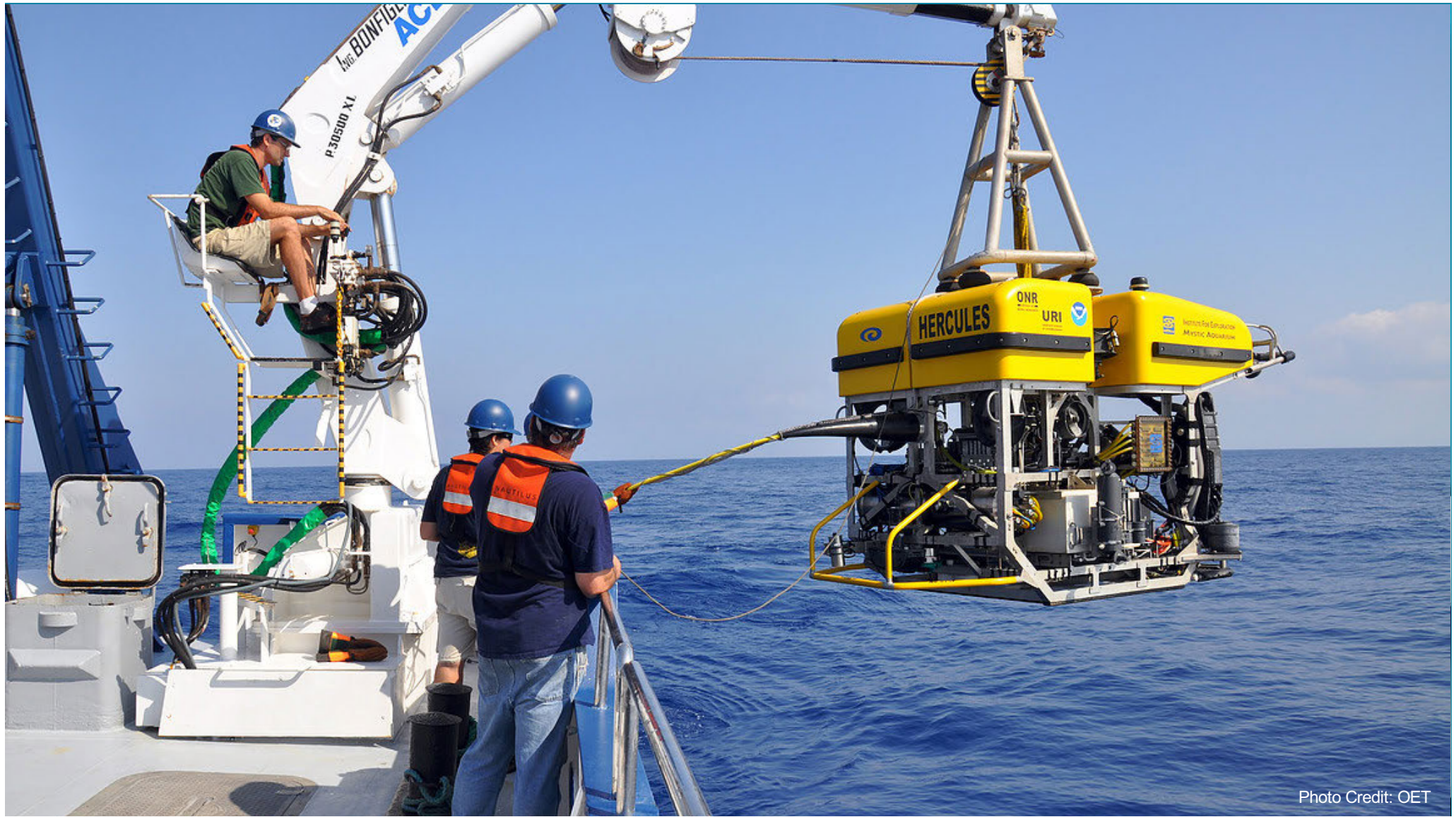


Photo Credit: OET









Photo Credit: NASA

SUBSEA Cruise B Information Cycle



Dive Plan to Ship



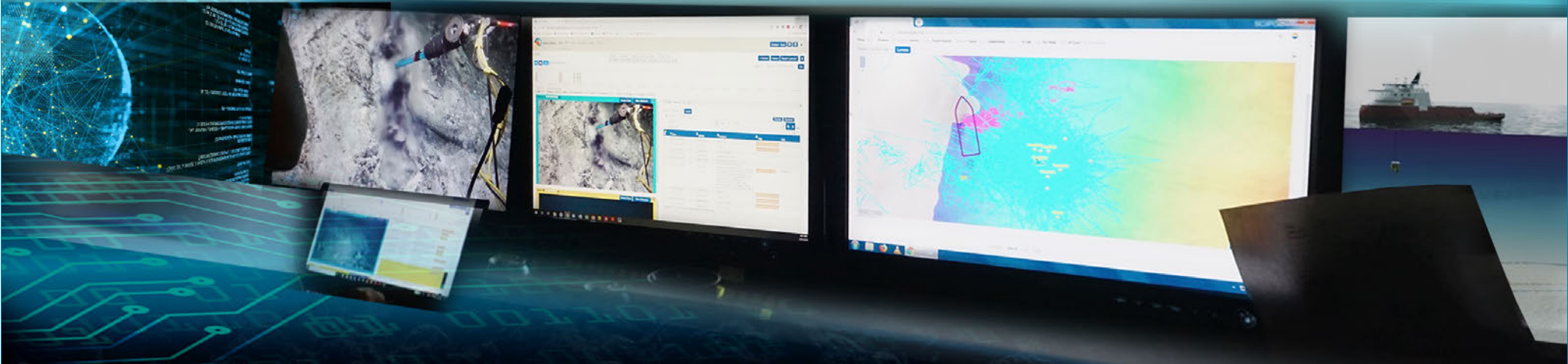
DIRDAR to ISC



- One dive plan per day (24 hour cycle)
- 16 hour target dive time
- Dive Recovery and data report (DIRDAR) sent at end of dive
- Mode 1: No other communication
- Mode 2: Audio and text chat during dive

Overview

- What is xGDS?
- SUBSEA 2019
- xGDS for ocean exploration



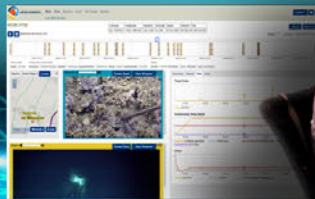
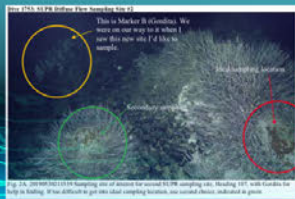
What is xGDS?

- An open source web site/application
- Science focused tools for data synthesis, multi-user real-time collaboration and decision-making
- Science teams love it!



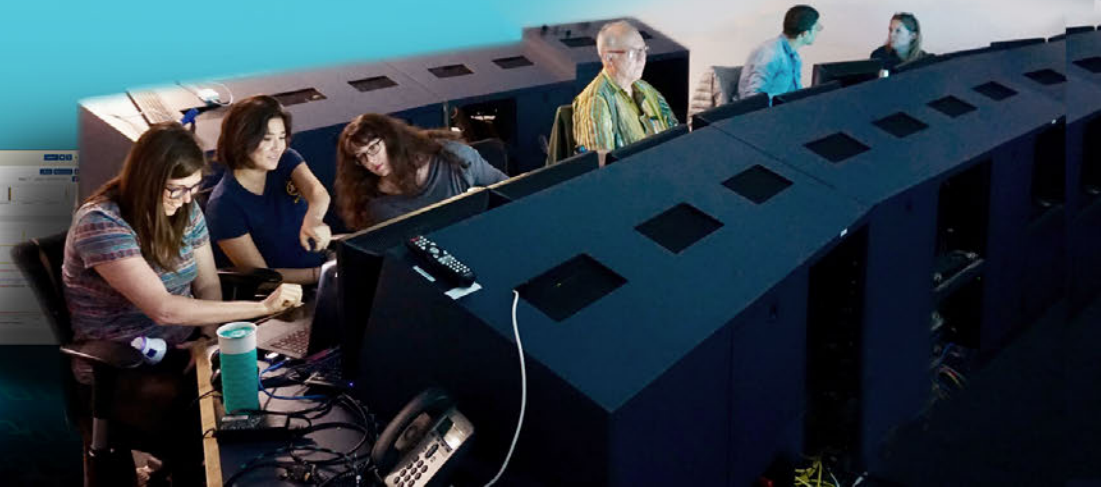
xGDS Technology Goals

- Empower non-specialist users to explore/annotate data independently
- Correlate and present disparate data products to scientists
- Support rapid search for useful items in large volumes of data
- Enable effective decision making during field operations

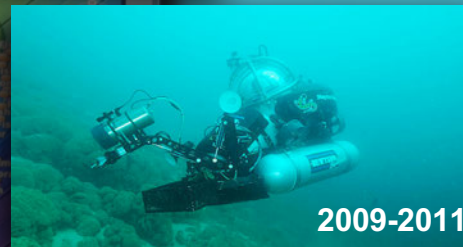
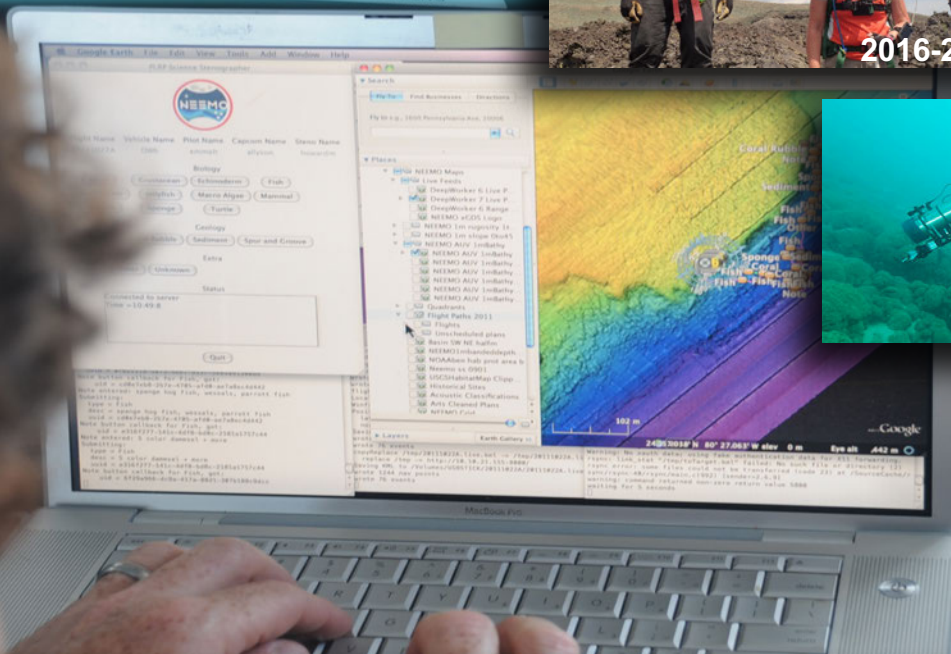


xGDS Foundations

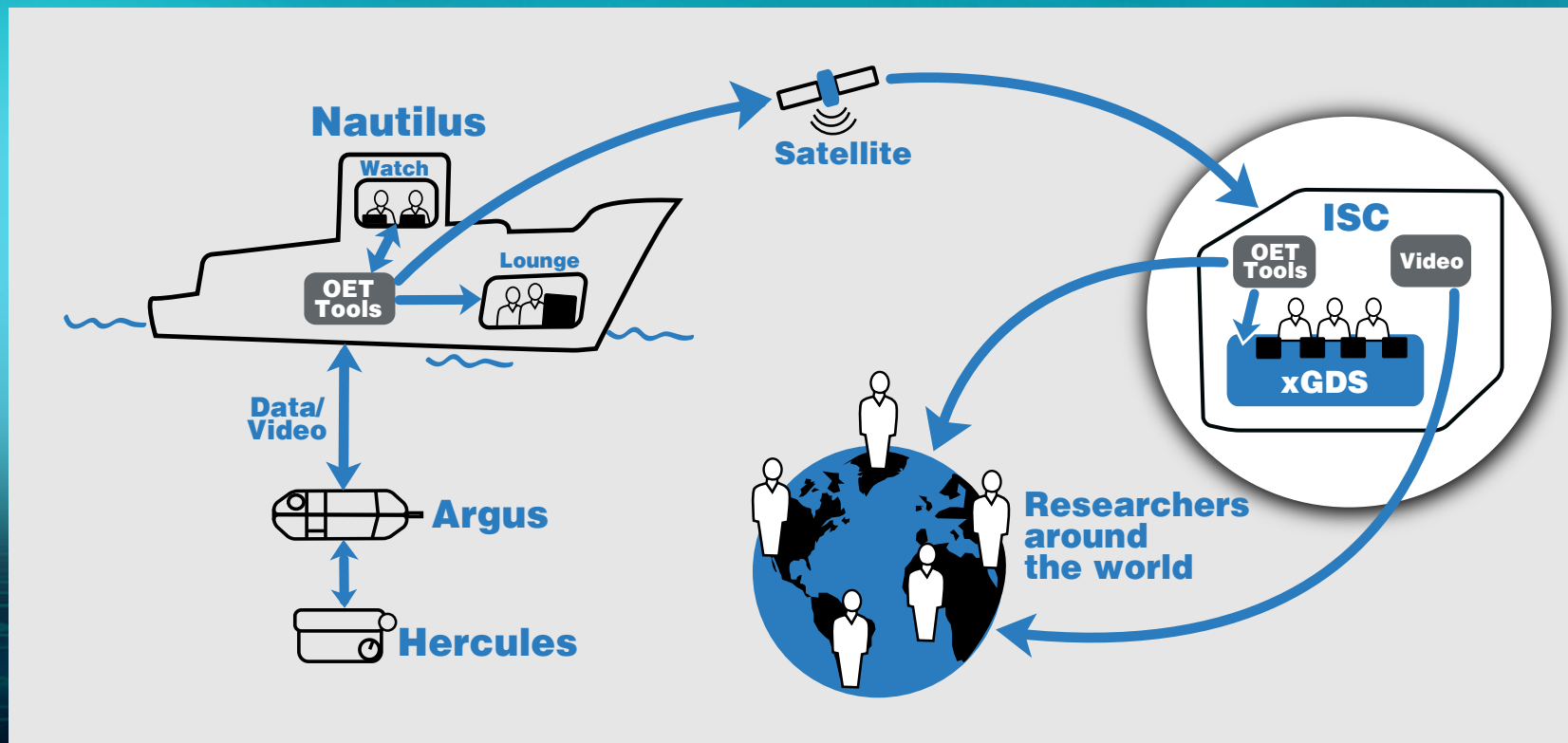
- Built on well established open-source frameworks/apps
- Support open standards when possible
- Allows for easier sharing with collaborators



xGDS has supported a wide array of platforms.



xGDS for SUBSEA at Inner Space Center (ISC)



xGDS Workflow Process

Pre-Cruise

During Cruise

Post Cruise

Plan






Monitor/Archive

Explore



RESOLVE-20120714T231723-000000
 RESOLVE-20120714T231723-000000
 Timestamp: 2012/07/14 23:17:23 UTC
 Longitude: -195.467816492
 Latitude: 19.761603798
 Size: 280 x 210



Label	Note	Still	Video
sponge	area of barrel sponges		Full Video Compressed Video
sponge	space sponges		Full Video Compressed Video
other	completed first pass		Full Video Compressed Video
other	going in reverse		Full Video Compressed Video
other	start moving to waypoint		Full Video Compressed Video

SUBSEA xGDS Success

- Deployed xGDS at ISC for NA108
- Active science team participation from ISC

Planning

- Science team authored and delivered dive plans to Nautilus daily.
- Science team made navigation and data collection decisions from shore

Monitoring

- Recorded events in xGDS

Exploring

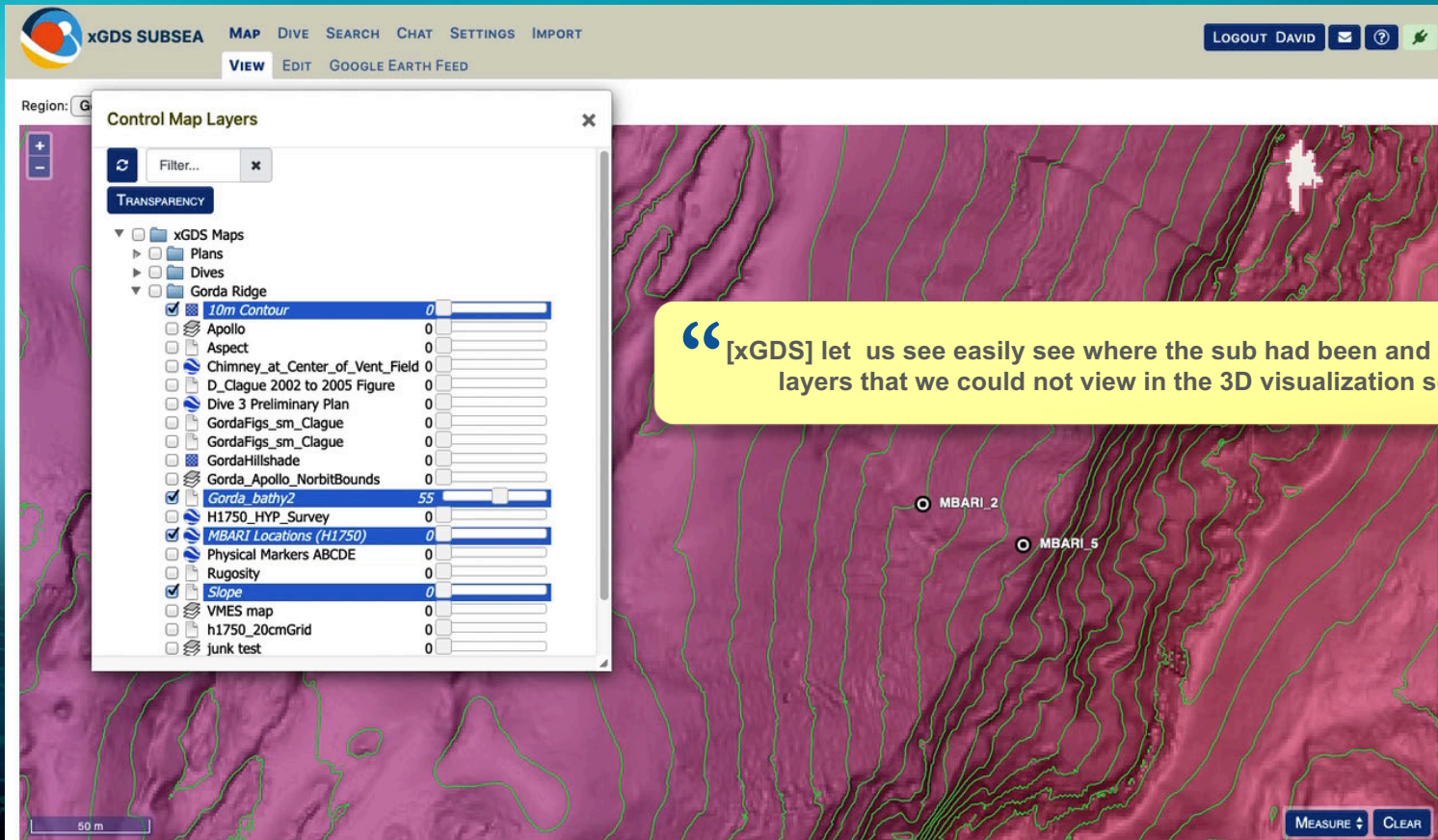
- Interactive data exploration through xGDS

xGDS for SUBSEA by the numbers

ISC science team (beyond Nautilus data logger & video):

- ~1000 still images from the video feed (10K on ship).
- ~700 accesses to map layers.
- ~600 observations and tags on data from ship (3300 on ship).
- ~230 accesses to the video replay page.
- 53 ROV plans created during NA108 cruise
- 7 final plans delivered to Nautilus for 7 dive days.
- 16 hour expected dive duration.

Scientist Authored Map Layers for Interactive Visualization



The screenshot displays the xGDS SUBSEA web application interface. At the top, there is a navigation bar with options: MAP, DIVE, SEARCH, CHAT, SETTINGS, and IMPORT. A user profile section shows 'LOGOUT DAVID' and icons for email, help, and a green checkmark. Below the navigation bar, there are tabs for 'VIEW', 'EDIT', and 'GOOGLE EARTH FEED'. The main content area features a bathymetric map of a seafloor ridge with green contour lines. A white cursor is visible on the map. Two circular markers labeled 'MBARI_2' and 'MBARI_5' are placed on the map. A 'Control Map Layers' panel is overlaid on the left side of the map. This panel includes a 'Filter...' search box, a 'TRANSPARENCY' section, and a list of map layers with checkboxes and sliders. The layers include 'xGDS Maps', 'Plans', 'Dives', and 'Gorda Ridge'. Under 'Gorda Ridge', several layers are checked, including '10m Contour', 'Gorda_bathy2', 'MBARI Locations (H1750)', and 'Slope'. A '50 m' scale bar is located at the bottom left of the map, and 'MEASURE' and 'CLEAR' buttons are at the bottom right.

Region: G

Control Map Layers

Filter...

TRANSPARENCY

- xGDS Maps
 - Plans
 - Dives
 - Gorda Ridge
 - 10m Contour 0
 - Apollo 0
 - Aspect 0
 - Chimney_at_Center_of_Vent_Field 0
 - D_Claque 2002 to 2005 Figure 0
 - Dive 3 Preliminary Plan 0
 - GordaFigs_sm_Claque 0
 - GordaFigs_sm_Claque 0
 - GordaHillshade 0
 - Gorda_Apollo_NorbitBounds 0
 - Gorda_bathy2 55
 - H1750_HYP_Survey 0
 - MBARI Locations (H1750) 0
 - Physical Markers ABCDE 0
 - Rugosity 0
 - Slope 0
 - VMES map 0
 - h1750_20cmGrid 0
 - junk test 0

50 m

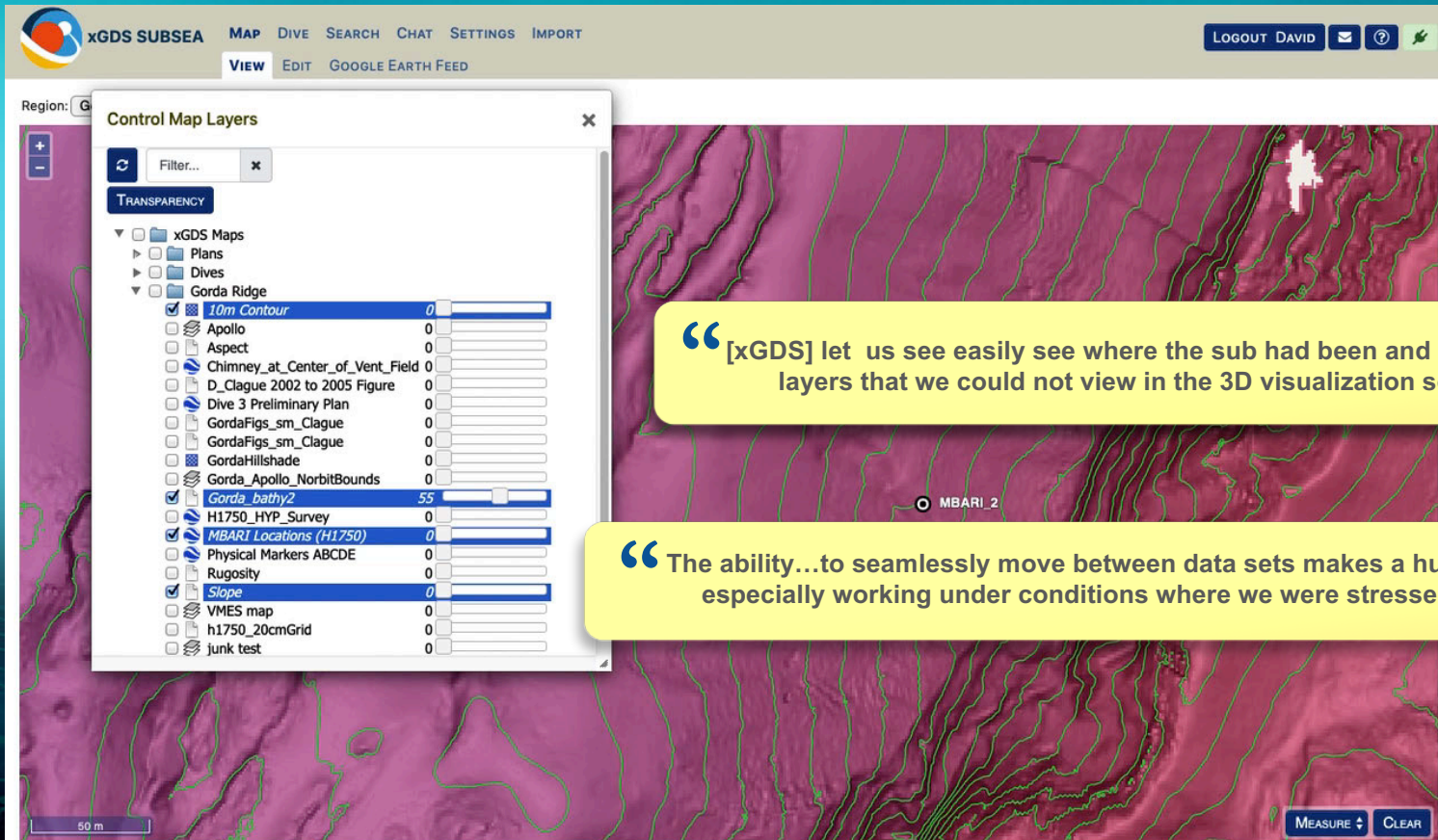
MEASURE CLEAR

MBARI_2

MBARI_5

“ [xGDS] let us see easily see where the sub had been and quickly access layers that we could not view in the 3D visualization software. ”

Scientist Authored Map Layers for Interactive Visualization



Region: G

xGDS SUBSEA MAP DIVE SEARCH CHAT SETTINGS IMPORT

VIEW EDIT GOOGLE EARTH FEED

LOGOUT DAVID

Control Map Layers

Filter...

TRANSPARENCY

- xGDS Maps
 - Plans
 - Dives
 - Gorda Ridge
 - 10m Contour 0
 - Apollo 0
 - Aspect 0
 - Chimney_at_Center_of_Vent_Field 0
 - D_Claque 2002 to 2005 Figure 0
 - Dive 3 Preliminary Plan 0
 - GordaFigs_sm_Claque 0
 - GordaFigs_sm_Claque 0
 - GordaHillshade 0
 - Gorda_Apollo_NorbitBounds 0
 - Gorda_bathy2 55
 - H1750_HYP_Survey 0
 - MBARI Locations (H1750) 0
 - Physical Markers ABCDE 0
 - Rugosity 0
 - Slope 0
 - VMES map 0
 - h1750_20cmGrid 0
 - junk test 0

50 m

MEASURE CLEAR

“ [xGDS] let us see easily see where the sub had been and quickly access layers that we could not view in the 3D visualization software. ”

“ The ability...to seamlessly move between data sets makes a huge difference, especially working under conditions where we were stressed and tired. ”



Dive Planning: Collaborate



xGDS SUBSEA MAP DIVE SEARCH CHAT SETTINGS IMPORT LOGOUT

LIST ROV PLANS **EDIT GORDA_H1756_A_PLAN_JH_AG_AS2**

NAVIGATE EDIT ADD Duration: 19:01:46 (hh:mm:ss)
Distance: 1769.14 m UNDO REDO RELOAD SAVE AS SAVE RESET LAYOUT

07/12/19 19:08:27 UTC

Start 1 End 2

05/26 16:00 05/26 18:00 05/26 20:00 05/26 22:00 05/27 00:00 05/27 02:00 05/27 04:00 05/27 06:00 05/27 08:00 05/27 10:00

LAYERS

Meta Sequence Search Tools Links

Targets/Segments	
Start	02:05:24
74 m	+00:09:52
1	11:36:16
451 m	+01:00:11
2	12:36:27
1244 m	+02:45:50
End	19:01:46

Target 1

Target Properties
Duration: +09:21:00

CUT COPY PASTE DELETE

- Video Documentation 00:20:00
- Setup: Sample 00:15:00
- Temp Probe 01:00:00
- IGT 00:15:00
- IGT 00:15:00
- Setup: Sample 00:30:00
- SUPR Filter 00:25:00
- SUPR Filter 00:25:00
- SUPR Filter 00:25:00
- Setup: Sample 00:05:00
- SUPR Bag Flush 00:03:00
- SUPR Bag 00:05:00
- SUPR Bag Flush 00:03:00
- SUPR Bag 00:05:00
- Setup: Sample 00:10:00

Target Properties

Name: WP1

Notes: New vent site to north. All fluid sampling will take place IGTs and SUPR tubes, a high temperature chimney is

Id: STN1

Uuid: 227e21ab-af36-487f-9f2b-e1a1b4394319

Coordinate System: Lon, Lat

Lon, Lat: -126.7054563, 42.7613961

“Often without xGDS, scientists know what they want but don’t know if it’s possible or how to create plans.”

Dive Planning: Take frame grab from video and mark it up

Dive 1753: SUPR Diffuse Flow Sampling Site #2



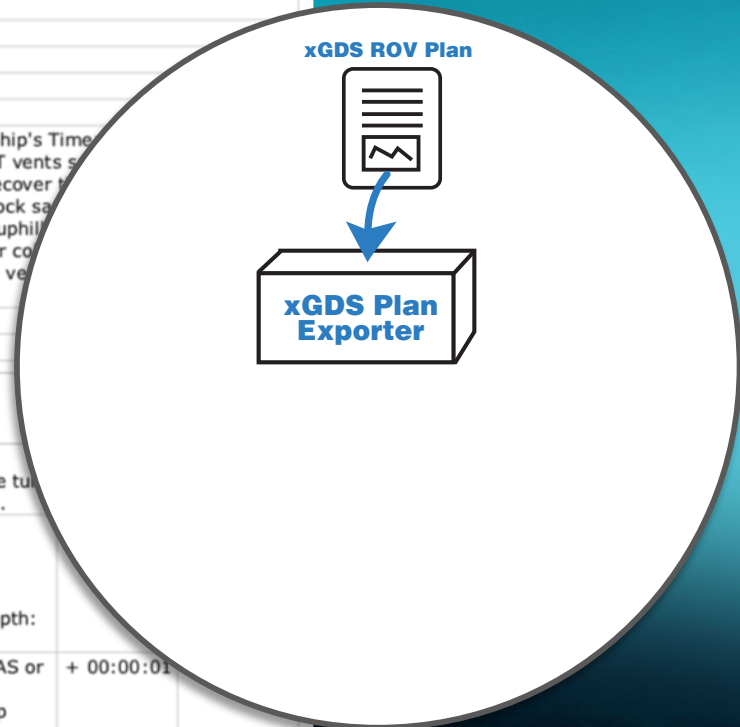
Fig. 2A. 20190530211539 Sampling site of interest for second SUPR sampling site. Heading 107, with Gordita for help in finding. If too difficult to get into ideal sampling location, use second choice, indicated in green.

Dive Planning: Export data for other users & systems

ROV Plan: Gorda_H1753_C_PLAN_JH_AG_CG

Name:	Gorda_H1753_C_PLAN_JH_AG_CG
ID:	gorda_ridgeH091_C_PLAN
Author:	cgerman
Created:	04/17/19 18:51:49 UTC
Modified:	05/31/19 22:17:56 UTC
Notes:	This fourth dive to Gorda Ridge has 6 objectives. (1) Ensure that the ROV is back on deck by 20h00 Ship's Time; (2) Conduct low temperature fluid and rock sampling at/around a patch of blue-lilac ciliate mats, uphill from the high-T vents along the same ridge with chimneys that leads up to the colonization experiments at Marker A; (3) Recover microbial colonization experiments deployed on Dive H1750; (4) Conduct low temperature fluid and rock sampling at location identified from Dive H1751; (5) Conduct a series of Geotransits on the bathymetric platform uphill including pits that are targets of interest along the suggested Geotransit path; (6) Collect Niskin water column ascent, as close together as possible without interrupting the ascent, as soon as (but NOT before) the vehicle is deeper than 2100m.
Duration:	21:48:35
Distance:	3714.34 m

SN#	WP ID	Lat/Long	Depth	HDG°	BRG°/Dist	Notes
	Target STN0: Launch	42.754913, -126.709650	2732.00m	999.00°	121.77°	The dive is designed to start about 50m downhill from the first sampling site. Please turn on lasers as soon as you arrive on bottom.
	Activity DES: Descent					This time duration includes two parts: - Descent to at 25 m/min to the seafloor - 15 minutes on bottom for ROV engineer setup. Assume standard operating procedure. depth: 2732
	Activity MSC: Purge SUPR Valve					In top 100 meters or so, SUPR operator (AS or EC) should purge the SUPR valve during descent. The vehicle does not need to stop during this activity. + 00:00:01
	Segment SEG1: Transit to diffuse flow sampling site				51.72 m	Please confirm that lasers are turned on before setting off. + 00:06:54 02:11:11

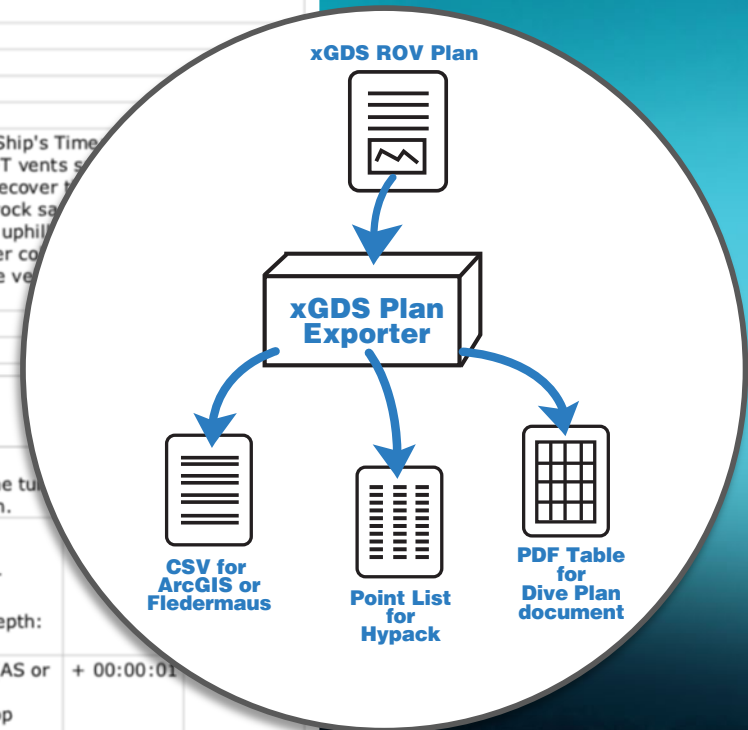


Dive Planning: Export data for other users & systems

ROV Plan: Gorda_H1753_C_PLAN_JH_AG_CG

Name:	Gorda_H1753_C_PLAN_JH_AG_CG
ID:	gorda_ridgeH091_C_PLAN
Author:	cgerman
Created:	04/17/19 18:51:49 UTC
Modified:	05/31/19 22:17:56 UTC
Notes:	This fourth dive to Gorda Ridge has 6 objectives. (1) Ensure that the ROV is back on deck by 20h00 Ship's Time; (2) Conduct low temperature fluid and rock sampling at/around a patch of blue-lilac ciliate mats, uphill from the high-T vents along the same ridge with chimneys that leads up to the colonization experiments at Marker A; (3) Recover the microbial colonization experiments deployed on Dive H1750; (4) Conduct low temperature fluid and rock sampling at the location identified from Dive H1751; (5) Conduct a series of Geotransits on the bathymetric platform uphill including pits that are targets of interest along the suggested Geotransit path; (6) Collect Niskin water column ascent, as close together as possible without interrupting the ascent, as soon as (but NOT before) the vehicle is deeper than 2100m.
Duration:	21:48:35
Distance:	3714.34 m

SN#	WP ID	Lat/Long	Depth	HDG°	BRG°/Dist	Notes
	Target STN0: Launch	42.754913, -126.709650	2732.00m	999.00°	121.77°	The dive is designed to start about 50m downhill from the first sampling site. Please turn on lasers as soon as you arrive on bottom.
	Activity DES: Descent					This time duration includes two parts: - Descent to at 25 m/min to the seafloor - 15 minutes on bottom for ROV engineer setup. Assume standard operating procedure. depth: 2732
	Activity MSC: Purge SUPR Valve					In top 100 meters or so, SUPR operator (AS or EC) should purge the SUPR valve during descent. The vehicle does not need to stop during this activity.
	Segment SEG1: Transit to diffuse flow sampling site				51.72 m	Please confirm that lasers are turned on before setting off.





xGDS

Active Team Participation: Record Events



NA108: H1753

Latitude	Longitude	Heading	Altitude	Depth	Position Time
42.755141	-126.709494	87.467	2.561	2731.516	06/05/19 00:12:59

06/05/19 00:12:59 UTC

Speed: 1 Jump to: 06/04/19 HH:mm:ss Go

Temp Probe Conductivity Temp Depth O2Sat
 Temp: 1.91 C Pressure: 2772.41 decibars Salinity: 34.62 psu Sound Velocity: 1502.72 m/s Temp: 1.76 C Conductivity: 3.14 S/m O2 Sat: 15.58 % O2 Temp: 1.80 C O2 Conc: 67.61 microMolar

Links

06/05/19 00:12:59 UTC Now

Collecting low temperature fluid sample 1.91C

SUPR-TUBE x Choose tags

Don't clear tags

SAVE CLOSE

Tags Link

Tags	Link
Sample Niskin	NA108-061
Sample Niskin	NA08-060
Sample Niskin	NA108-059
Sample Niskin	NA1078-058
Sample Niskin	NA108-057
Sample Niskin	NA108-056
Sample SUPR-TUBE	NA108-055

06/05/19 02:08:34 Ashley Davis SAMPLEID: NA108-056 Water column, Niskin 7

06/05/19 00:12:59 Ashley Davis SAMPLEID: NA108 055 H1753 S11 PhysicalMarkerC - flow rate , final volume, Herc HDG 87 deg, slightly NE of physical marker C, sampling outside of vent fluid for

06/04/19 22:55:37 Aubrey Fouik SAMPLEID: NA108-053 Rock - angular

06/04/19 00:12:59 UTC

Temp: 1.91 C Pressure: 2772.41 decibars Salinity: 34.62 psu Sound Velocity: 1502.72 m/s Temp: 1.76 C Conductivity: 3.14 S/m O2 Sat: 15.58 % O2 Temp: 1.80 C O2 Conc: 67.61 microMolar

Argus

FRAME GRAB NEW WINDOW

“If you don't annotate/collect/organize data during field deployment it often takes a long time or doesn't happen.”

“Filled in for observations that people on watch did not capture.”

“Liked to see what everyone was logging, so you could avoid duplicate observations.”



Interactive Data Exploration: Synchronized Products

NA108: H1753

Latitude	Longitude	Heading
42.754700	-126.709120	132.1

06/04/19 20:53:44 UTC

Temp Probe Conductivity Temp Depth
Temp: 47.70 C Pressure: 2749.83 decibars Salinity: 34.63 psu Sound Velocity: 1503.64 m/s Temp: 2.05 C Conductivity: 3.17 S/m O2 Sat: 15.47 % O2 Temp: 2.26 C

Region: Gorda Ridge LAYERS
Geochemistry
High Temperature Vent
MEASURE CLEAR

Hercules FRAME GRAB NEW WINDOW

Argus FRAME GRAB NEW WINDOW

Summary Search Plot Links

Temp Probe
14:59 16:59 18:59 20:59 22:59 00:59 02:59
Temp: 47.70 C

Conductivity Temp Depth
14:59 16:59 18:59 20:59 22:59 00:59 02:59
Pressure: 2749.83 decibars Salinity: 34.63 psu Sound Velocity: 1503.64 m/s Temp: 2.05 C
Conductivity: 3.17 S/m

O2 Sat
14:59 16:59 18:59 20:59 22:59 00:59 02:59
O2 Sat: 15.47 % O2 Temp: 2.26 C O2 Conc: 66.27 microMolar

“ The plot is spectacular, you can pause and go back to where the temperature spikes were. ”

“ Often use search to look for keywords or tags to find prior time/location/data. ”



xGDS

Interactive Data Exploration: Replay data in sync



xGDS SUBSEA MAP DIVE SEARCH CHAT SETTINGS IMPORT

LOGOUT

LIST ROV PLANS

NA108: H1754

Latitude	Longitude	Heading	Altitude	Depth	Position Time
42.763967	-126.739808	169.702	5.245	3076.420	06/06/19 05:54:27

+ EVENT RESET LAYOUT

06/06/19 05:54:27 UTC

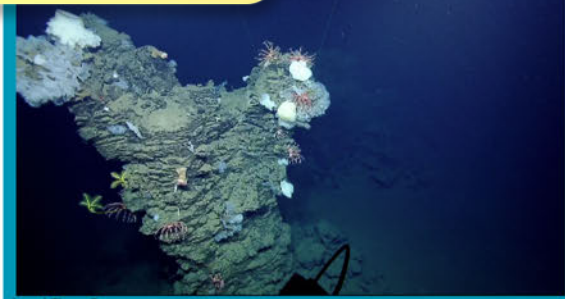
Speed: 1 Jump to: 06/05/19 HH:mm:ss Go

“Being able to rewind during a dive to review data/video makes it less exhausting, decreasing paranoia about missing something.”



O2 Sat: 1.75 C Conductivity: 3.16 S/m O2 Sat: 15.98 % O2 Temp: 1.80 C O2 Conc: 69.35 microMolar

FRAME GRAB NEW WINDOW



Argus

FRAME GRAB NEW WINDOW



Summary Search Plot Links

Search for: Event LOAD

Subscribe Time Control

Keyword

Display 10

All

Time

- 06/06/19 05:58:29 Megan Lubetkin striking layers of basalt, exposed cave-like areas below Geology
- 06/06/19 05:57:51 Angela Garcia collapsed sheet Geology
- 06/06/19 05:57:48 Jon Willis LENGTH: 00:01 basalt layer cake AudioVideo Rating5
- 06/06/19 05:57:35 Angela Garcia xsection of sheet going up and over ridge Geology
- 06/06/19 05:57:09 Megan Lubetkin gravel and rubble at base of thin layered vertical structures Geology

“Synchronizing ROV position with video and data replay was very helpful.”



Active Team Participation: Jump to events



xGDS SUBSEA MAP DIVE SEARCH CHAT SETTINGS IMPORT STATUS

LOGOUT DAVID [email icon] [help icon] [share icon]

LIST ROV PLANS

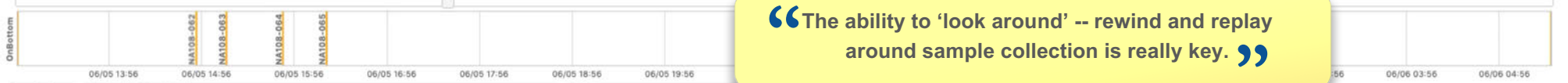
H1754

Latitude	Longitude	Heading	Altitude	Depth	Position Time
42.754781	-126.709191	156.417	1.028	2705.900	06/05/19 16:33:41

+ EVENT VIDEO RESET LAYOUT [lock icon]

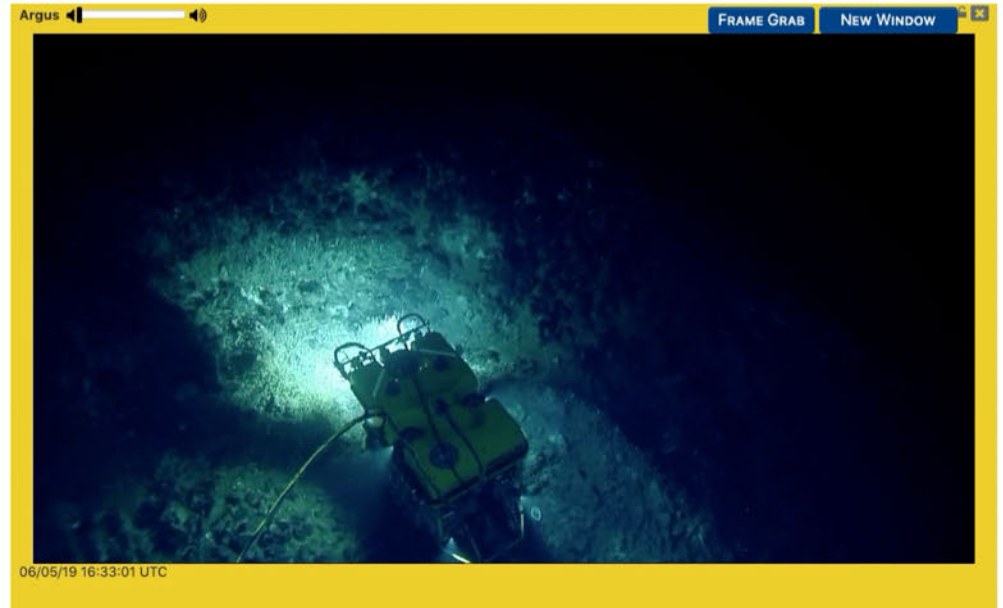
[play icon] [pause icon] LIVE 06/05/19 16:33:01 UTC

Speed: 1 Jump to: 06/05/19 HH:mm:ss Go



“The ability to ‘look around’ -- rewind and replay around sample collection is really key.”

Temp Probe Conductivity Temp Depth O2Sat
Temp: 10.0 C Pressure: 2744 decibars Salinity: 35 psu Sound Velocity: 1518 m/s Temp: 5.6 C Conductivity: 3 S/m O2 Sat: 17% O2 Temp: 5.4 C O2 Conc: 66 microMolar



Example: Apollo Vent Field Discovery

xGDS SUBSEA MAP DIVE SEARCH CHAT SETTINGS IMPORT

LIST ROV PLANS

NA108: H1756

Latitude	Longitude	Heading	Altitude	Depth	Position Time
42.761475	-126.705812	162.454	5.206	2756.441	06/07/19 13:13:03

06/07/19 13:23:51 UTC

Speed: 1 Jump to: 06/07/19 HH:mm:ss Go

Temp Probe Conductivity Temp Depth O2Sat
 Temp: 2.05 C Pressure: 2780.19 decibars Salinity: 34.63 psu Sound Velocity: 1504.21 m/s Temp: 2.06 C Conductivity: 3.17 S/m O2 Sat: 15.76 % O2 Temp: 1.93 C O2 Conc: 68.17 microMolar

Hercules FRAME GRAB NEW WINDOW

Region: Gorda Ridge LAYERS

- 06/07/19 13:55:53 Tprobe at 290.4C solid rock stable Apollo site Geochemistry High Temperature Vent TempProbe
- 06/07/19 13:34:53 video of Apollo site. HT chimneys for IGT sampling High Temperature Vent
- 06/07/19 13:23:51 chimney apollo
- 06/07/19 13:22:32 LENGTH: 00:01 Apollo vent field closeup AudioVideo Rating4
- 06/07/19 13:13:01 Moving laterally on ridge near Apollo vent site
- 06/07/19 13:09:48 Nice chimneys at deep end of Apollo Vent Field Geochemistry High Temperature Vent Geology
- 06/07/19 13:02:27 Moving to Apollo vent site

Showing 11 to 19 of 19 entries (filtered from 11,313 total entries)

Example: Apollo Vent Field Discovery

“xGDS was helpful when we were looking for the Apollo site, because it let us see easily see where the sub had been”

NA108: H17

Speed: 1 Jump to: 06/07/19 HH:mm:ss Go

Temp Probe Conductivity Temp Depth O2Sat
 Temp: 2.05 C Pressure: 2780.19 decibars Salinity: 34.63 psu Sound Velocity: 1504.21 m/s Temp: 2.06 C Conductivity: 3.17 S/m O2 Sat: 15.76 % O2 Temp: 1.93 C O2 Conc: 68.17 microMolar

Hercules

Region: Gorda Ridge LAYERS

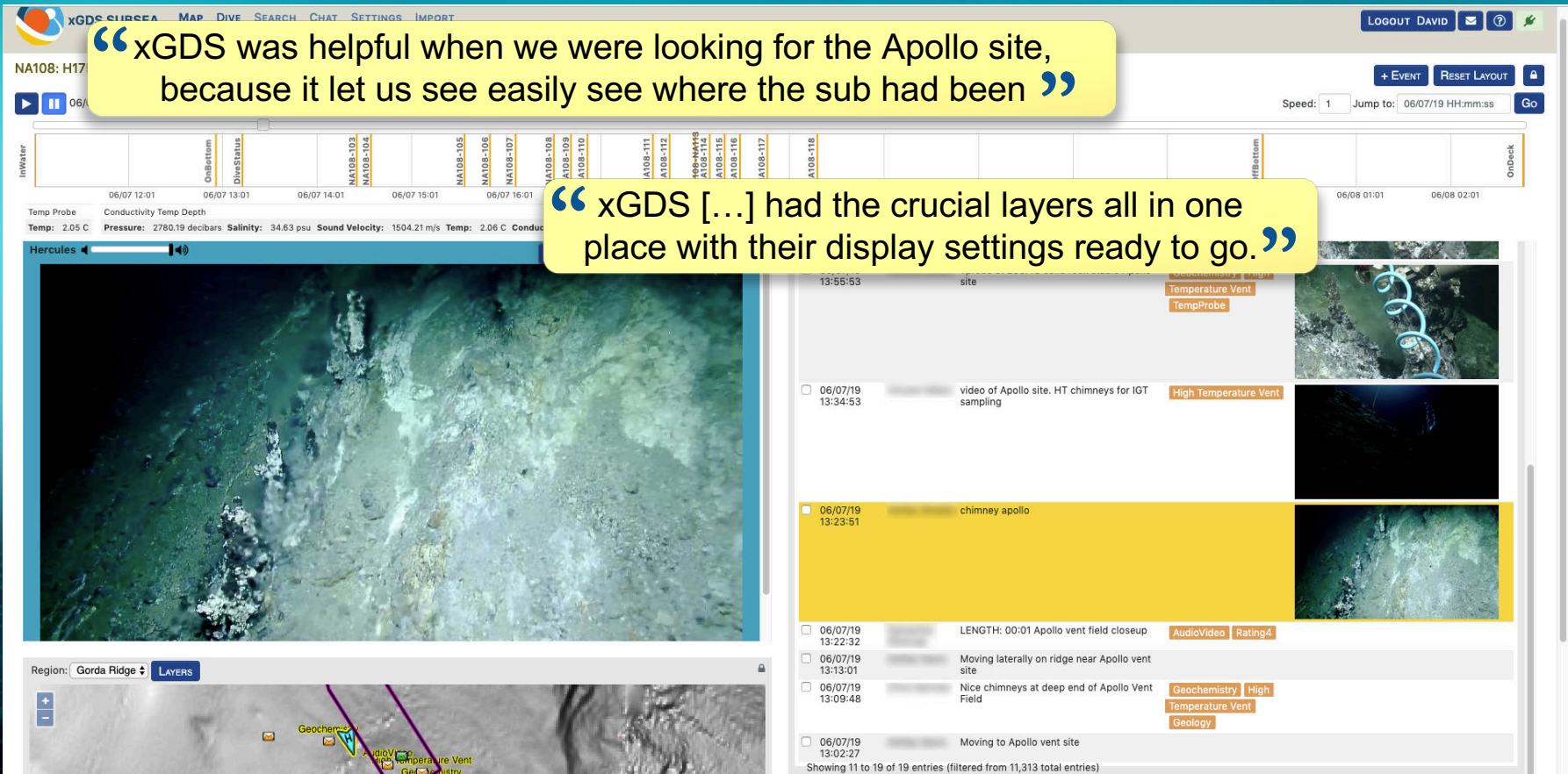
- 06/07/19 13:55:53 Tprobe at 290.4C solid rock stable Apollo site **Geochemistry High Temperature Vent TempProbe**
- 06/07/19 13:34:53 video of Apollo site. HT chimneys for IGT sampling **High Temperature Vent**
- 06/07/19 13:23:51 chimney apollo
- 06/07/19 13:22:32 LENGTH: 00:01 Apollo vent field closeup **AudioVideo Rating4**
- 06/07/19 13:13:01 Moving laterally on ridge near Apollo vent site
- 06/07/19 13:09:48 Nice chimneys at deep end of Apollo Vent Field **Geochemistry High Temperature Vent Geology**
- 06/07/19 13:02:27 Moving to Apollo vent site

Showing 11 to 19 of 19 entries (filtered from 11,313 total entries)

Example: Apollo Vent Field Discovery

“xGDS was helpful when we were looking for the Apollo site, because it let us see easily see where the sub had been”

“xGDS [...] had the crucial layers all in one place with their display settings ready to go.”



The screenshot displays the xGDS web interface. At the top, there are navigation tabs: MAP, DIVE, SEARCH, CHAT, SETTINGS, and IMPORT. The user is logged in as DAVID. The main content area is divided into several sections:

- Map:** Shows a top-down view of the Gorda Ridge with various data layers overlaid. A yellow callout box highlights the text: "xGDS was helpful when we were looking for the Apollo site, because it let us see easily see where the sub had been".
- Event List:** A list of events with columns for date, time, description, and tags. One event is highlighted in yellow: "06/07/19 13:23:51 chimney apollo". Other events include "video of Apollo site. HT chimneys for IGT sampling" and "LENGTH: 00:01 Apollo vent field closeup".
- Video/Thumbnail:** A large video player on the left shows a close-up of the seafloor. To the right of the event list are smaller thumbnails of video frames.
- Metadata:** At the bottom left, it shows "Region: Gorda Ridge" and "LAYERS".

xGDS for SUBSEA by the numbers

ISC science team (beyond Nautilus data logger & video):

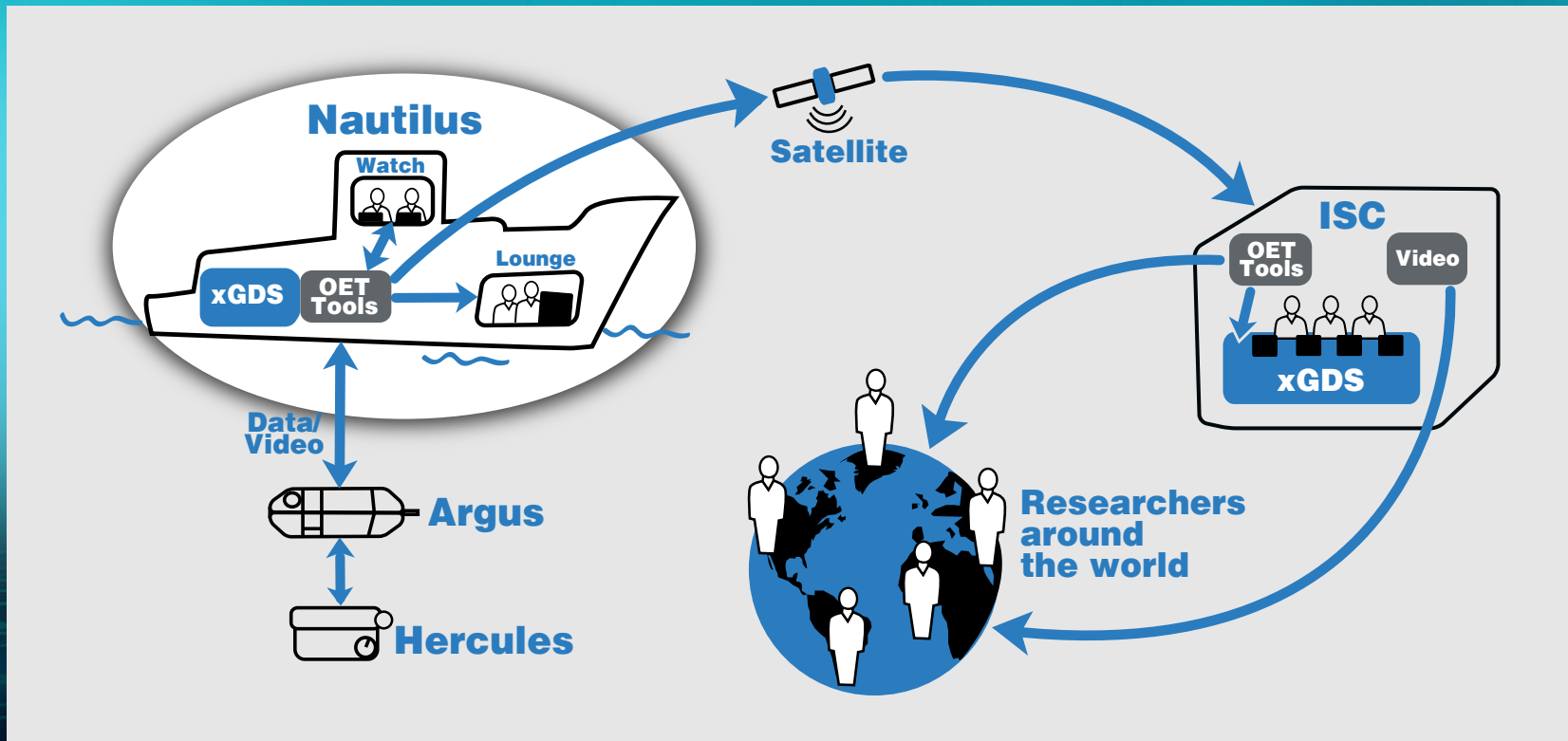
- ~1000 still images from the video feed.
- ~700 accesses to map layers.
- ~600 observations and tags on data streamed from ship.
- ~230 accesses to the video replay page.
- 53 ROV plans created during NA108 cruise
- 7 final plans delivered to Nautilus for 7 dive days.
- 24 hour maximum dive length

OET's Shipboard Needs are Similar

- Collaborative planning
- Empowering watch lead
- Search Data & Replay Dive



Next Steps: xGDS on Ship





Next Steps: Archiving

images

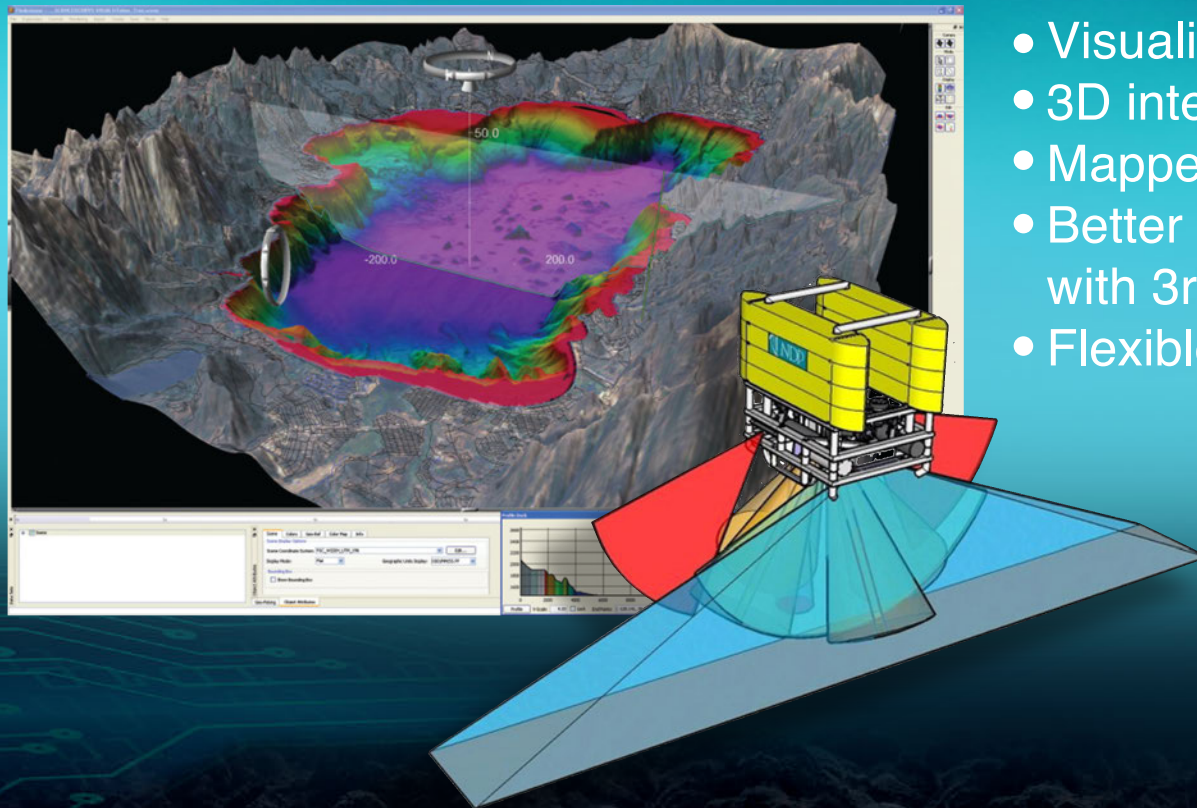
chat

notes

video

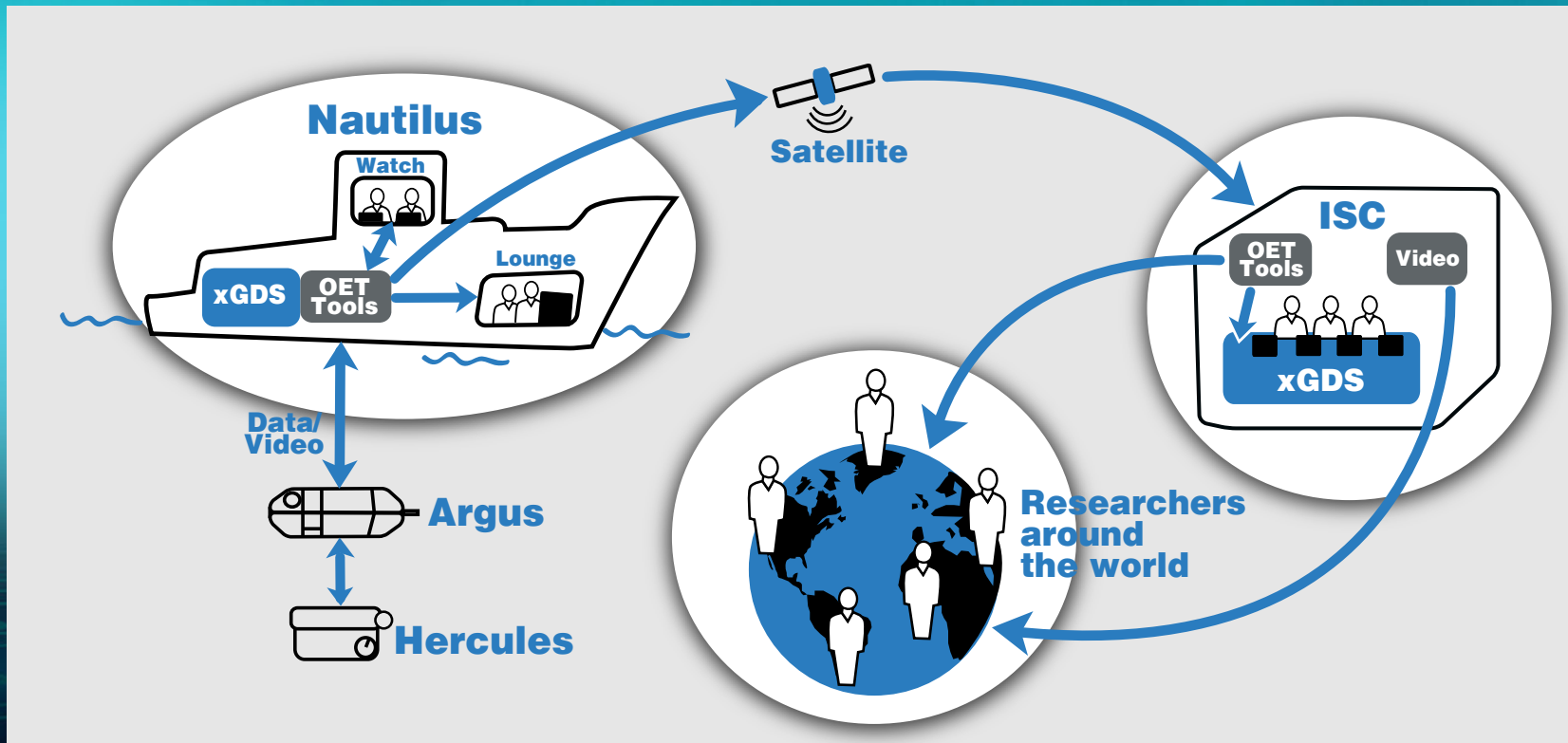
xGDS could provide standard format archives for all of its data, to integrate with permanent NOAA archives.

Next Steps: New capabilities and improved integration

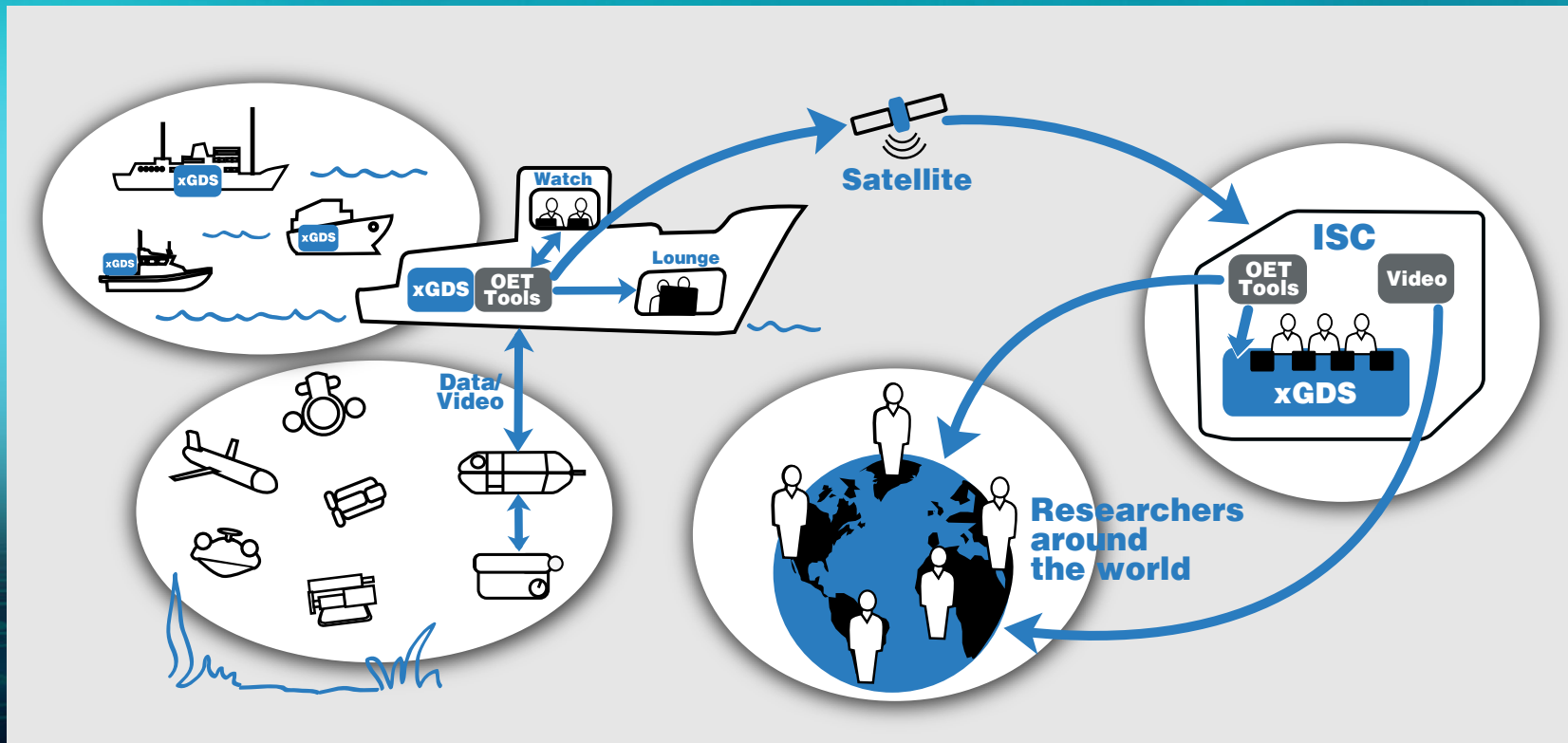


- Visualizations
- 3D interactivity with data
- Mapped interactive data
- Better bidirectional integration with 3rd party tools
- Flexible location data sources

Next Steps: xGDS Distributed



Next Steps: More ships and ROVs



Why is now the right time

- Movement toward open data, especially government data.
- Internet makes users expect rapid access to clear, actionable data.
- Current technology makes this (more) feasible.
- Joint development of Ocean Worlds and Ocean Exploration technology will benefit both communities.
- Define requirements now to improve science and exploration return in future deployments.

Next steps

- Plan for and implement shipboard xGDS installation on *Nautilus*
- Test it on technical “shakedown cruise”
- Deploy on appropriate science-focused cruise
- Deploy on science cruise with ship *and* shore participation





More Information

- <https://spacescience.arc.nasa.gov/subsea>
- <https://tos.org/oceanography/issue/volume-31-issue-01-supplement>
- <https://ti.arc.nasa.gov/tech/asr/groups/intelligent-robotics/xgds>

david.s.lees@nasa.gov

