ROV's

Presented by:

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Introduction to Remotely Operated and Autonomous Vehicles

Society for Underwater Technology

By:

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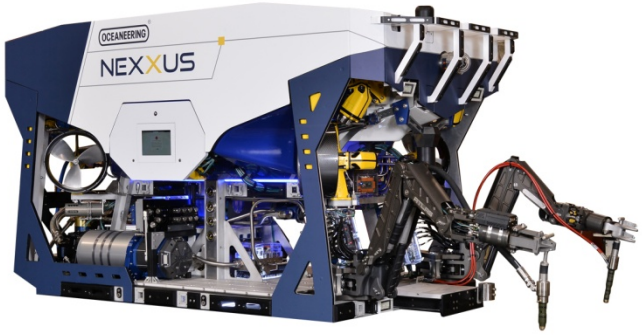
OCEANEERING®

Presentation Overview

- ROVs
  - Business
  - History
  - Key Hardware
  - Tools
- AUVs
  - Business
  - Key Hardware
  - Tools
- ASVs

Definitions

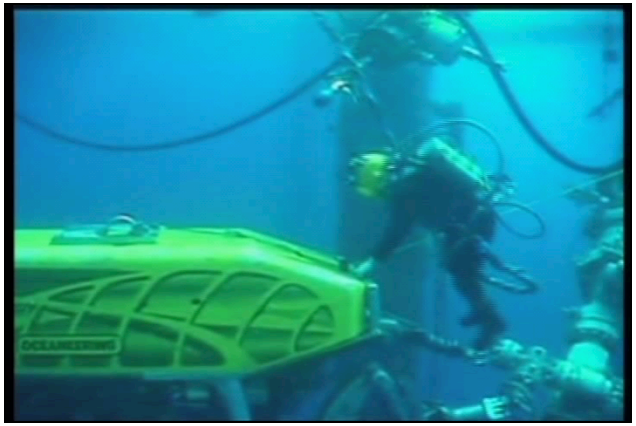
- **R**emotely **O**perated **V**ehicles (ROV)
  - Controlled from the surface via an umbilical
- **A**utonomous **U**nderwater **V**ehicles (AUV)
  - Preprogrammed operations – no input from operator , or supervised operations
  - In military applications, AUVs are often referred as unmanned undersea vehicles (UUVs)
- **A**utonomous **S**urface **V**essels (ASV)
  - Surface unmanned vessel
  - Preprogrammed operations – no input from operator, or supervised operation



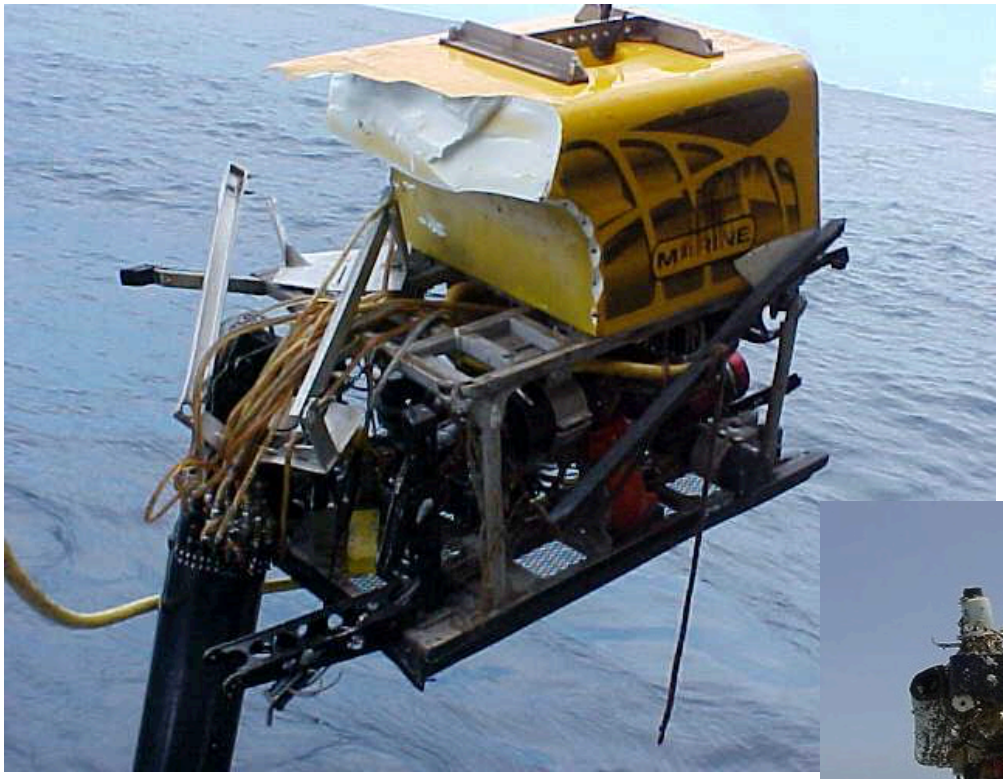
Remotely Operated Vehicles (ROVs)

Harsh and Dangerous Environments

- Extreme Weather and Temperature
- Vessel Movement
- High Voltages (5000+VAC)
- High Pressures (15000+psi)
- Heavy Loads
- Divers…



Bad Things Happen



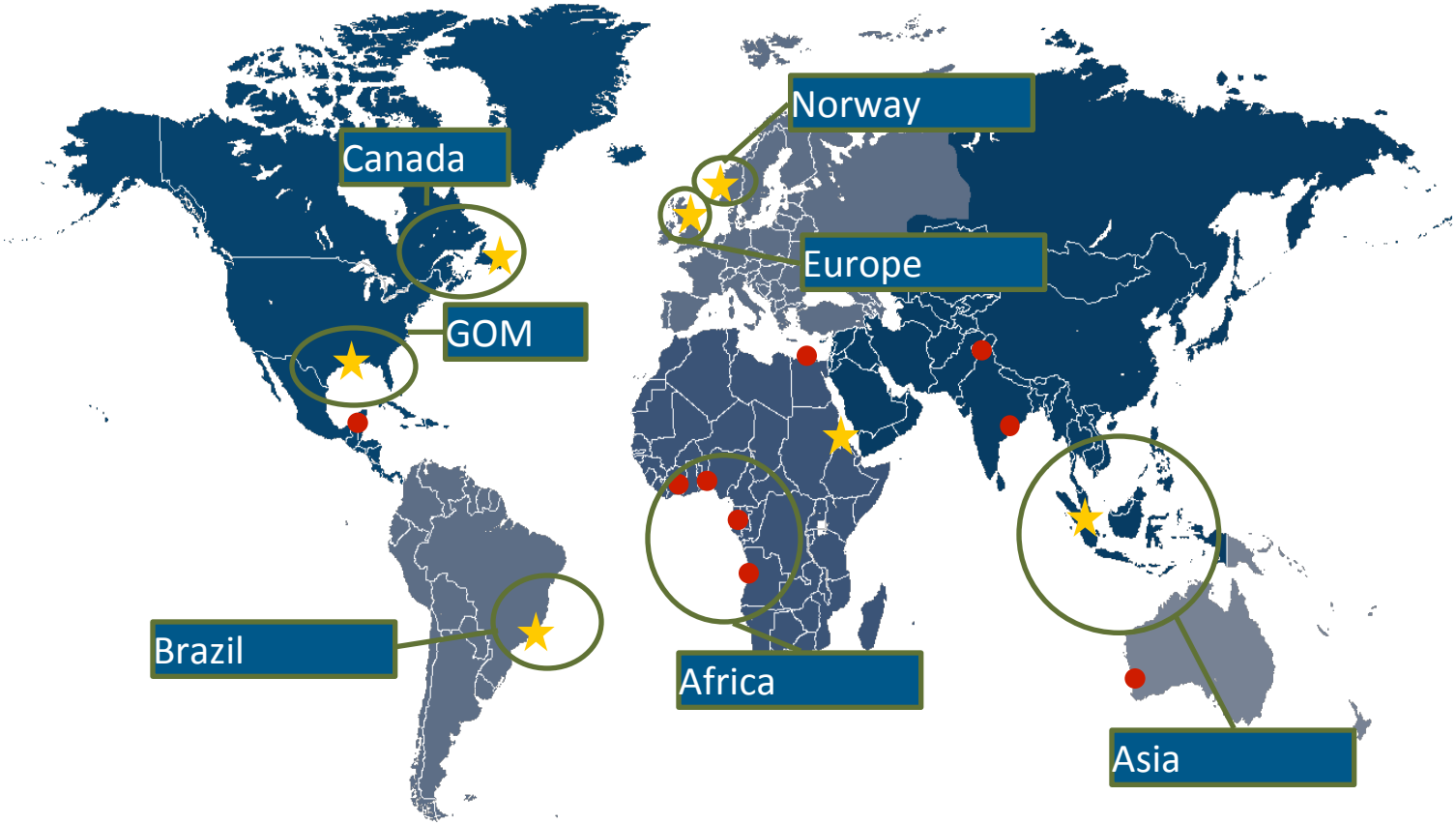
Typical ROV Services

- **Drill Support**
  - Mud /cuttings /concrete management from well, template or manifold
  - Routine inspection, monitoring, cleaning and intervention tasks on and around the BOP
  - Alignment and leveling during template or manifold installation

- **Well and Subsea Completion**
  - Construction support - trees, manifolds, jumper, flowlines, umbilicals, etc.
  - Monitoring and control for commissioning of well

- **Inspection, Maintenance and Repair**
  - Light well Intervention - stimulation, remediation, P&A, tie-backs Installations - flowlines and umbilicals
  - Pipeline Repairs, Strake Installations, Hydrotesting, Choke / Pod Change-outs
  - Mattress Installations and Crossings of Pipelines, Flowlines, and Umbilicals

Where ROVs Operate Today



The ROV Crew

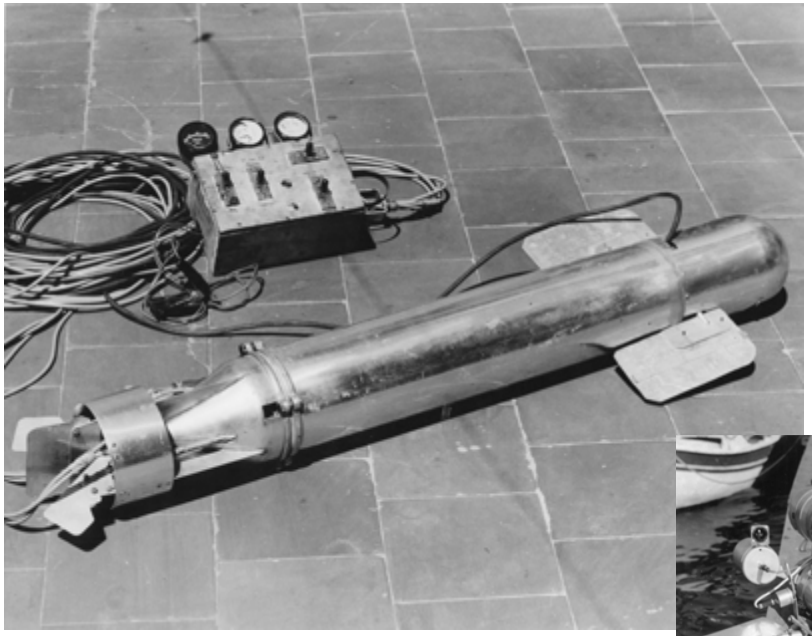
- Crew consists of 3-men per 12-hour shift x 7 days / week
  - 1 x Supervisor
  - 2 x Pilot (Mechanical and Electrical Technicians)
- Typical tour is 28-days (with 28-days off)
- Personnel Skill Requirements
  - Technical: Electronics, Electrical, Computers, Hydraulics, Mechanics
  - Team Dynamics
  - Safety Conscious

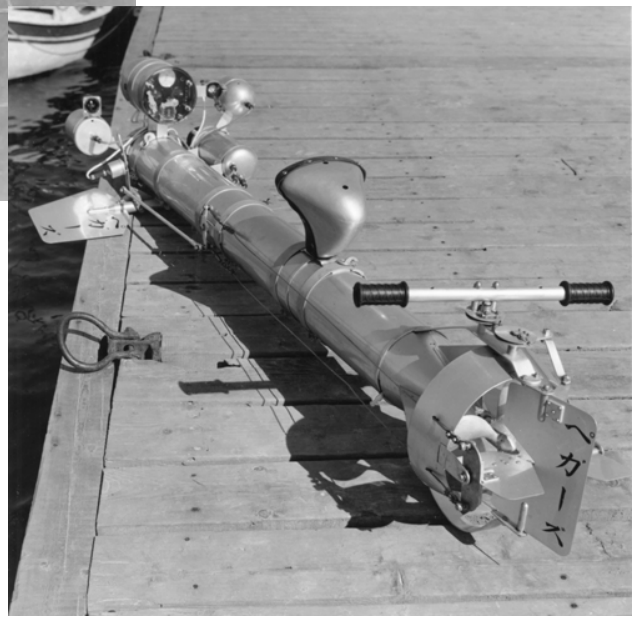
ROV Training

Commercial

- ROV services
  - Typically contracted directly with Operator
  - Charged on a day rate basis
  - Transit rates: manned and unmanned rates
  - System mobilization/demobilization costs
- Day Rates broken up as follows:
  - Crewing for 12 hour or 24 hours operations
  - Single system or dual systems
  - Dedicated crews
- Hardware
  - LARS - Heave Compensation, Wind Shelter, Garage
  - Tooling Leased - standard tooling, skids, specialty systems
  - Tool Pool - managed tool issuance and maintenance/repair

ROV History: Commercial – 1950's



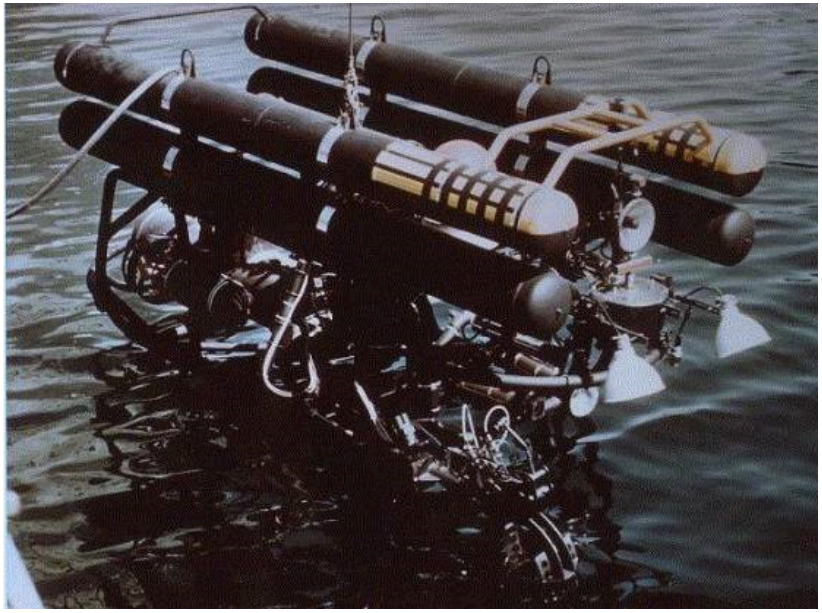


- First ROV…
- Dimitri Rebikoff developed the "Poodle" in 1952
- Camera & Lights/Strobe specialist
- **Developed hardware to support Jacque Cousteau expeditions**
- Pegasus diver vehicle

ROV History: Military Work Class ROVs

1950's – 1960's

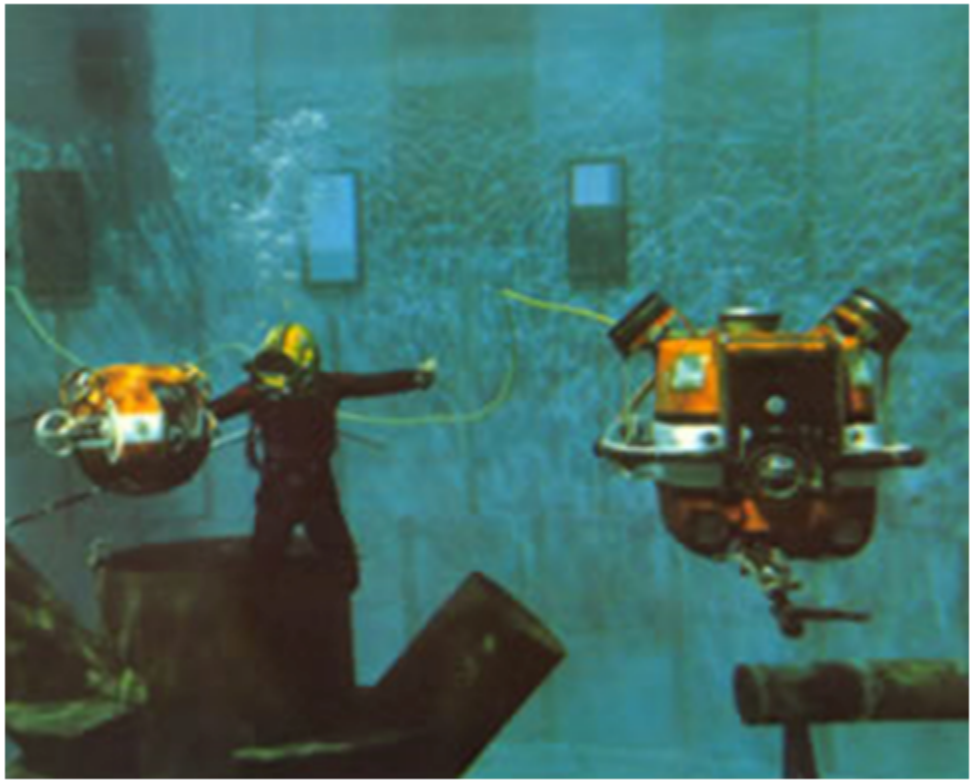
- **Military Applications** – torpedo recoveries
- **Electric thrusters** for propulsion
- **Camera and lights**
- "**Grabber Manipulator**" specifically designed to retrieve exercise torpedoes
- **1966 Palomares B-52 Plane Crash nuclear bomb recovery (2900ft)**
- **1973 Pisces submersible pilots rescue of Cork, Ireland (minutes to spare)**



ROV History: Observation Class ROVs

1970's – 1980's

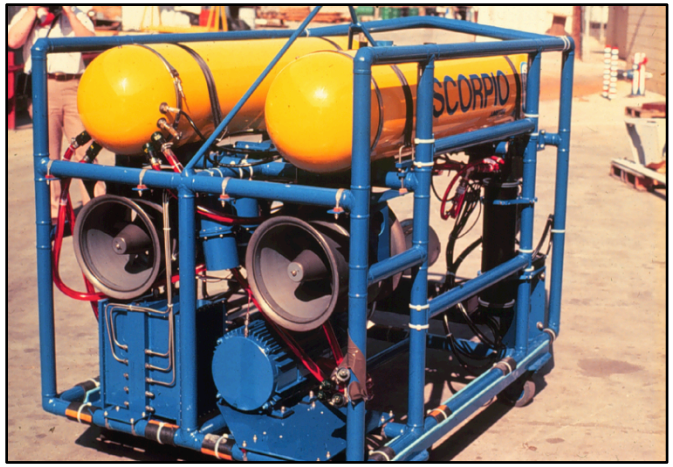
- TREC - 1st Generation ***Inspection ROV***
- **Air compensated technology**
- **Electric** motors were 1 hp **drill motors**
- Live Boat Launch/Recover System (No TMS)



- RCV-225 /150
- RC225 Torpedo Tubes
- 'State of the art' ROVs
- 4 x 150Vdc **Electric** Thrusters - Vertrans and Axial
- Side Entry (Cage) TMS Launch/Recovery System
- **SIT Camera with P&T**

ROV History: Work Class ROVs

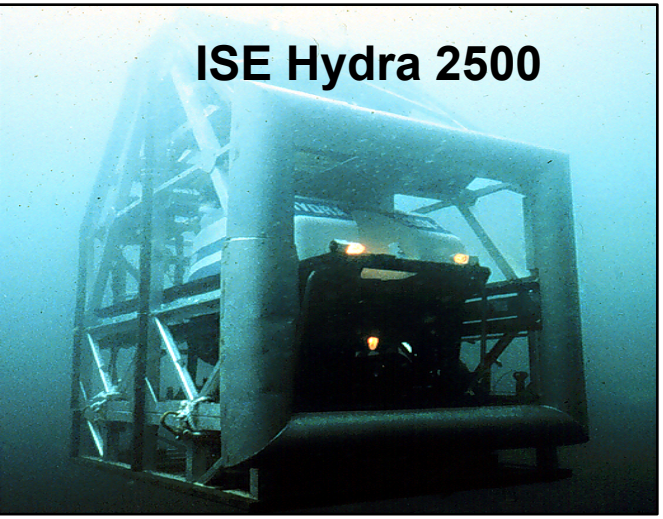
1970's – 1980's



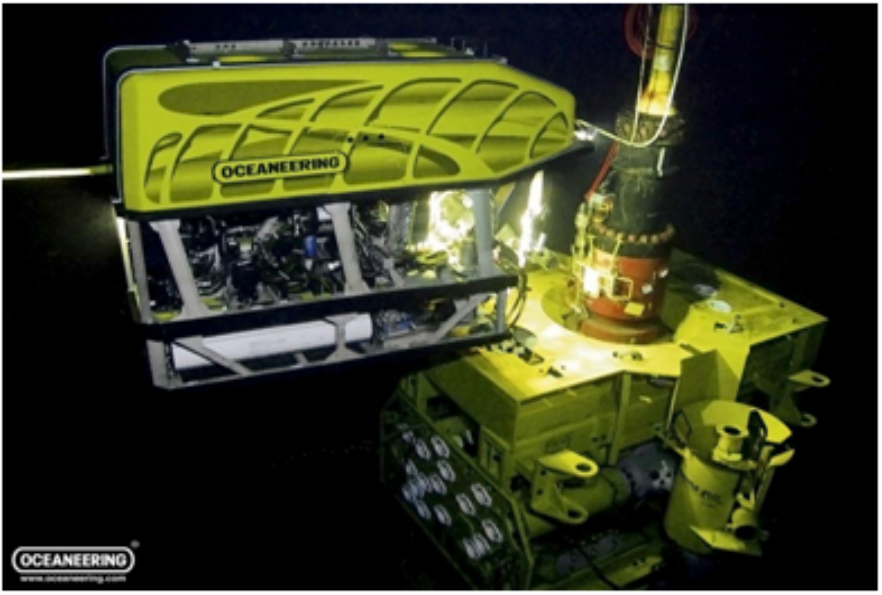
- Ametek **Scorpio** first commercially available ***Work Class*** ROV
- **20 HP Hydraulic**
- **Oil Compensated**
- Innerspace Thrusters
- B&W and Color Cameras
- Live Boat Launch/Recover System (no TMS)

- **TROV**
- **1,000 meter depth rating**
- **Use 1 x 7F and 1 x 5F manipulators**
- B&W and Color Cameras
- 40 hp Electric Thrusters - Constant RPM / **Variable Pitch**
- **Variable Ballast -Scuba bottle for ballast air supply**
- Live Boat Launch / Recovery System (No TMS)

ROV History: Work Class ROVs
1980s-1990s



- ISE **Hydra 2500**
- **2500** meter Depth rating
- **30 hp Power**
- Side Entry (Cage) TMS
- **High Voltage** ROV Systems (1600 Vac)
- 1st Commercial ROV using **Fiber Optics**
- **Reliable systems**



- Oceaneering **Magnum** and **Millennium** ROVs
- 3000 Meter Depth Rating
- **100** hp Hydraulic
- Side Entry (Cage) TMS
- Industry standard
- **Integrated into hardware and operations**

Today - Types of ROV's

Eyeball ROV

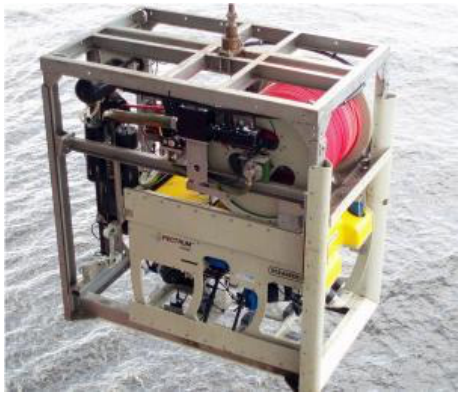
- Observation
- Light powered
- Lights and Cameras
- <500m depth

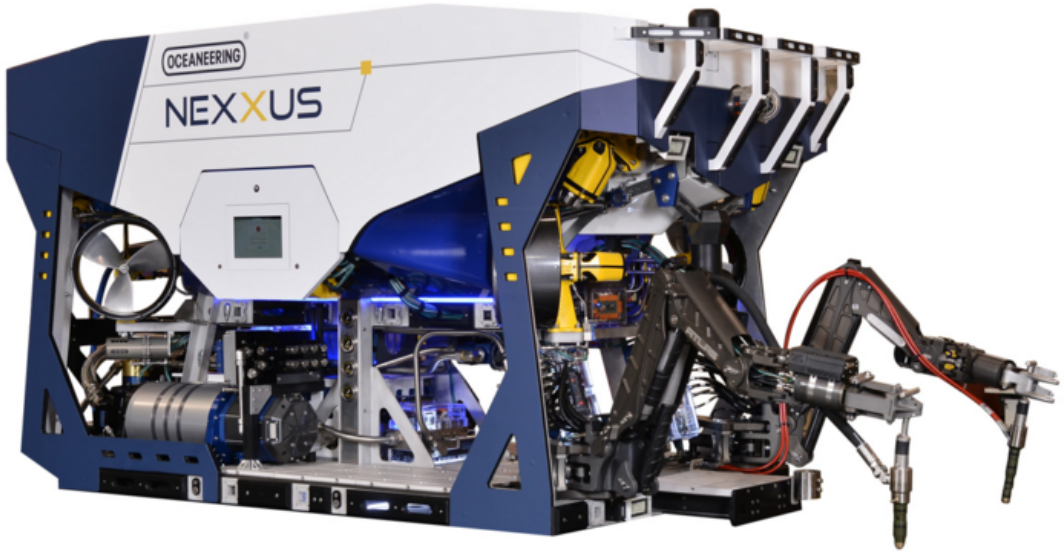
Heavy / Workclass ROV

- Heavy IMR
- Hydraulic
- 200-300 HP
- Power and operate heavy tools
- 4km depth

Light Workclass

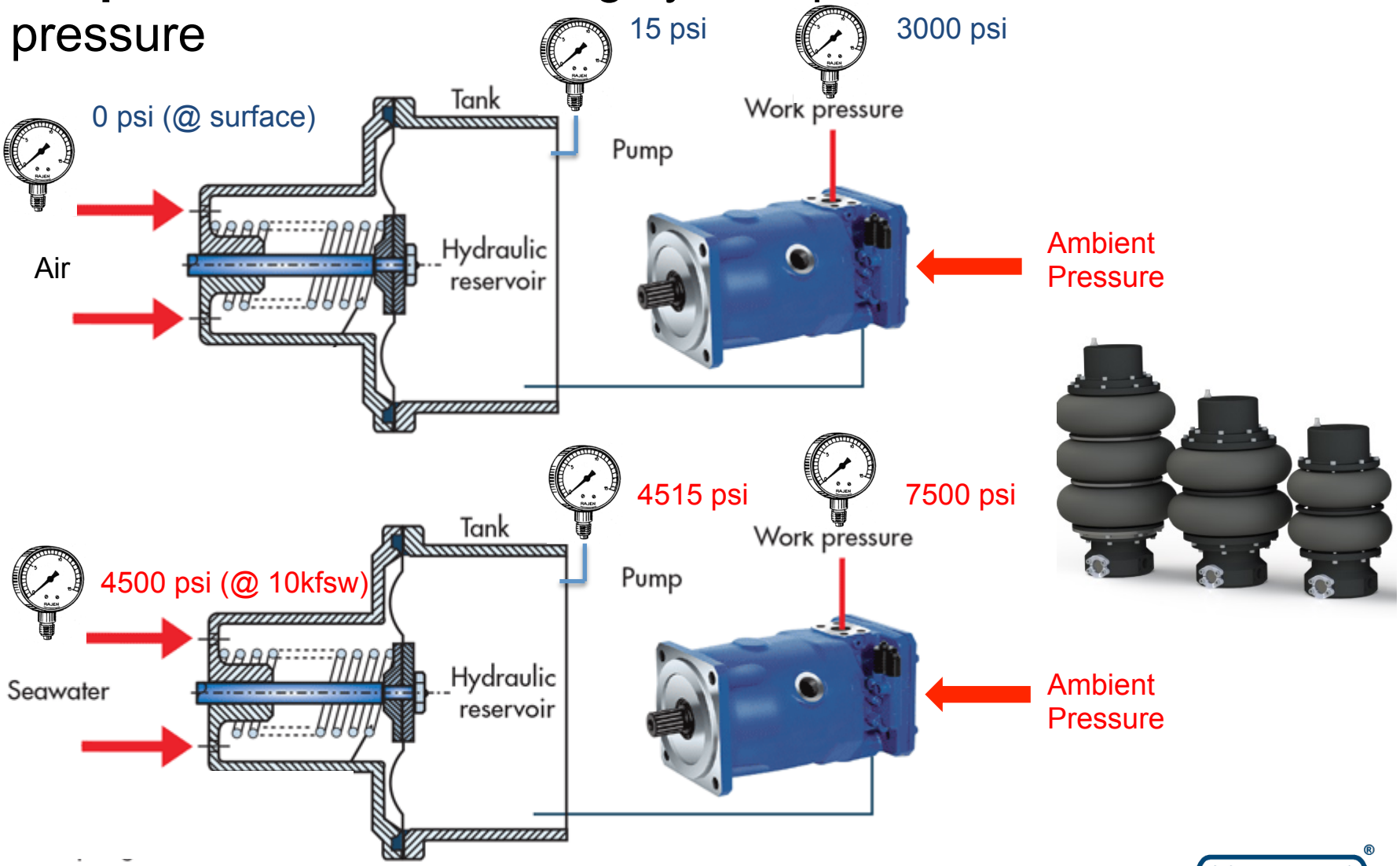
- Light IMR
- 5F Manipulator
- 3km depth
- Operate standard tools





Key Subsea Technology - Pressure Compensation

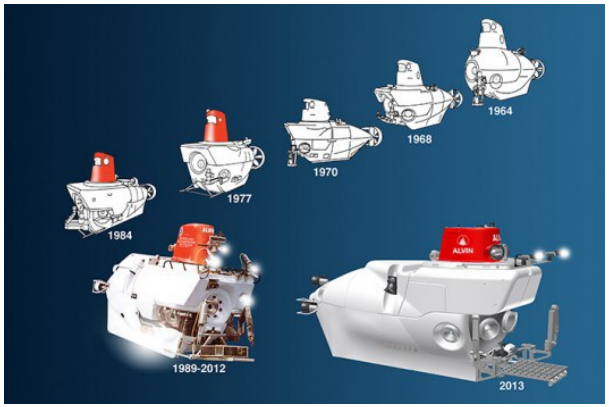
Compensation: Maintaining system pressure over ambient pressure

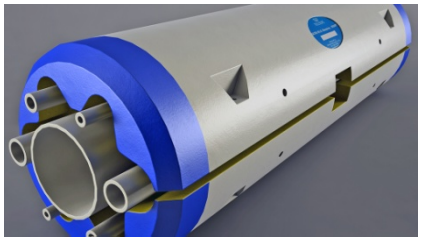


Key Subsea Technology - Buoyancy

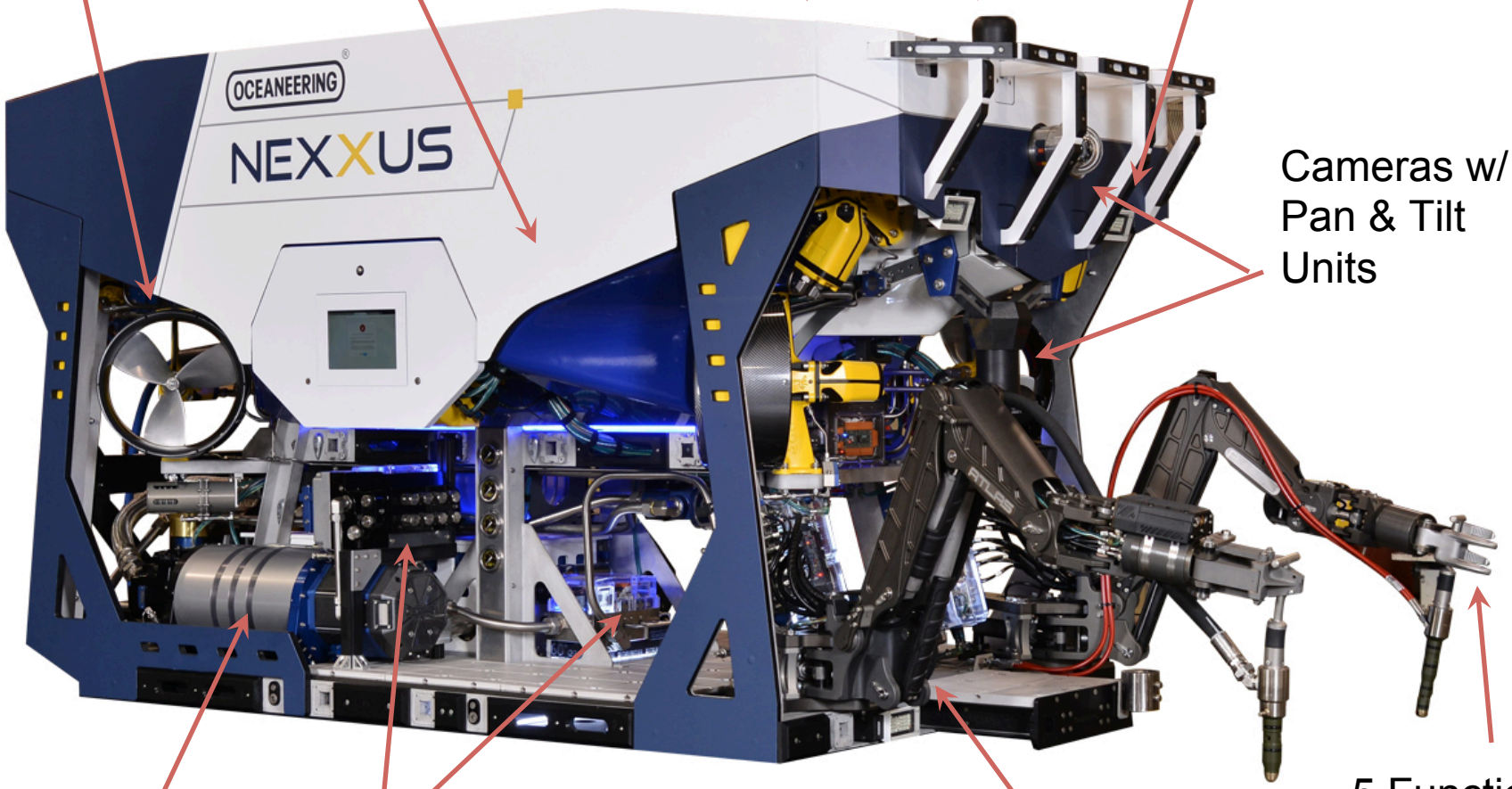
Syntactic Foam: " A class of material with pre-formed hollow glass spheres held in a polyester or epoxy binder"

Depth (m)	Density (lbs/ft^3)	Buoyancy Material	Volume float 2500 lbs load (ft^3)	Foam Weight (lbs)
200	14	Resin/ Air	50	700
500	20		57	1140
500	20	Resin/ Polymer Macrospheres	57	1140
1000	24		63	1512
1000	24-28	Resin/ Glass Microspheres (diff psi)	66	1716
3000	28-32		74	2220
4000	34		83	2822
6000	36-40		96	3648



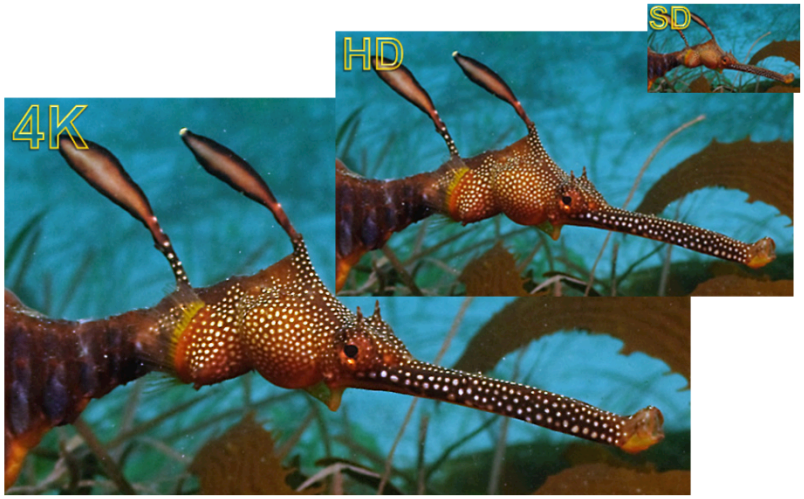


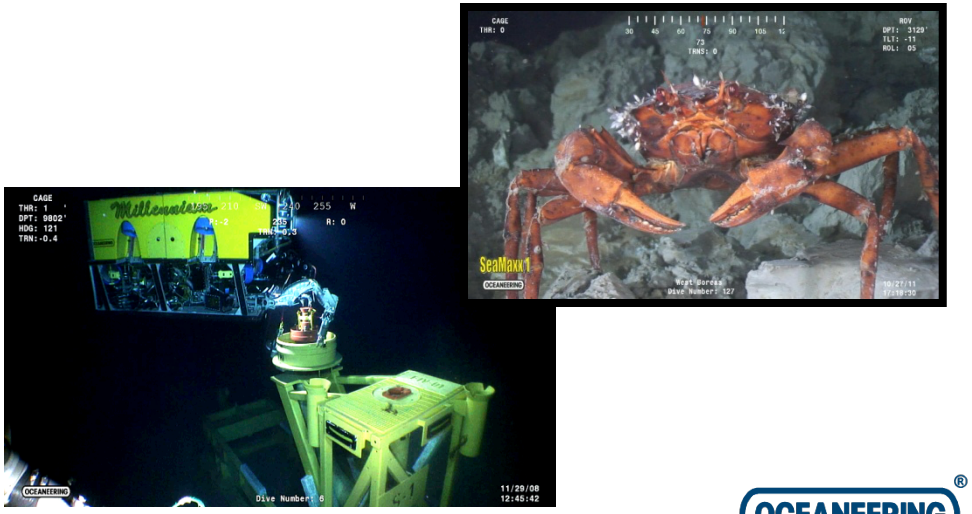
Review of ROV components and hardware



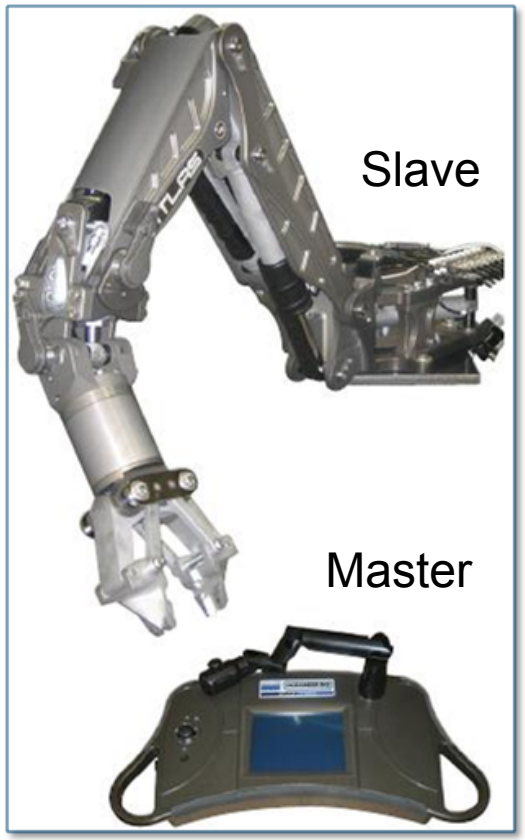
High Definition Camera Systems

- **HDTV Video**
- Video overlay
- Digital recording
- Streaming capable
- 4K Video
- 3D Video

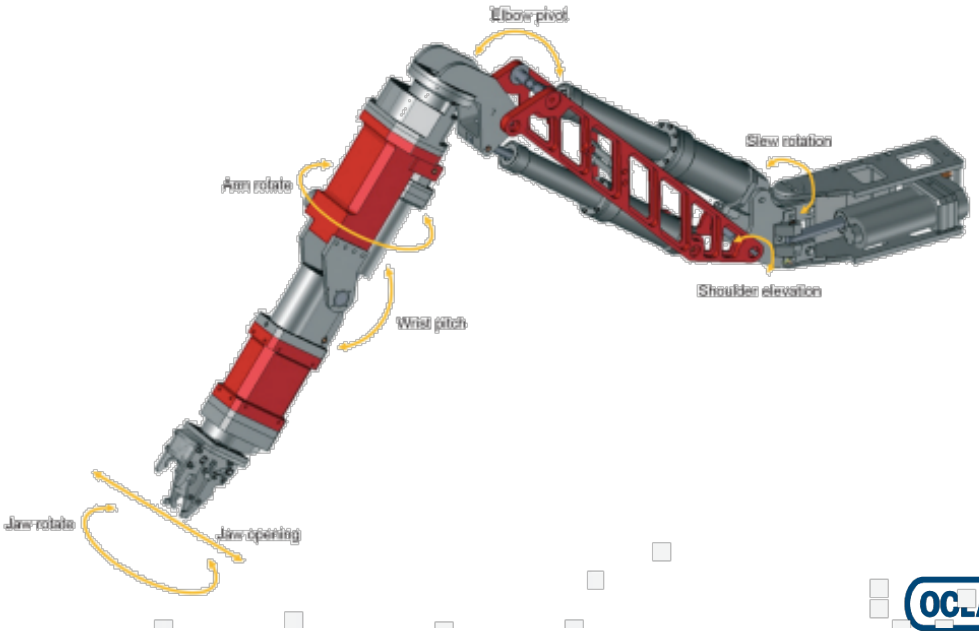




Types of Manipulators

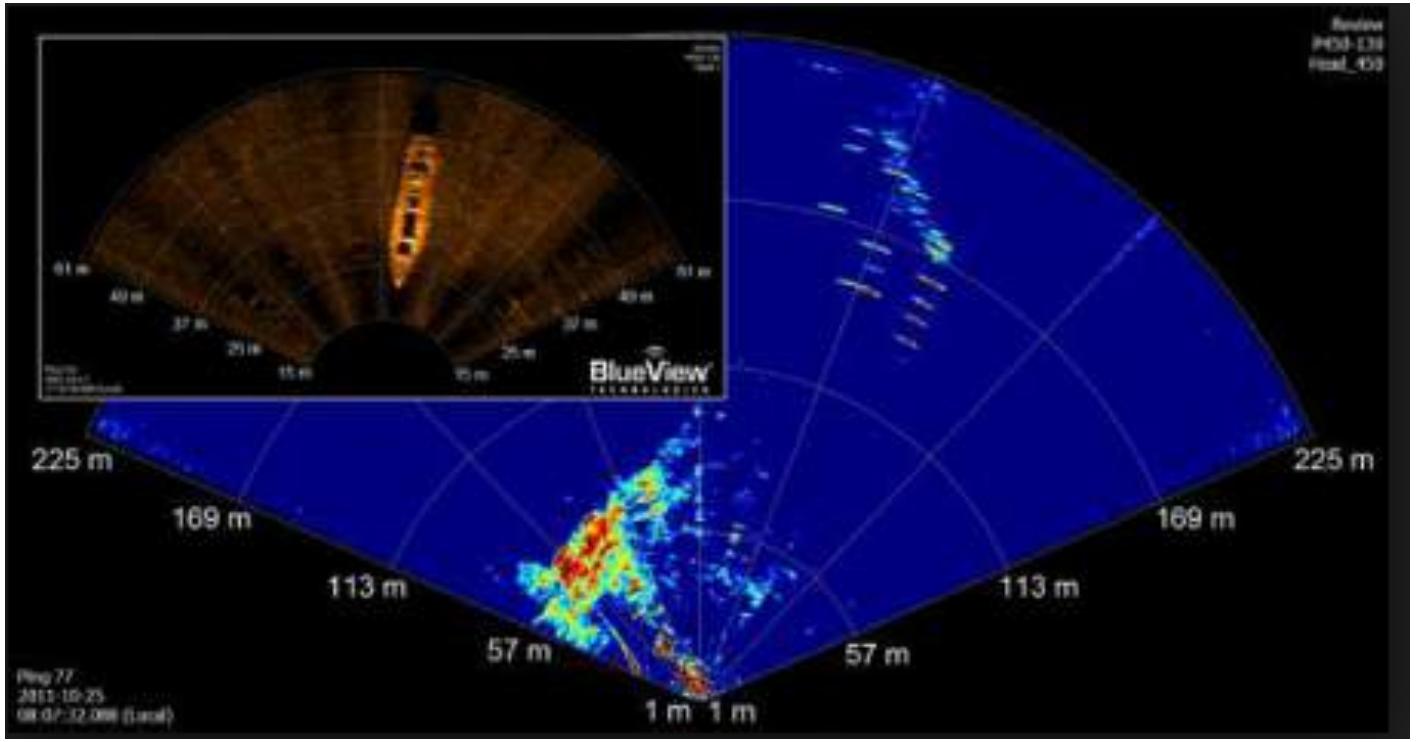


- 5 Function and 7 Functions
- Rate Feed - each individual joint controlled with simple on / off commands
- Spatial Correspondent (SC) - manipulator slave mimics movement of master arm on surface
- Hydraulic and Electric powered
  - Hydraulic dramatically higher loads: 500lbs@7ft vs. 85lbs@6ft for electric



Navigation

- Obstacle avoidance – Sonar / Imaging
- Attitude and Heading Reference System (AHRS)
- Distance from bottom - Altimeter
- Local movements - DVL and INS



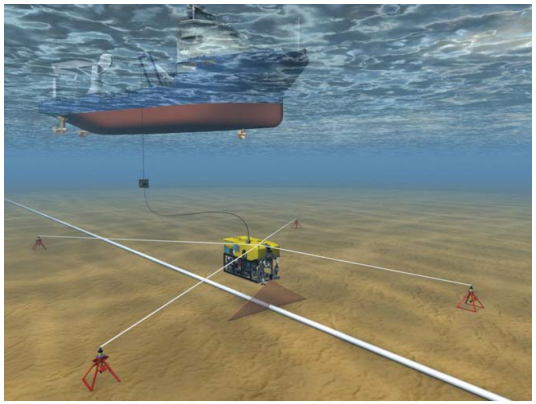
Doppler Velocity Log (DVL)

Inertial Navigation Sensor (INS)

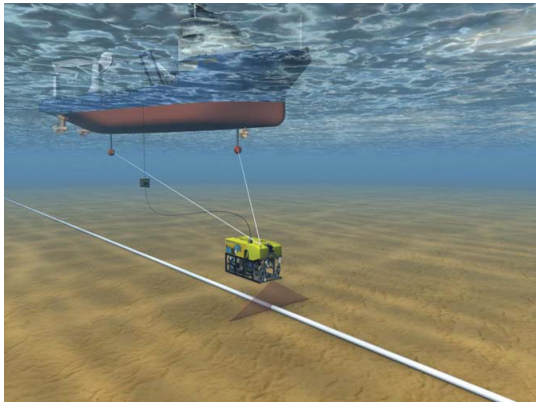
Key Subsea Technology - Navigation

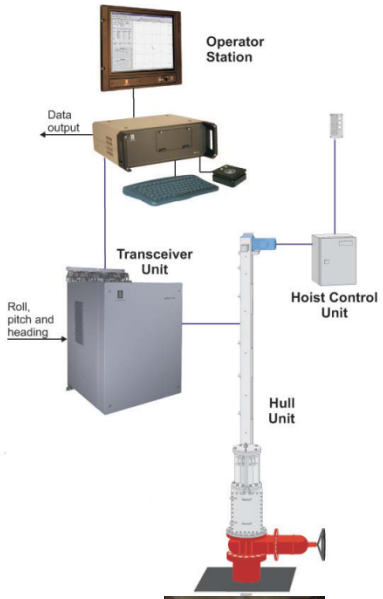
- Subsea Positioning – ROV, TMS, Hardware
  - Short, Ultra-Short and Long Baseline Systems

Long Baseline



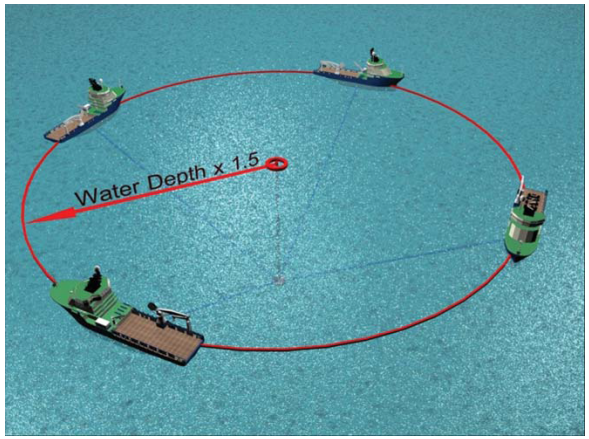
Short Baseline



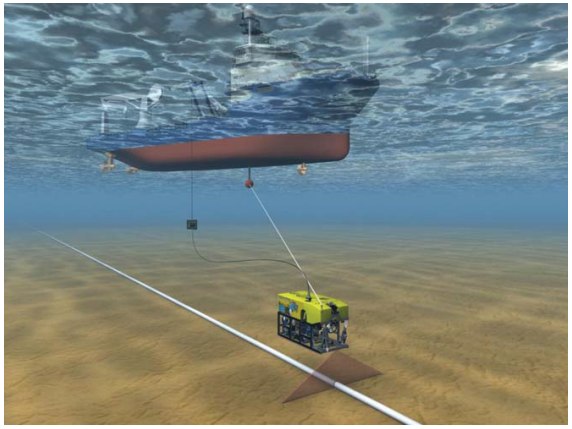


LBL Beacon

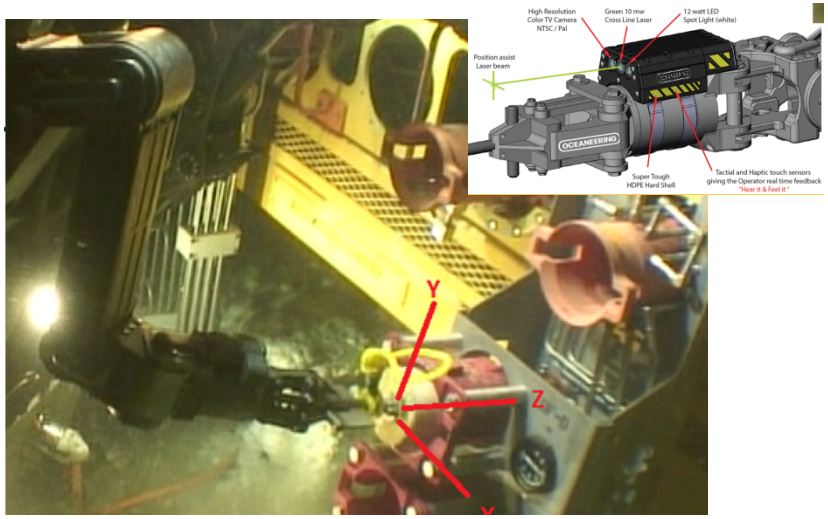
"Boxing -in" LBL Transponders

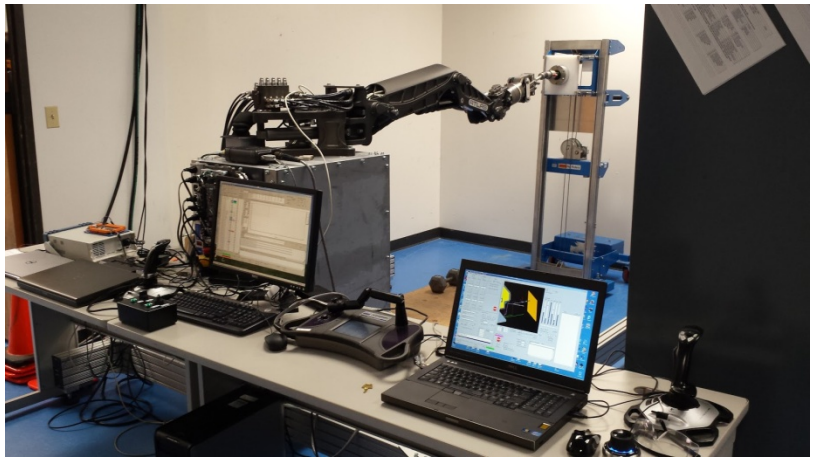


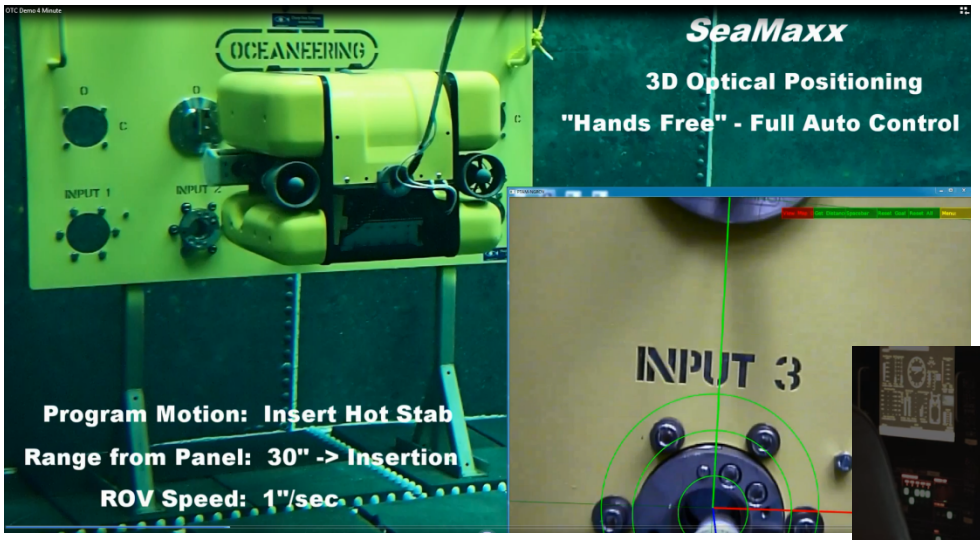
Ultra-Short Baseline

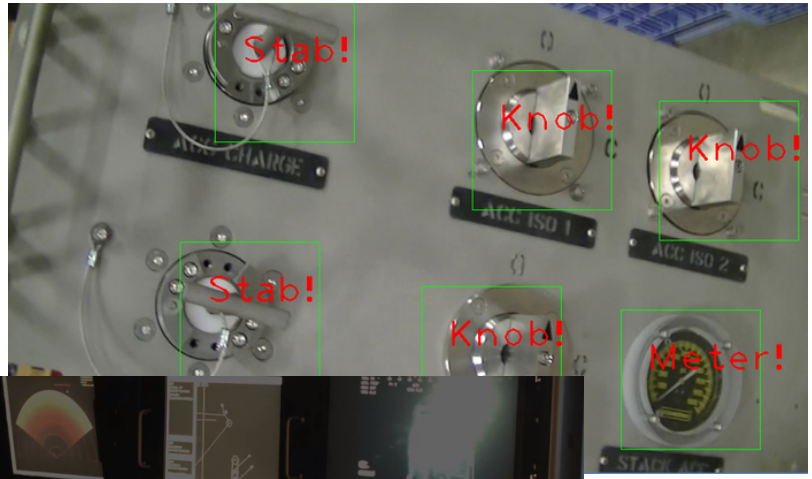


Control - Pilot Aids





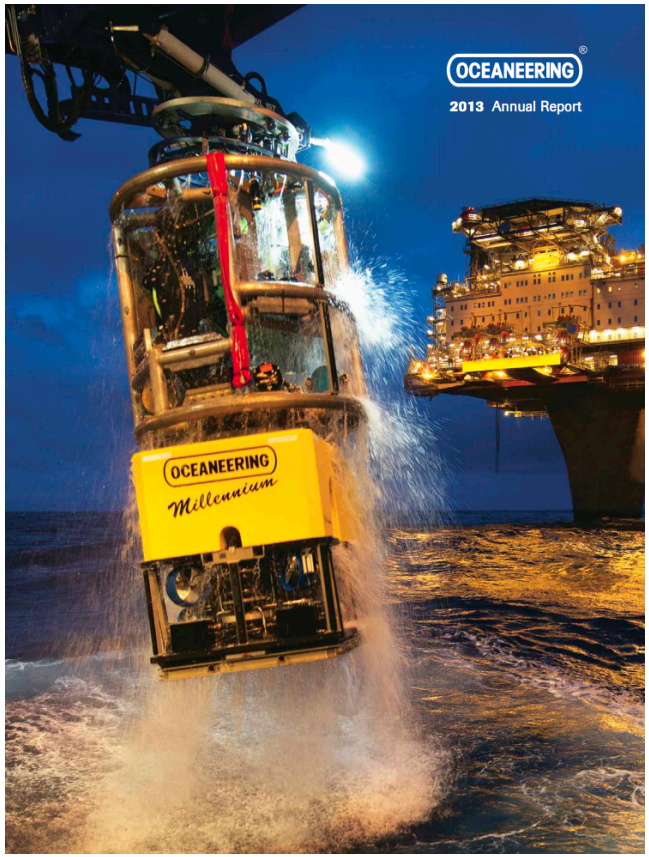




Major Components of ROV System

Installed on a Vessel

Key Subsea Technology: Tophat vs Side Entry Cage

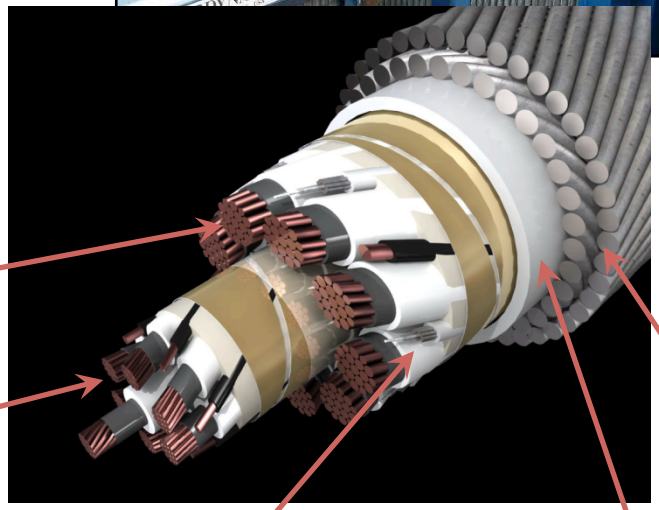


- Unlimited Skid Sizes
- Simple ROV + TMS Access on deck
- Difficult Docking & Dead ROV Recovery

- Lower Center of Gravity
- Greater Protection - Increased Weather Window
- Tool Platform
- Difficult access on deck

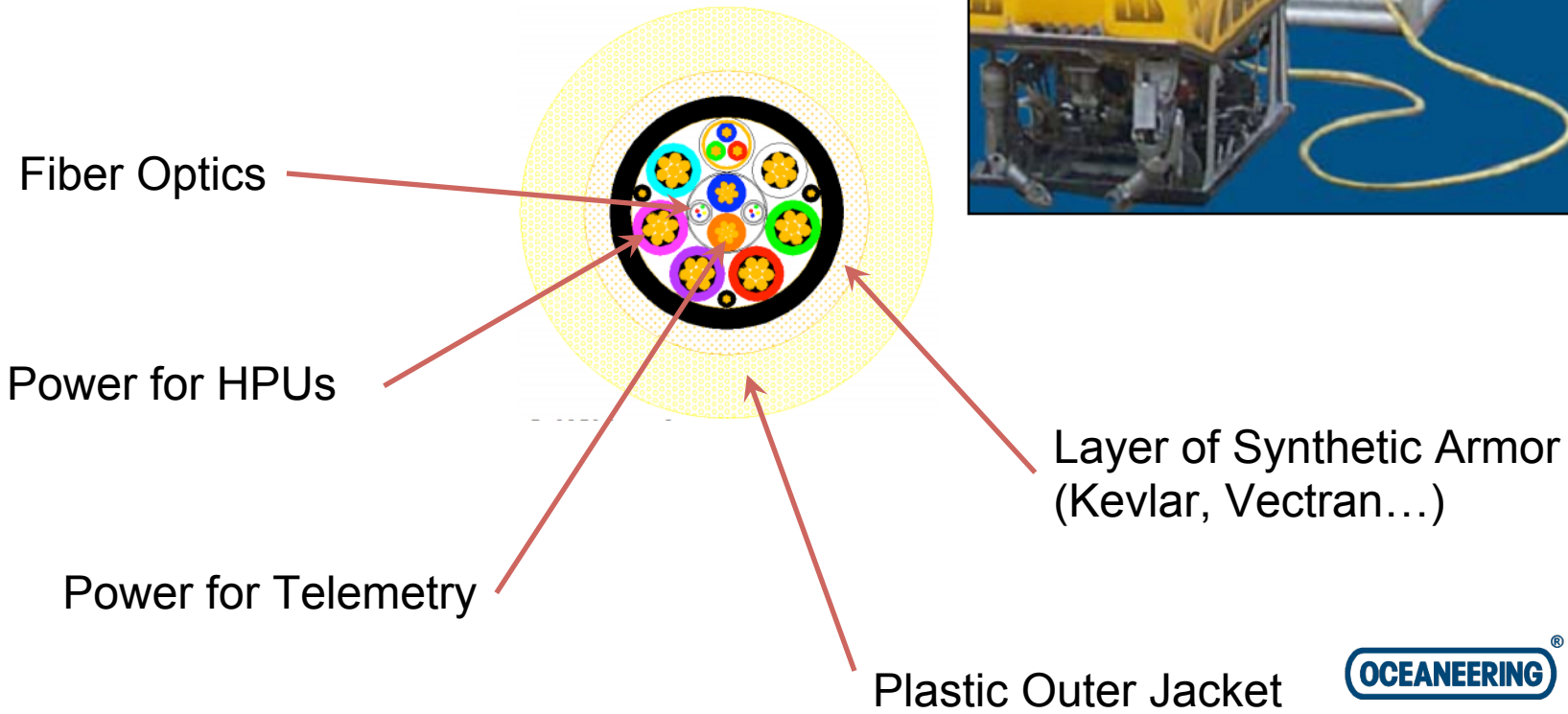
Umbilical

- Umbilical permits deployment of TMS to depth
- Provides path for power and control data to/from the TMS
- Fiber Optic and Electrical Slip rings



Tether

- Tether decouples motion of Vessel/TMS from ROV
- Provides path for power and control data to/from the ROV
- Tether stored on TMS mounted drum
- Fiber Optic and Electrical Slip Rings



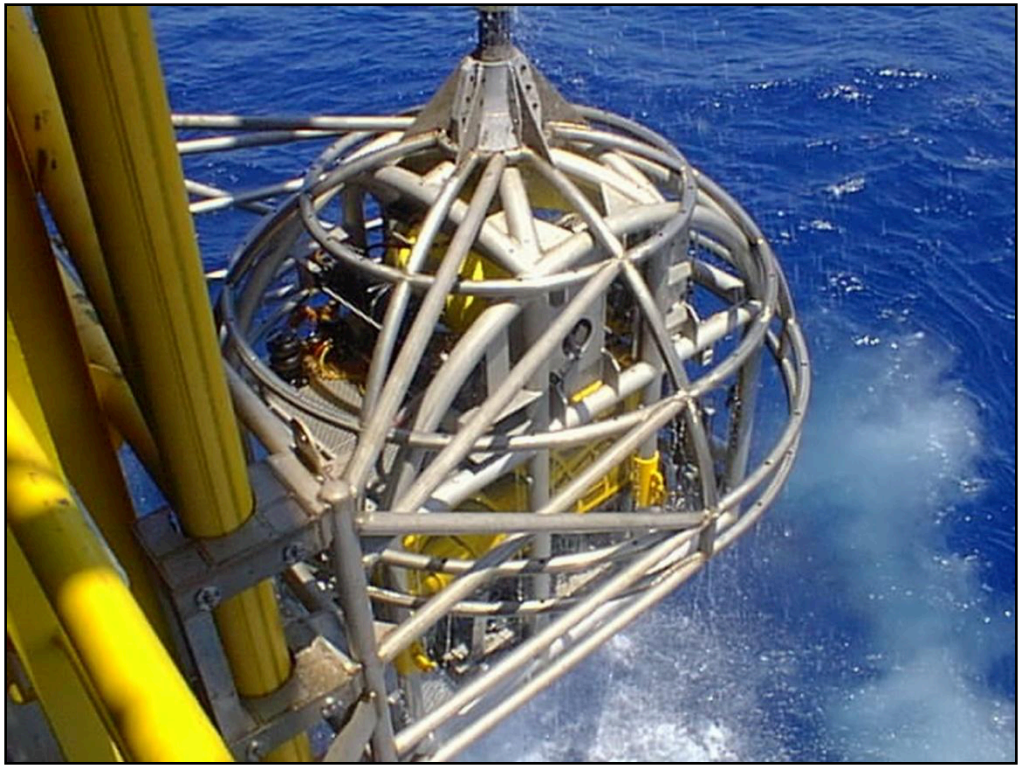
Control Consoles (Old and New)

Launch and Recovery

Over the Side

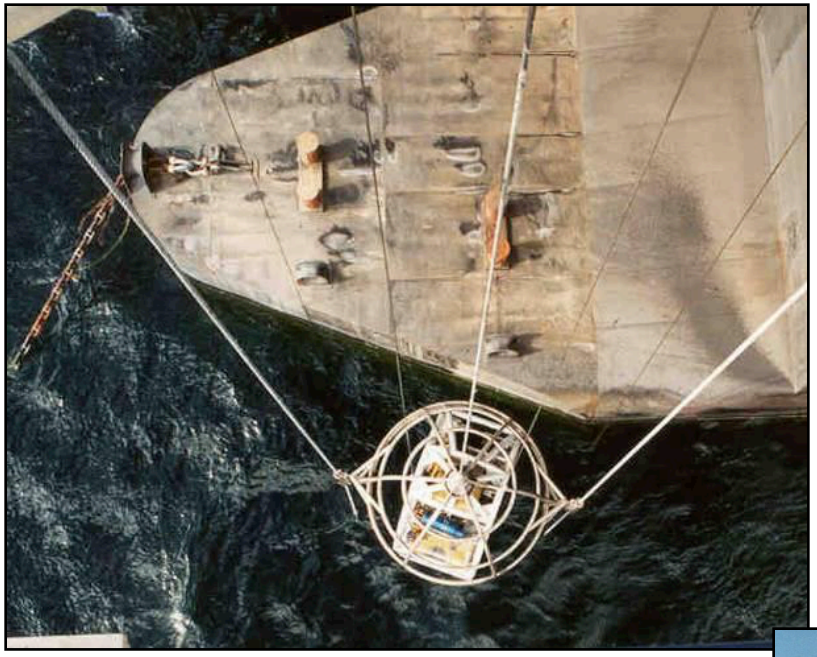
- Overboarding A-frame
- Traditional launch and recovery method
- Appropriate for short draft vessels
- Auto rotate docking head to align TMS/ ROV during recovery
- Portable

Cursor Rail System



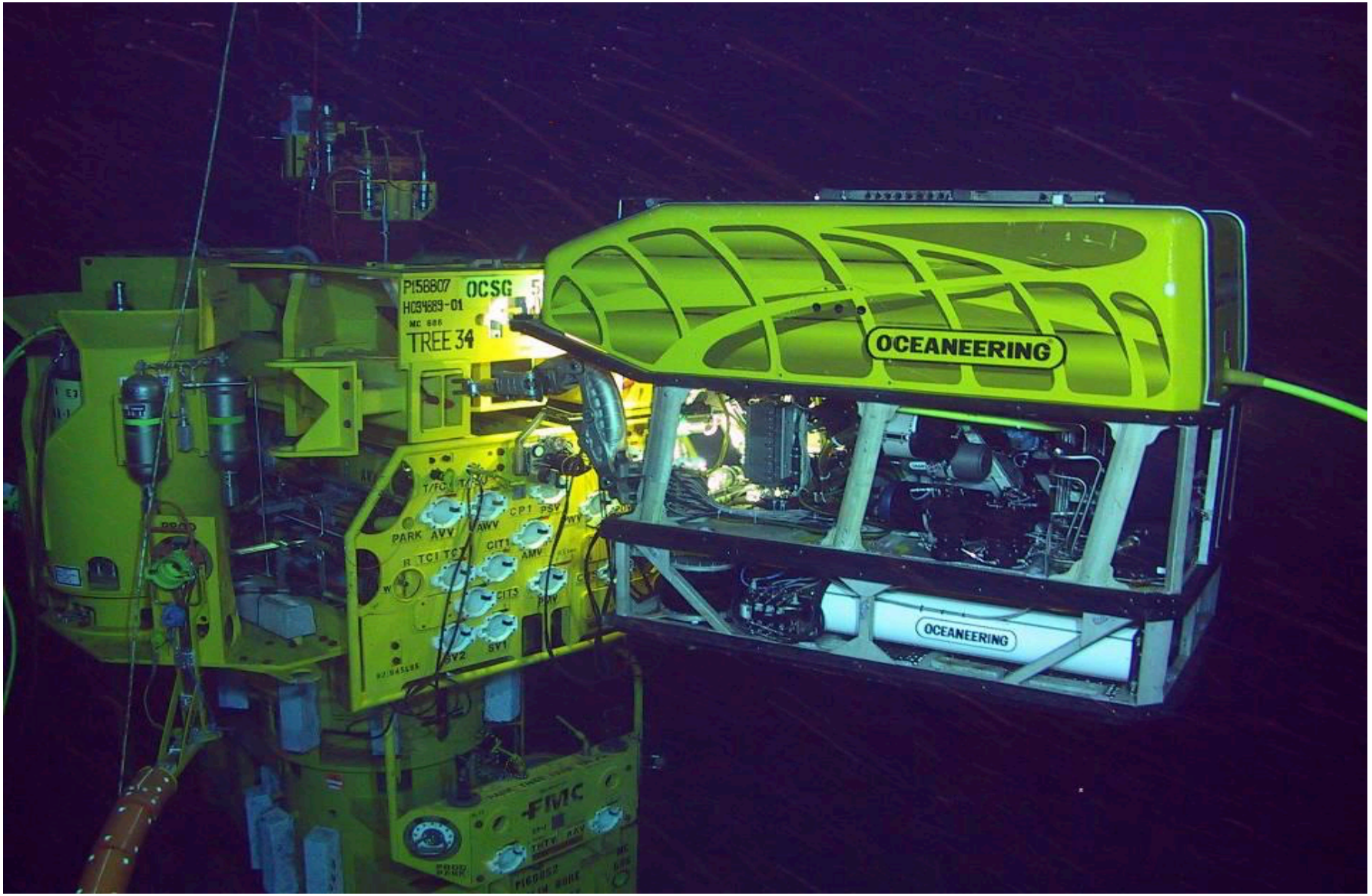
- Cursor systems for high draft vessels
- Stability via rail or guide wires
- Cursor funnel guides umbilical safely away from vessel hull and keel

Guide Wire Cursor System



- Guide wires provide stability around vessel appendages
- Fixed A-frame structures
- Retractable doors for access and work deck

Subsea Intervention



Subsea Intervention - Manipulator Tools

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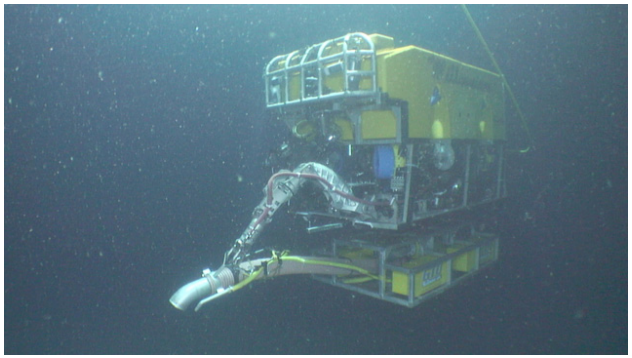
Trend: Hydraulic going Electric

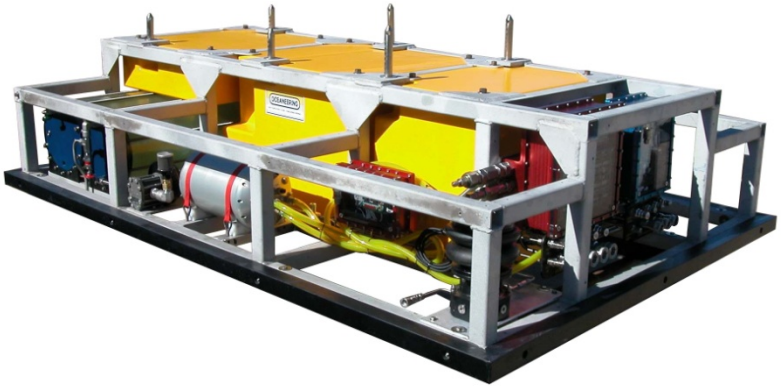
Subsea Intervention – Skid Supported Systems

BOP Intervention Skid

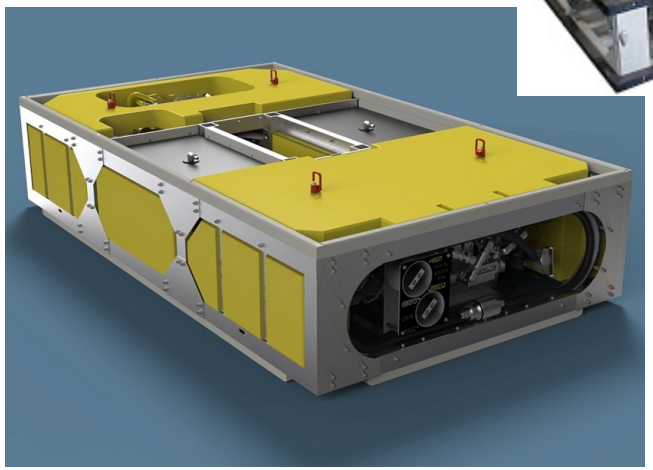
Dredging Skid



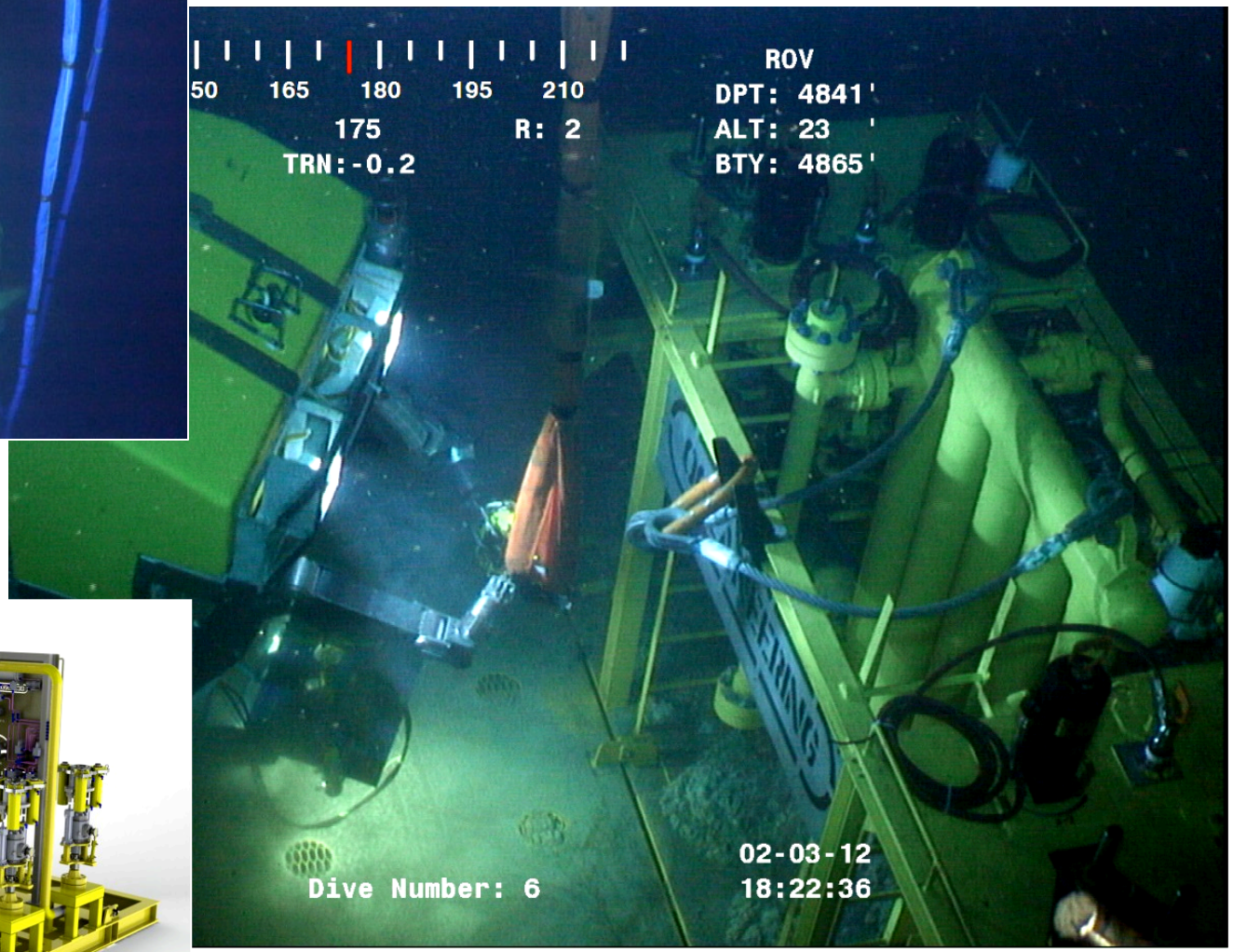
Auxiliary Hydraulic Power Unit Skid



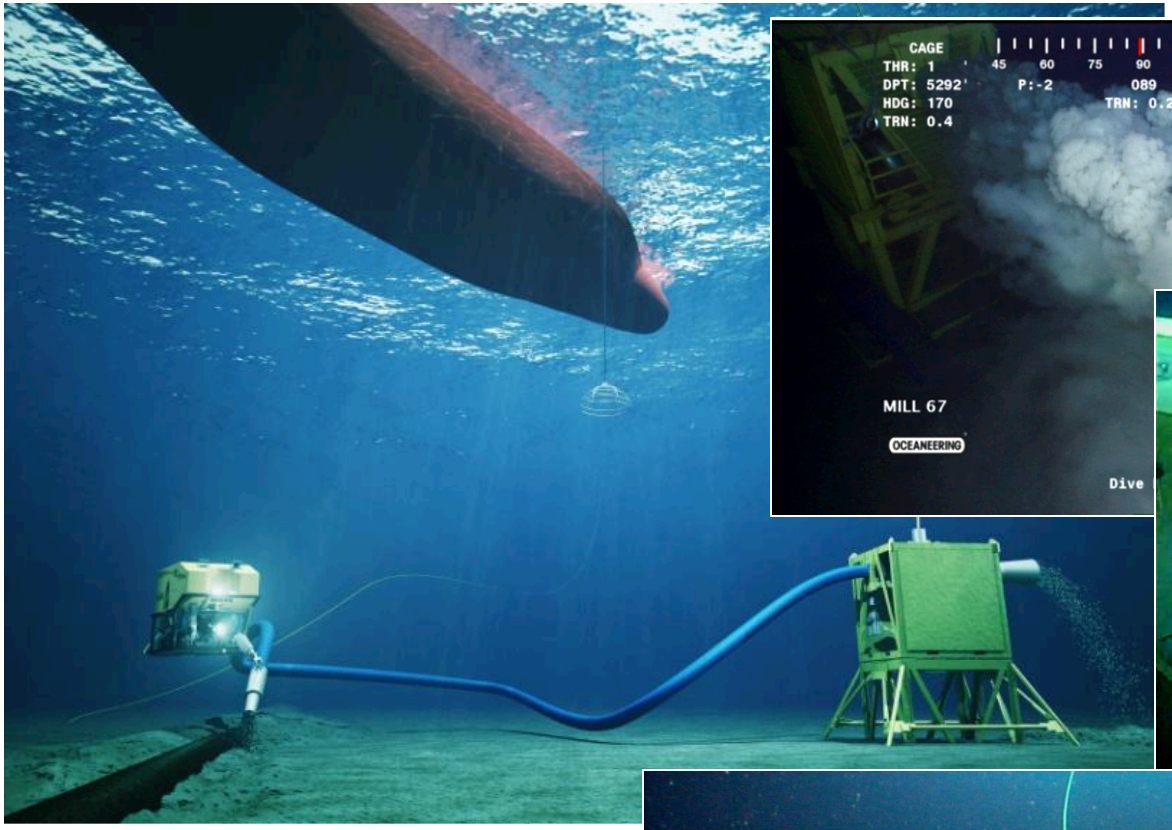
Fluid Intervention Skids

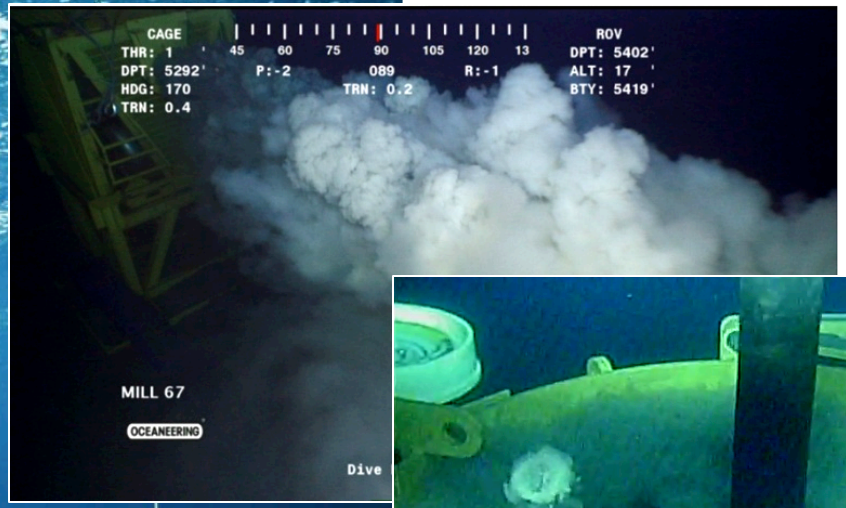


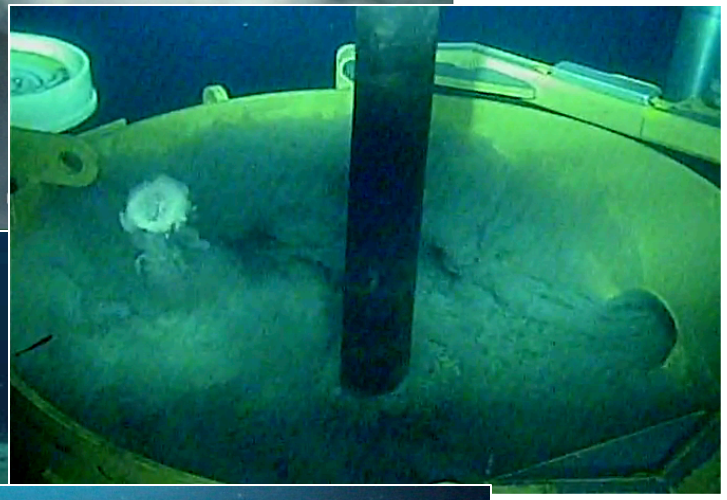
Subsea Systems – Well Stimulation & Flowline Remediation

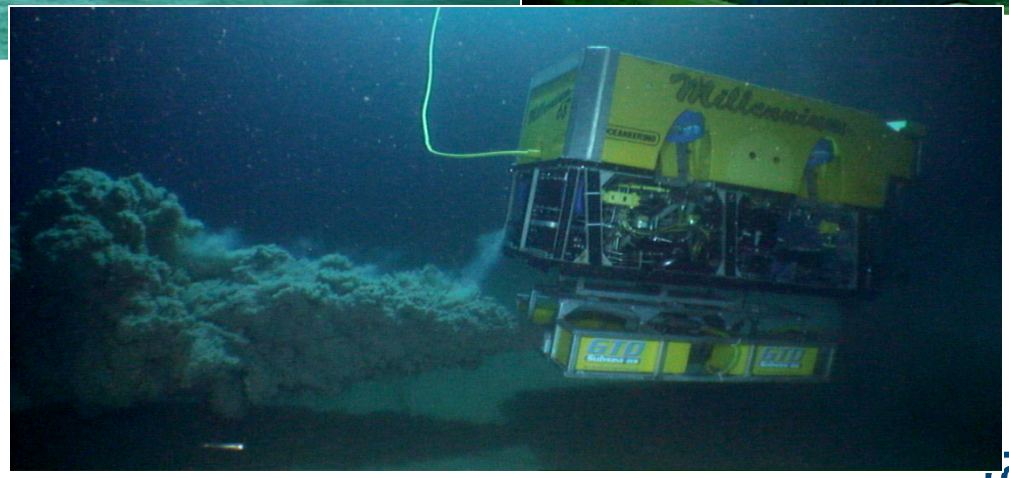


Subsea Systems - Subsea Dredging





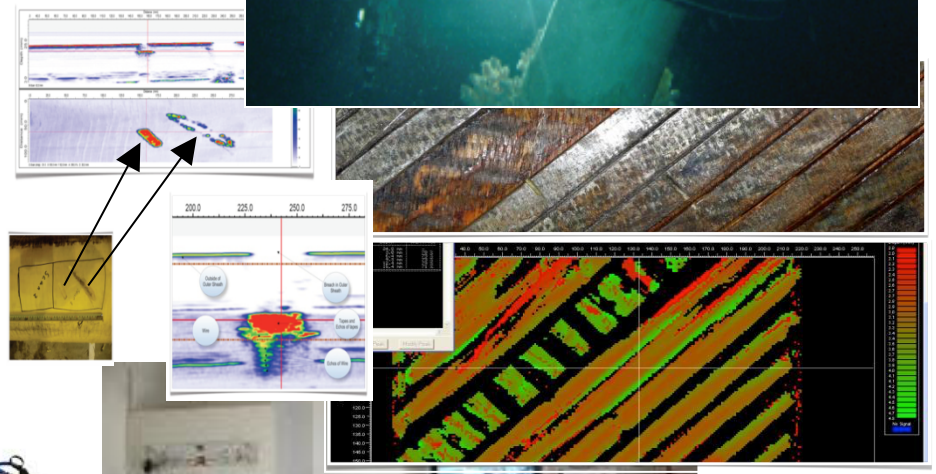


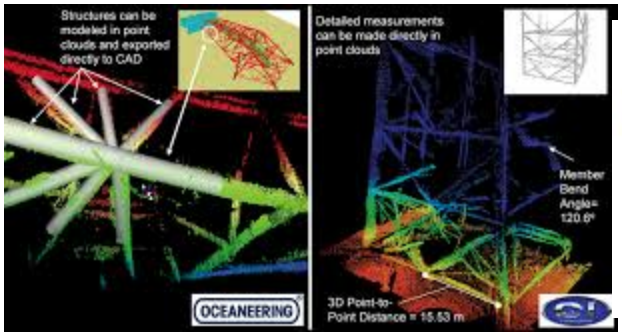


- Drill cutting /mud removal
- Local excavations for umbilicals, pipelines, ...

Subsea Systems – Inspection and NDE

- Ultrasonic
- Digital Radiography
- Phase Array
- Guided Wave
- Pulsed Eddy Current
- Laser Scanning
- …





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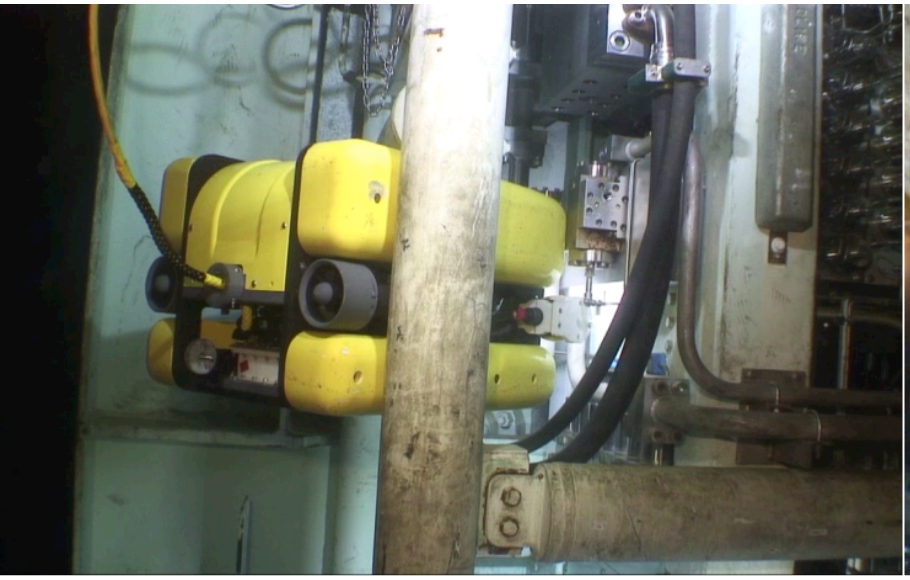
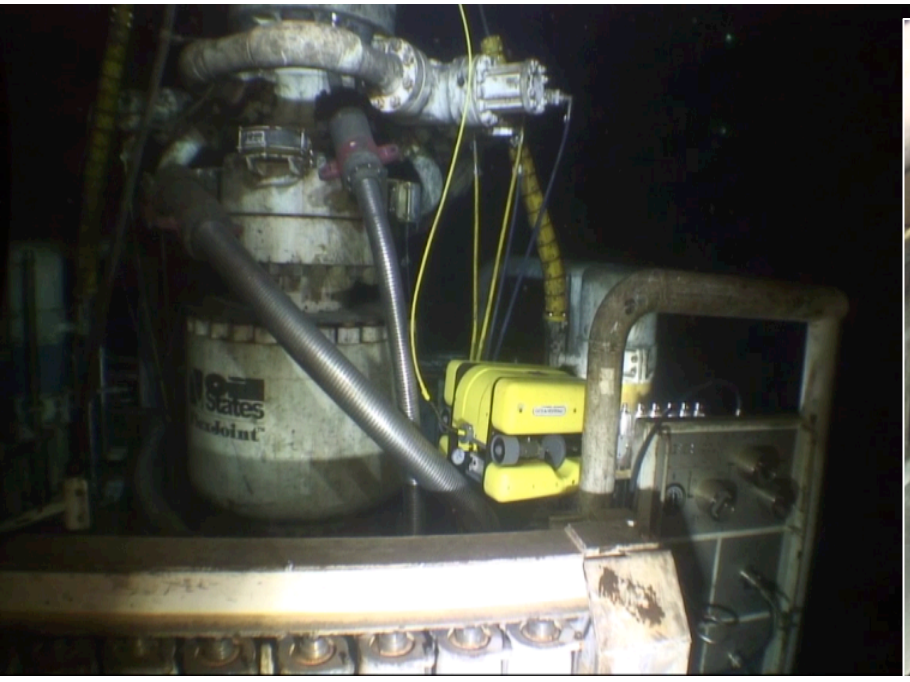
Eyeball Support

A little help

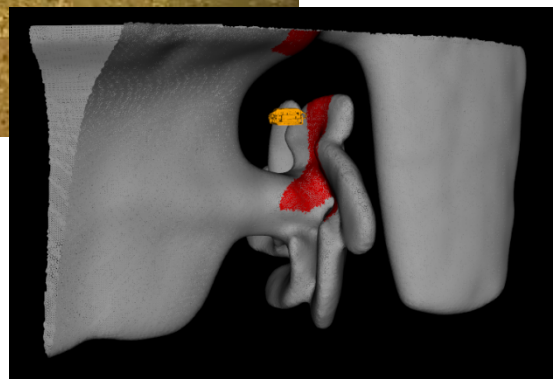




Autonomous Underwater Vehicles (AUVs)

AUV Services

- Military
  - Mine-hunting
  - Hull Scanning
  - Port security

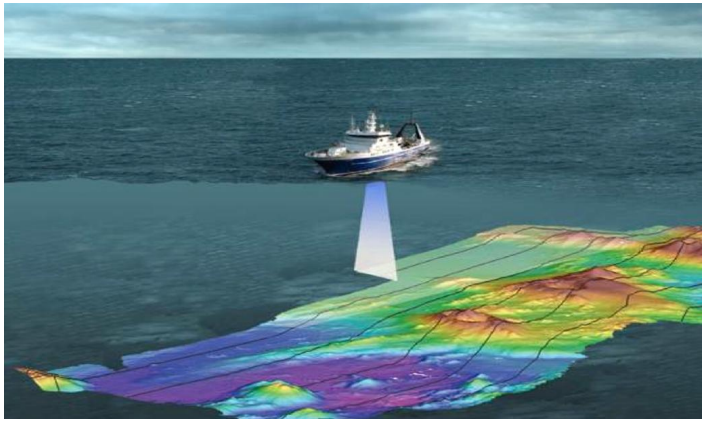


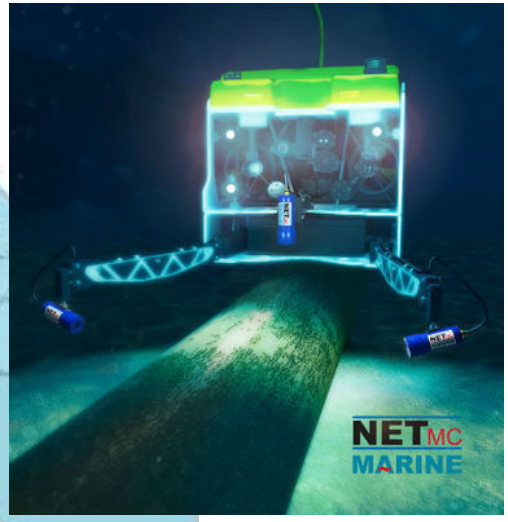
AUV Services

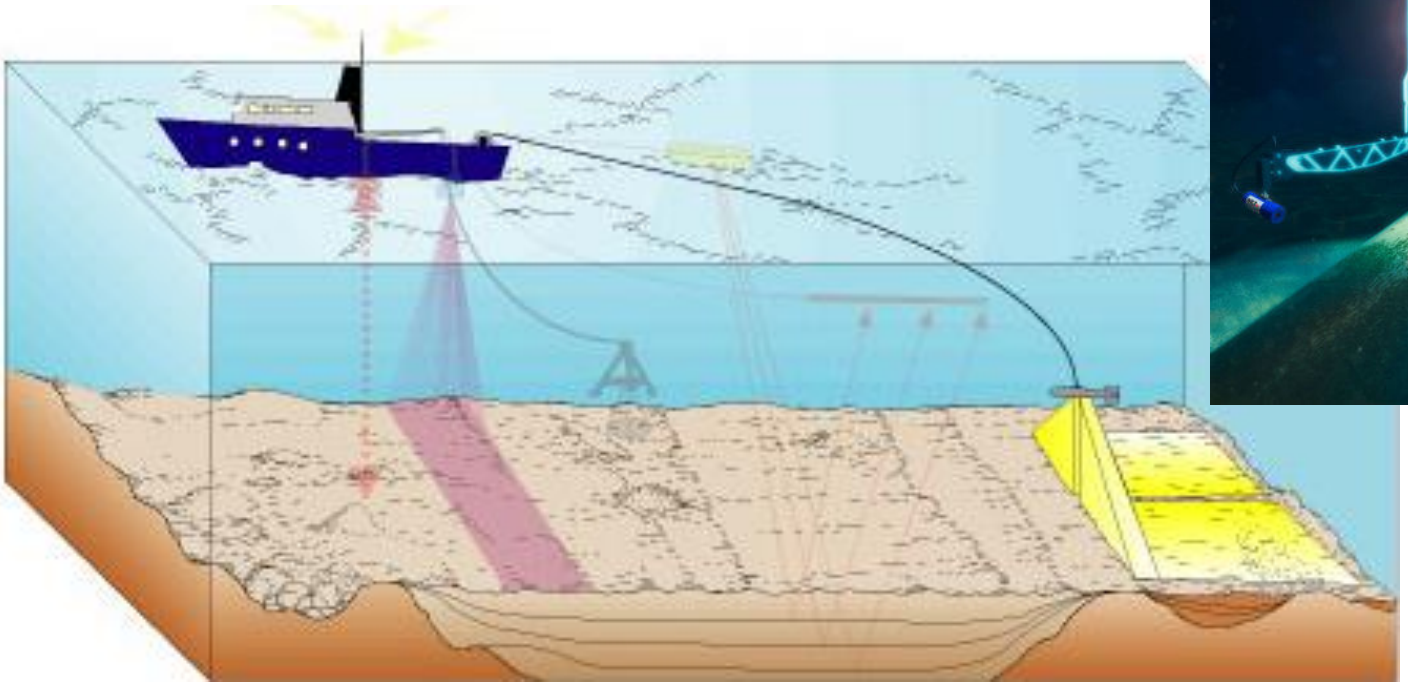
- Oil & Gas
  - **Geohazard** Surveys: identify any conditions at the seabed or in the foundation zone where **hazardous** subsurface features or unstable soil conditions exist.
  - **Pipeline** Surveys: pipelines and sub sea completions can be installed in the most cost **effective** manner with minimum disruption to the environment.
  - **As-Built** Surveys: **verify** the condition of the pipeline shortly after its construction.
  - **Block** Surveys: identify seafloor and subsurface features that may have an **adverse** effect on drilling operations.
  - **Archaeological** Surveys: required in the Gulf of Mexico where proposed bottom-disturbing activities may impact submerged archaeological **resources**
  - Deepwater **Benthic** Community Surveys: round-truthing of deepwater benthic communities to identify and localize, or disprove, their presence (clams, mussels, tubeworms, and other organisms that thrive in the absence of sunlight)
  - **Government and Academic** Surveys: perform deepwater coral mapping, historic shipwreck surveys, and geotechnical investigations.

Why AUVs?

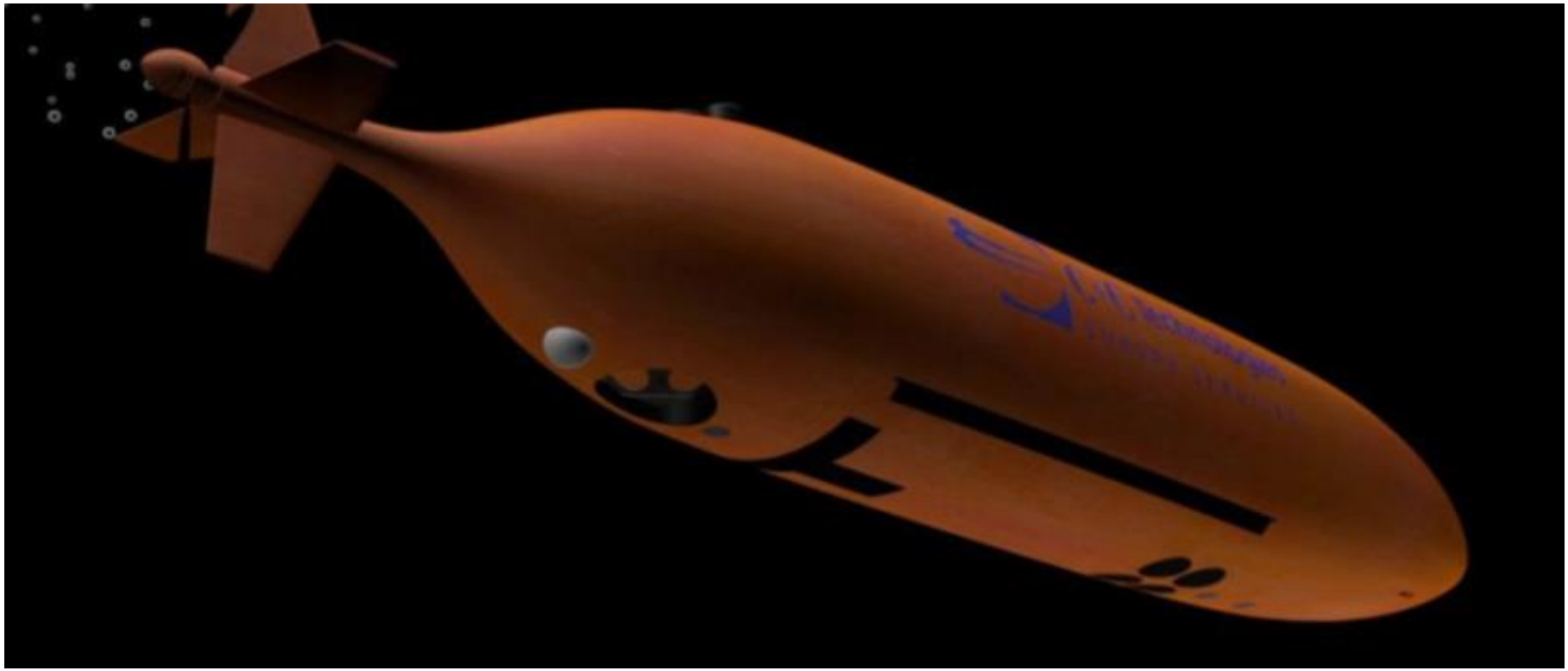
- Ship – mounted sonars
  - –Lack resolution in deep water
  - –Sound “spreads” as distance to seafloor increases
- Towed sonars
  - –Better resolution, but poor positioning
  - –“Deep Tow” (>1000m)
    - •Slow survey speed
    - •Line turns = 6+hours
    - •Difficult to adjust altitude
    - •Logistics become harder



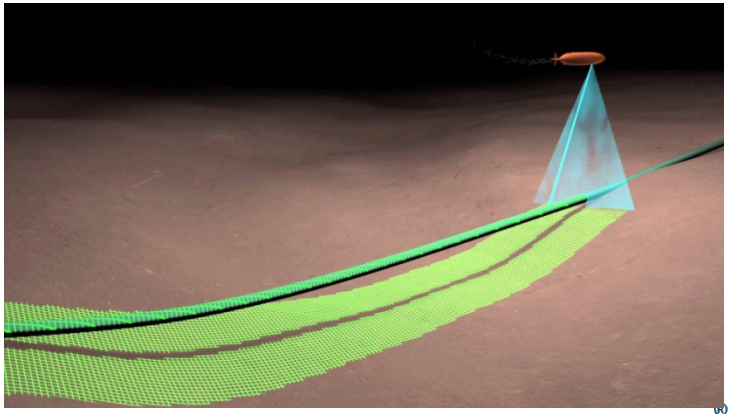




The Survey AUV: Advantages



- Faster than “Deep Tow” 3-4kts
- Line turns = 5 minutes or less
- Constant altitude over seafloor – Better data
- Untethered – Can work closer to seafloor infrastructure
- Better positioning – support vessel remains in position to track it



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AUV – Very brief history

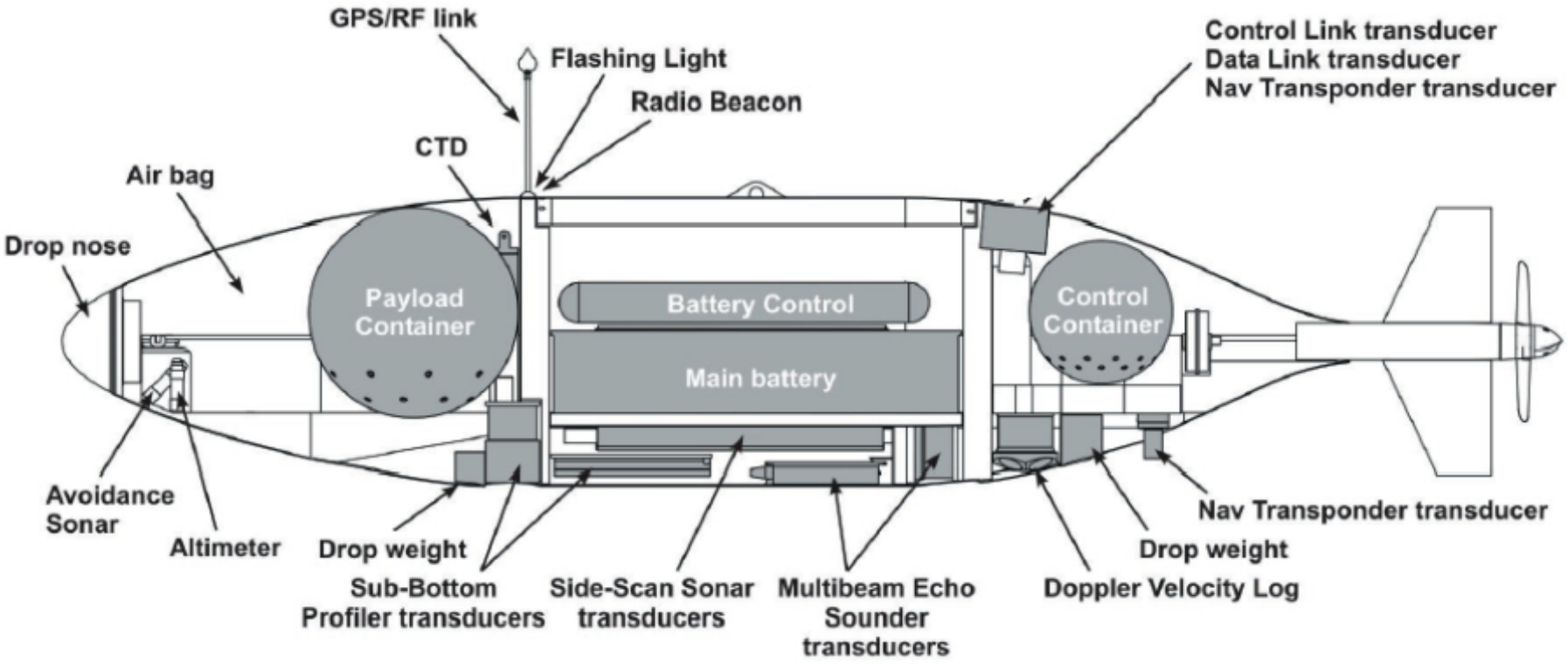
- First AUV developed at the Applied Physics Laboratory at the University of Washington as early as 1957
- "Special Purpose Underwater Research Vehicle", or SPURV, was used to study diffusion, acoustic transmission, and submarine wakes.

Classes of AUV

- Gliders
  - Ocean sampling missions - months
  - Small changes in its buoyancy in conjunction with wings to convert vertical motion to horizontal
  - Slocum, Seaglider, SeaExplorer, Spray
- Search Class
  - Lowest navigation and sensor resolution needs
  - Gavia, REMU 100, Iver OceanServer
- Survey Class
  - Survey grade navigation and sensors
  - C-Surveyors, Hugin 3000/4500, Hugin 1000
- Inspection Class
  - Inspection grade navigation solution and sensors
  - C-Surveyor VI

AUV layout

The C-Surveyor AUV



The Survey AUV: Challenges

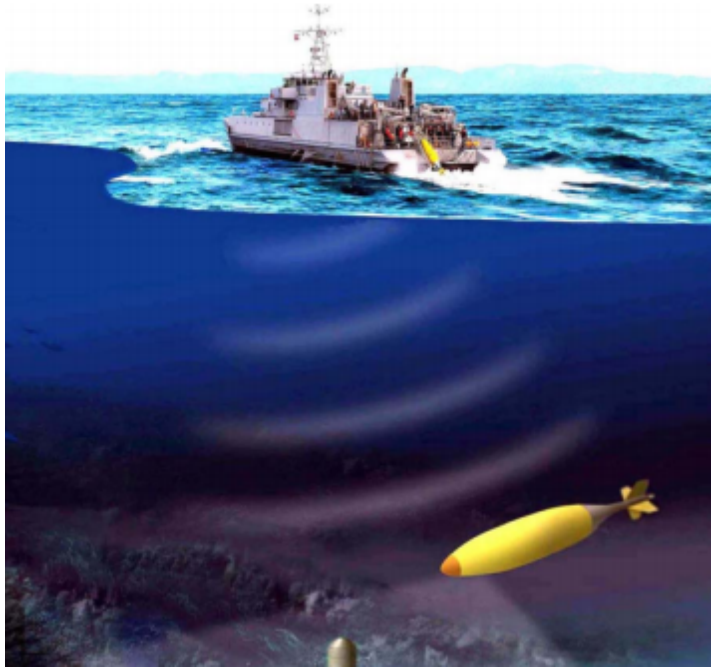
- Launch and recovery
- Positioning and navigation
  - USBL positioning – acoustic range/bearing from support vessel
  - Doppler velocity log (DVL) – measures velocity of AUV over seafloor
  - Inertial Measurement Unit – acceleration of AUV
  - Digiquartz pressure – depth
  - Kalman filter – combines all position sensors
- Power
  - Batteries: duration, recharging, logistics
  - Better chemistry / efficiency = longer dives, more surveying
- Communications
  - No umbilical to send commands or receive status
- Software
  - Behavior programming: unplanned event handling

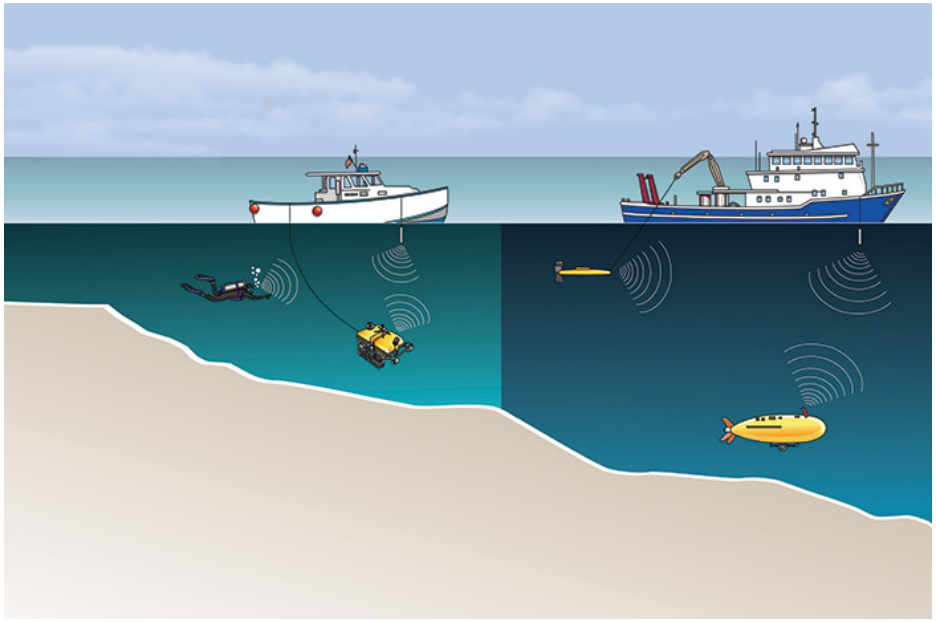
Launch and Recovery

- Launched from sled, aft of vessel
- Recovery:
  - AUV drops “nose-cone”
  - Line connecting nose-cone to is grappled, and AUV towed to support vessel

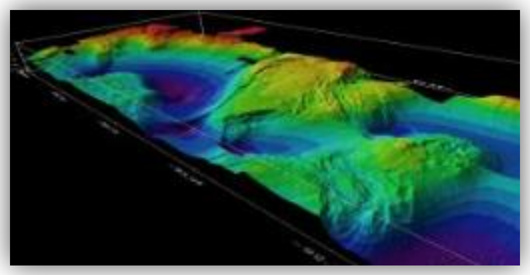
Navigation

- USBL: range and angle measured from vessel
  - Gives absolute geodetic position of AUV
  - Low update rate
- DVL: Velocity vector
- IMU: 3-D Accelerations
- Filtered solution: DVL/IMU updates position between USBL fixes
- Search class AUVs may use dead-reckoning, or return to surface for GPS position



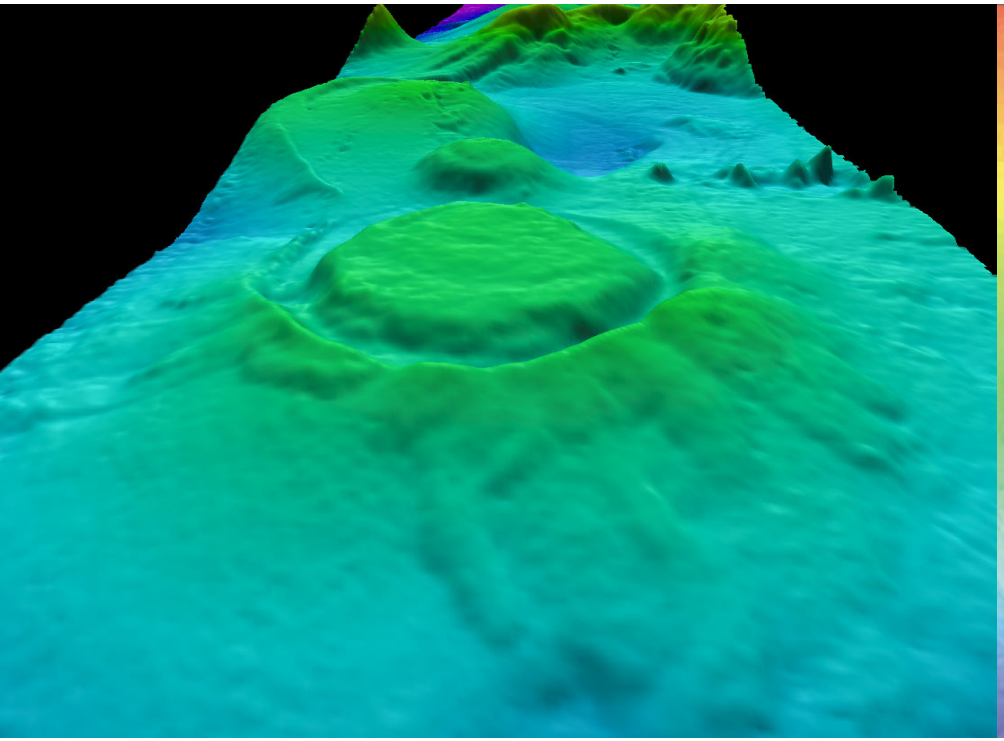


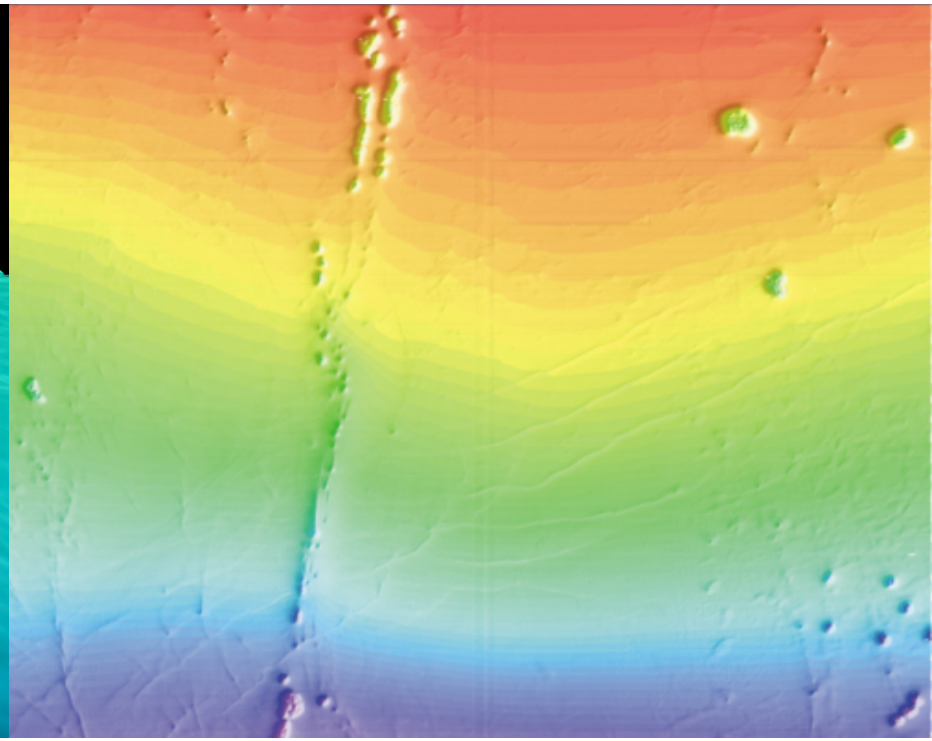
AUV Services



AUV Sensors: Multibeam

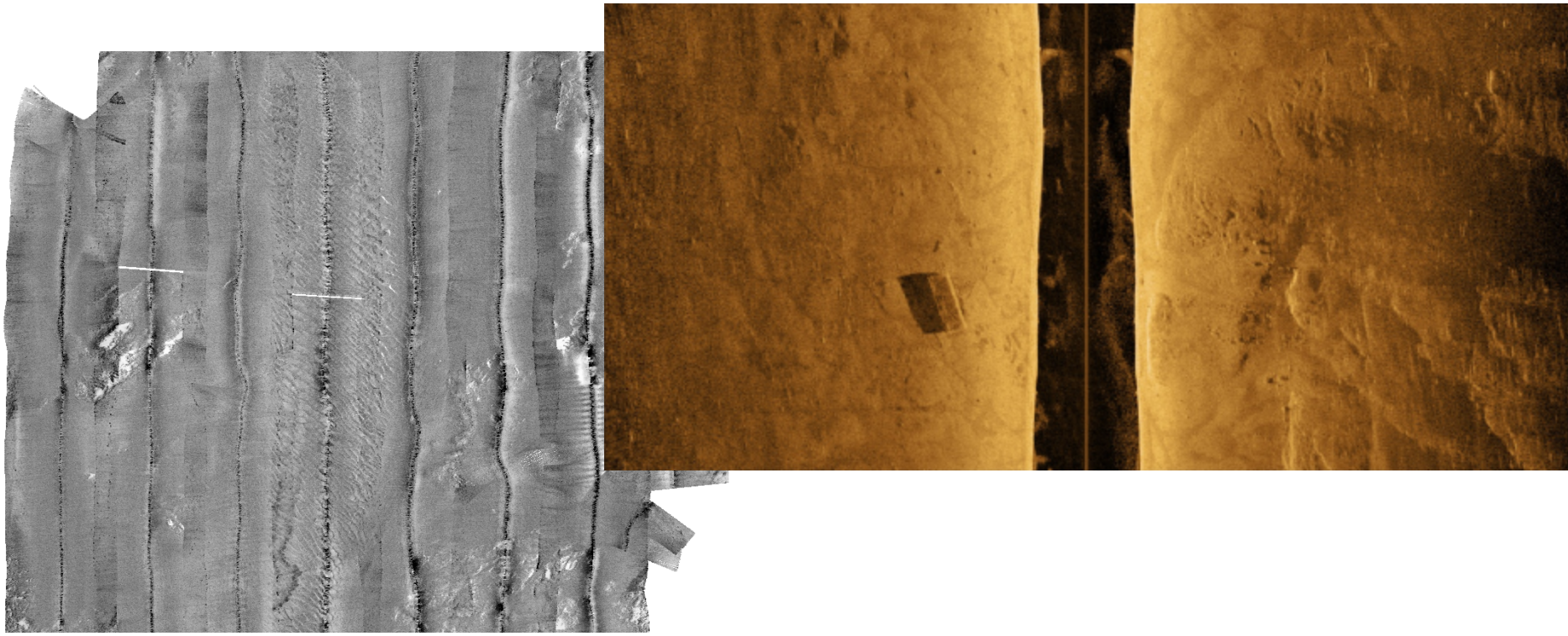
- Acoustic “time of flight” and angle measurements
- Depth is shown by color gradients or contour lines
- Requires accurate sound velocity sensor





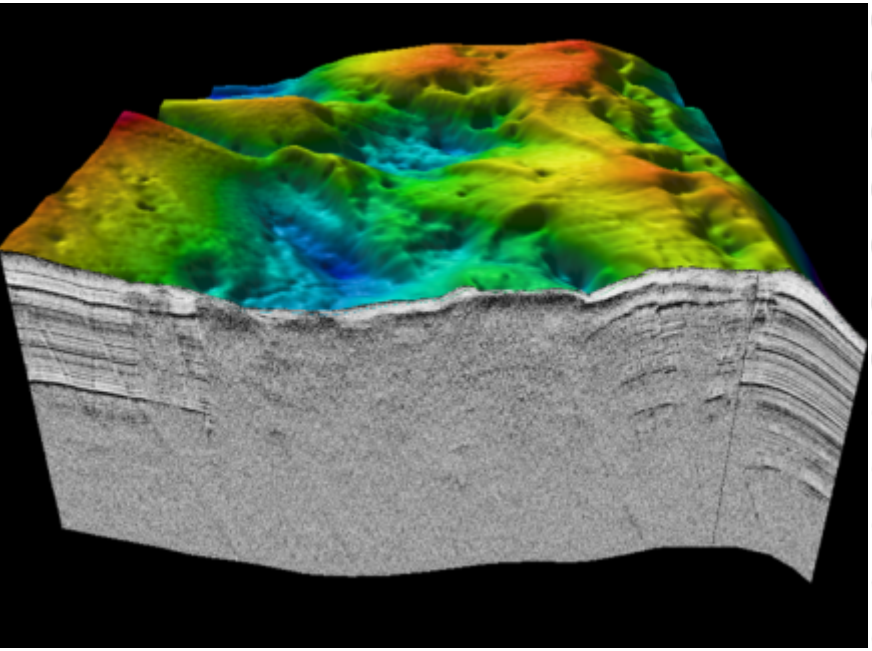
AUV Sensors: Sidescan Sonar

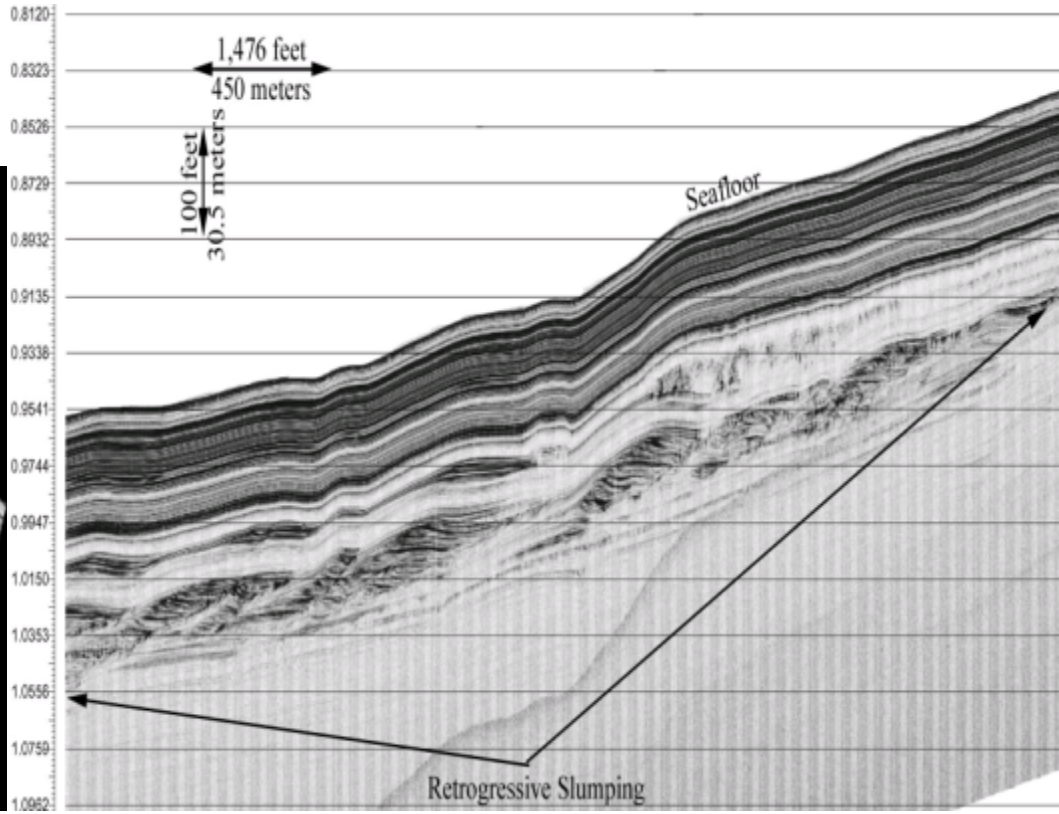
- Records intensity of reflected sound wave
- Stronger reflectors = rocks, hard bottom / weaker reflectors = mud, silt
- Can be used for target detection



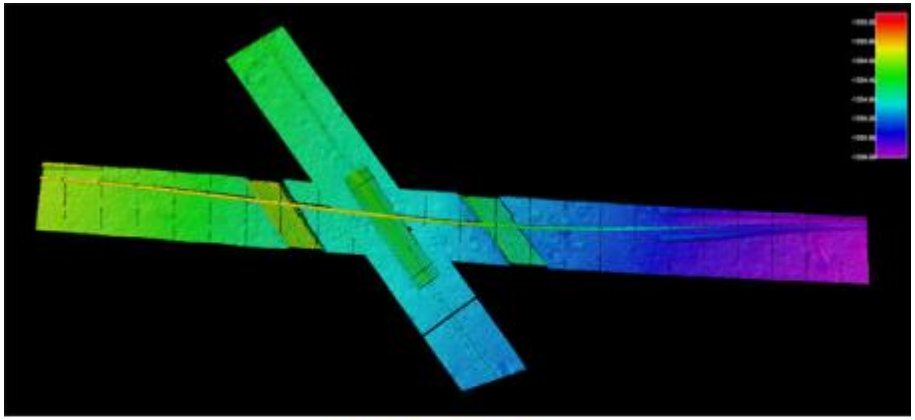
AUV Sensors: Subbottom Profiler

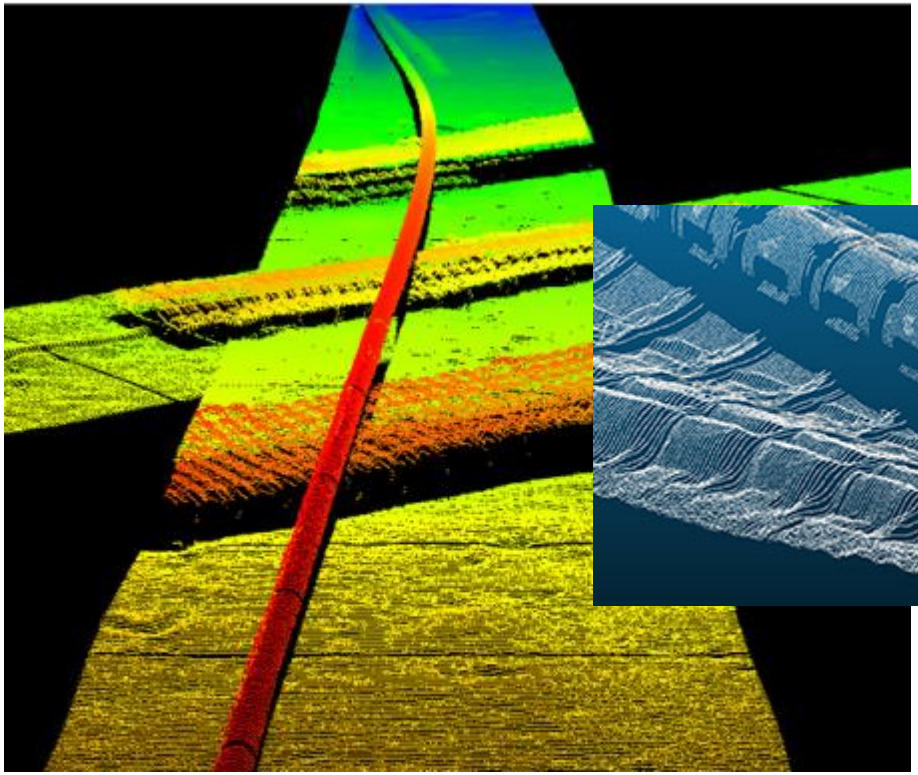
- Lower frequency acoustic – penetrates seafloor
- Used for seafloor classification, construction, burial

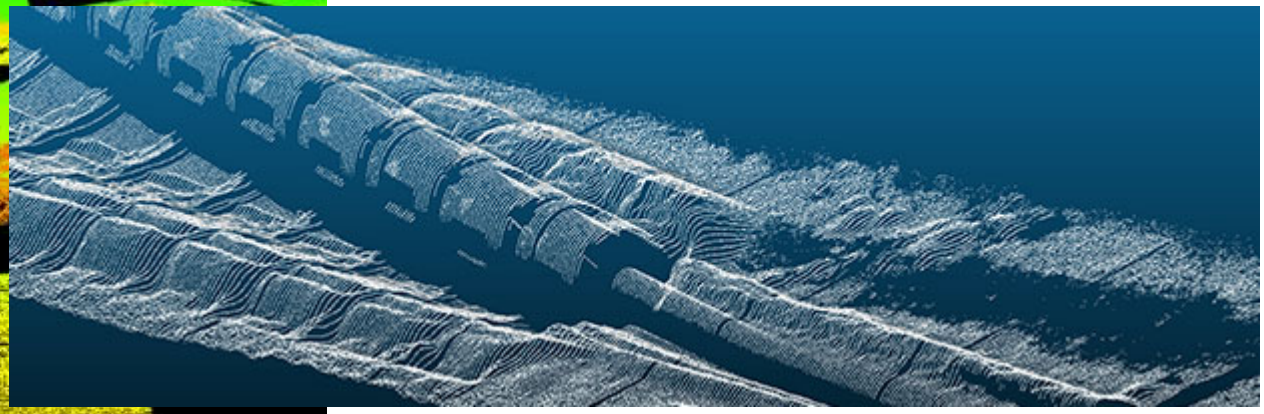




AUV Sensors: Laser Bathymetry

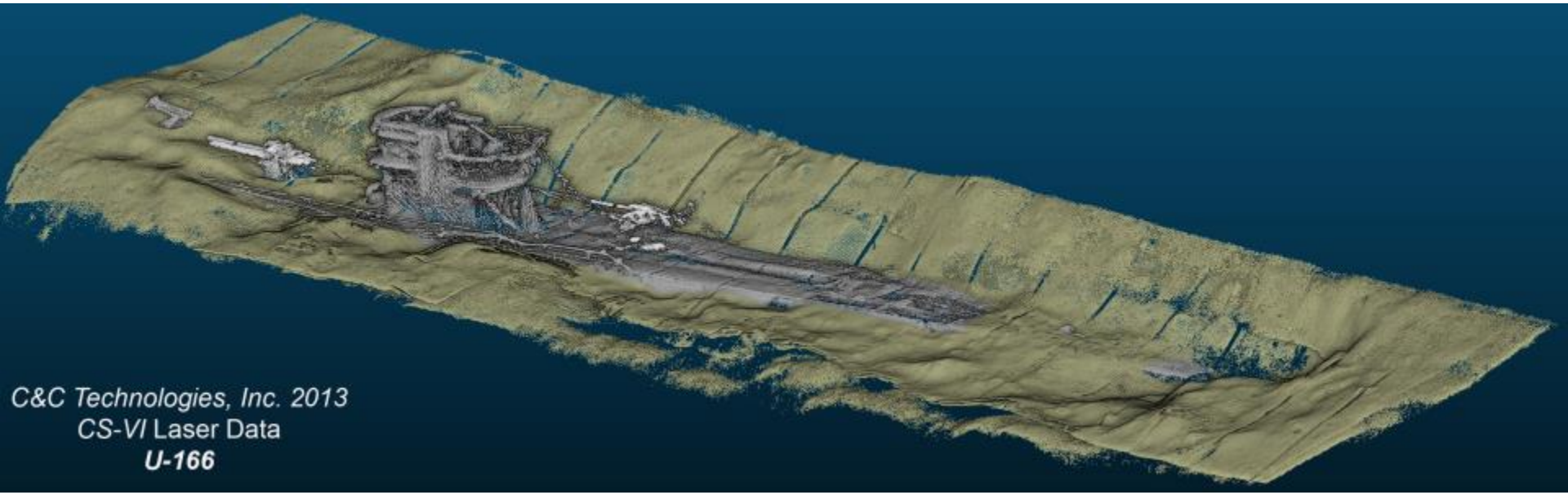




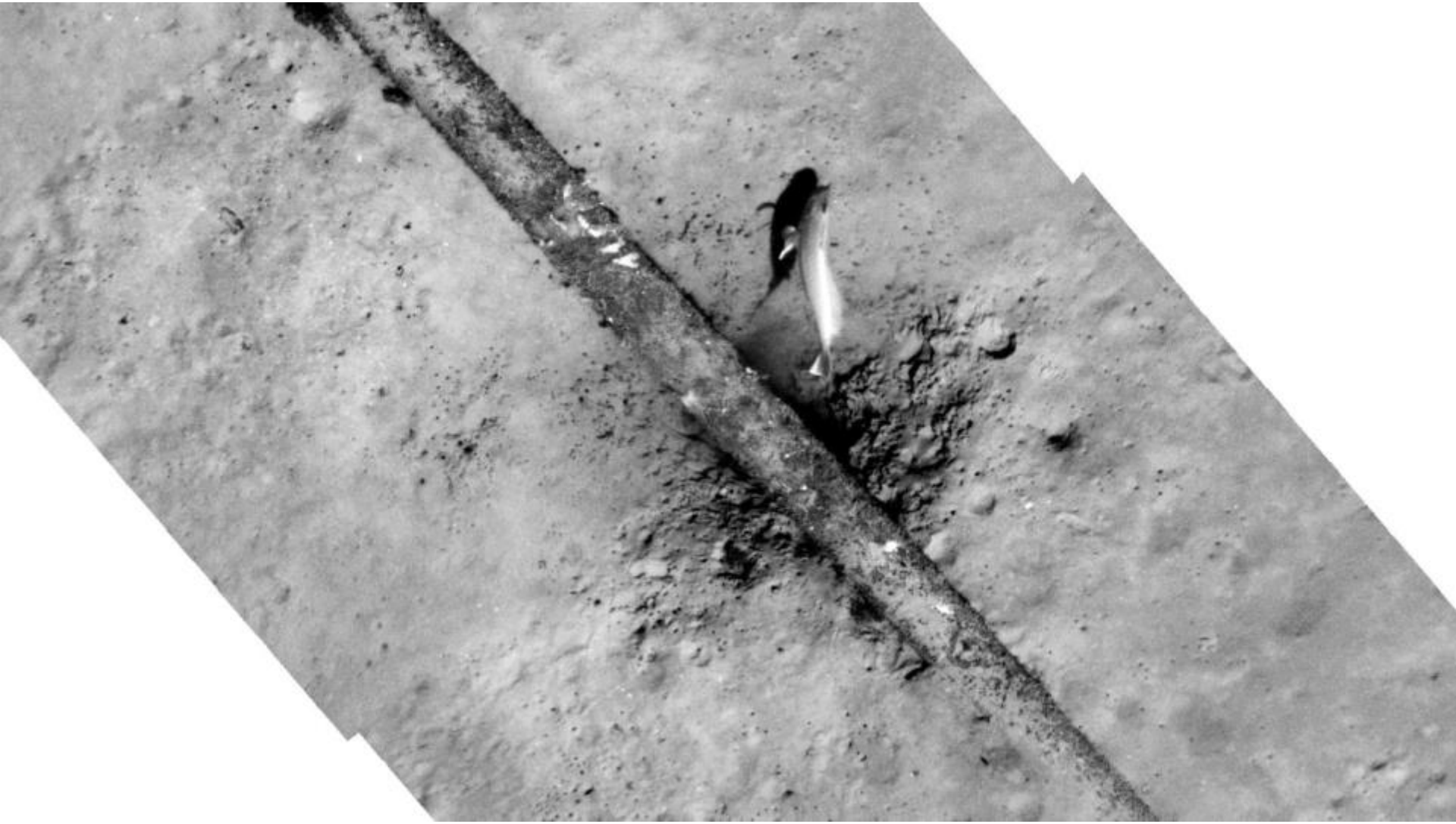


- Laser Bathymetry
  - High resolution
  - Pipeline tracking

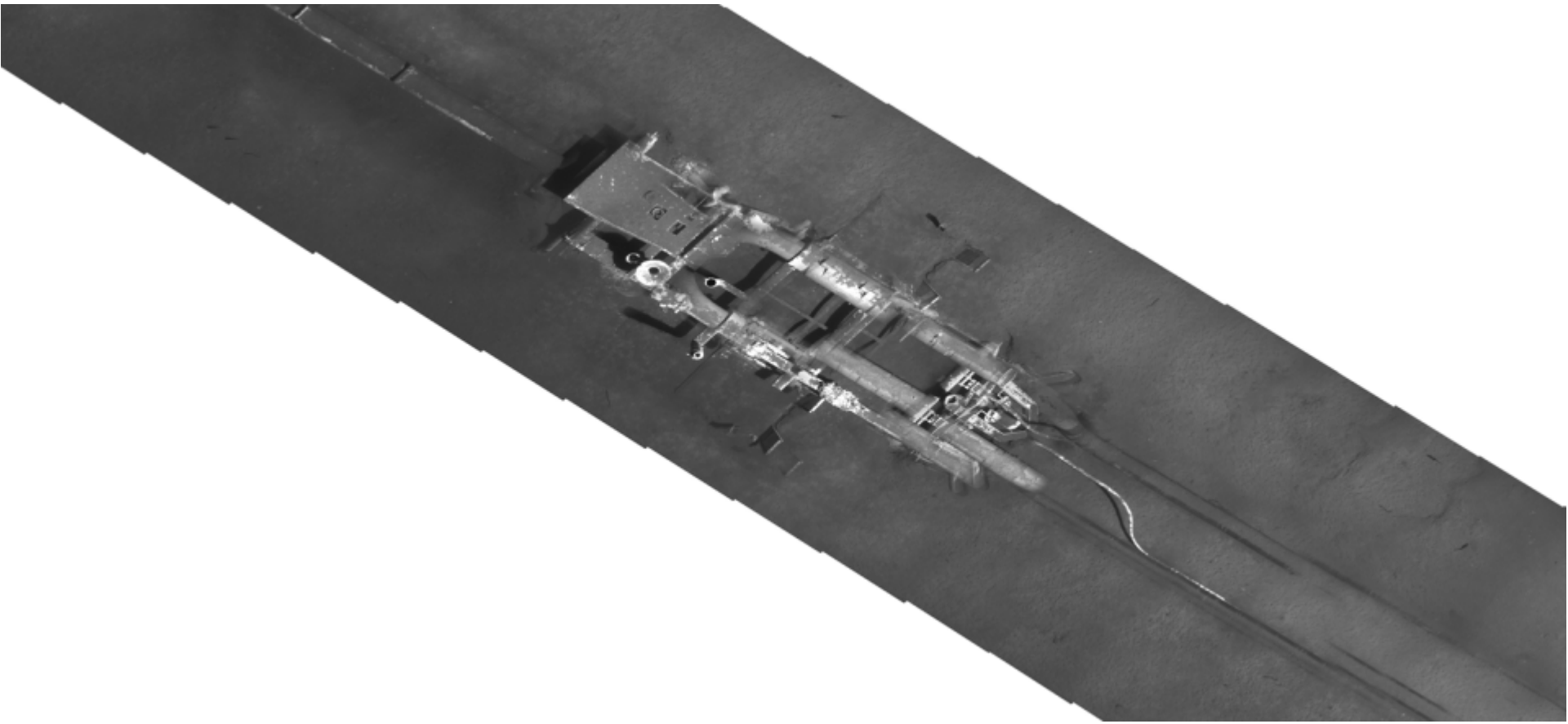
AUV Sensors: Laser Bathymetry



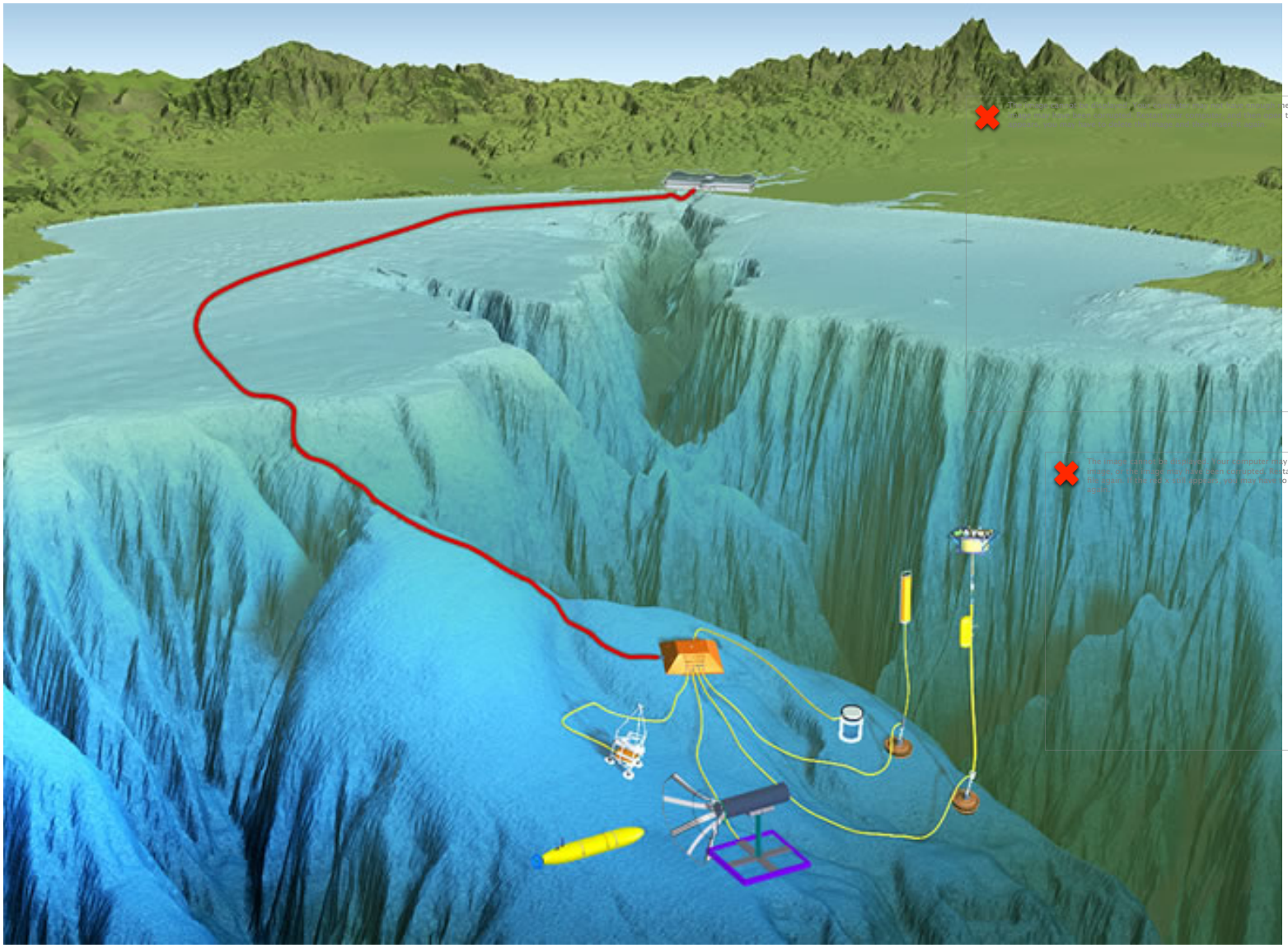
AUV Sensors: Camera



AUV Sensors: Camera



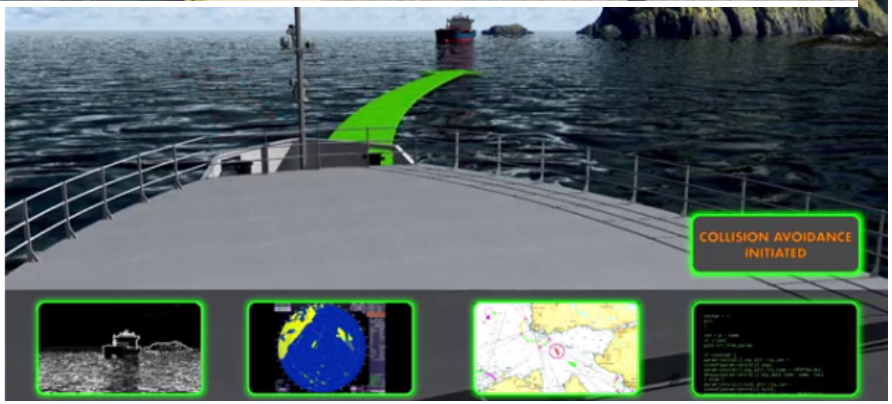
AUV Future

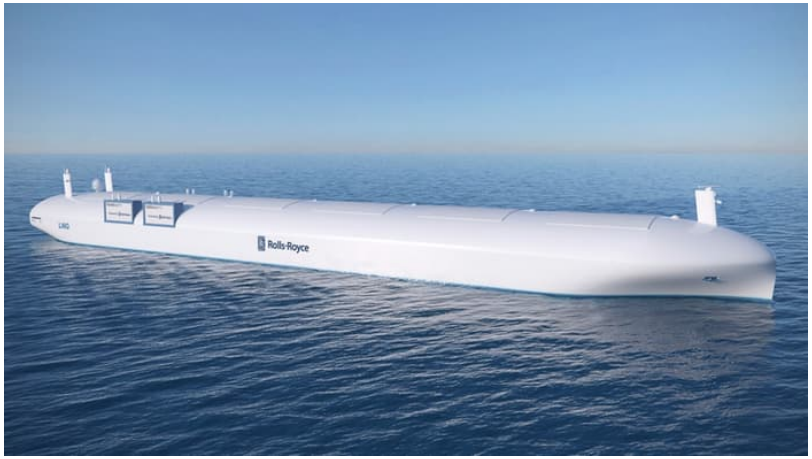


Autonomous Surface Vessels (ASVs)

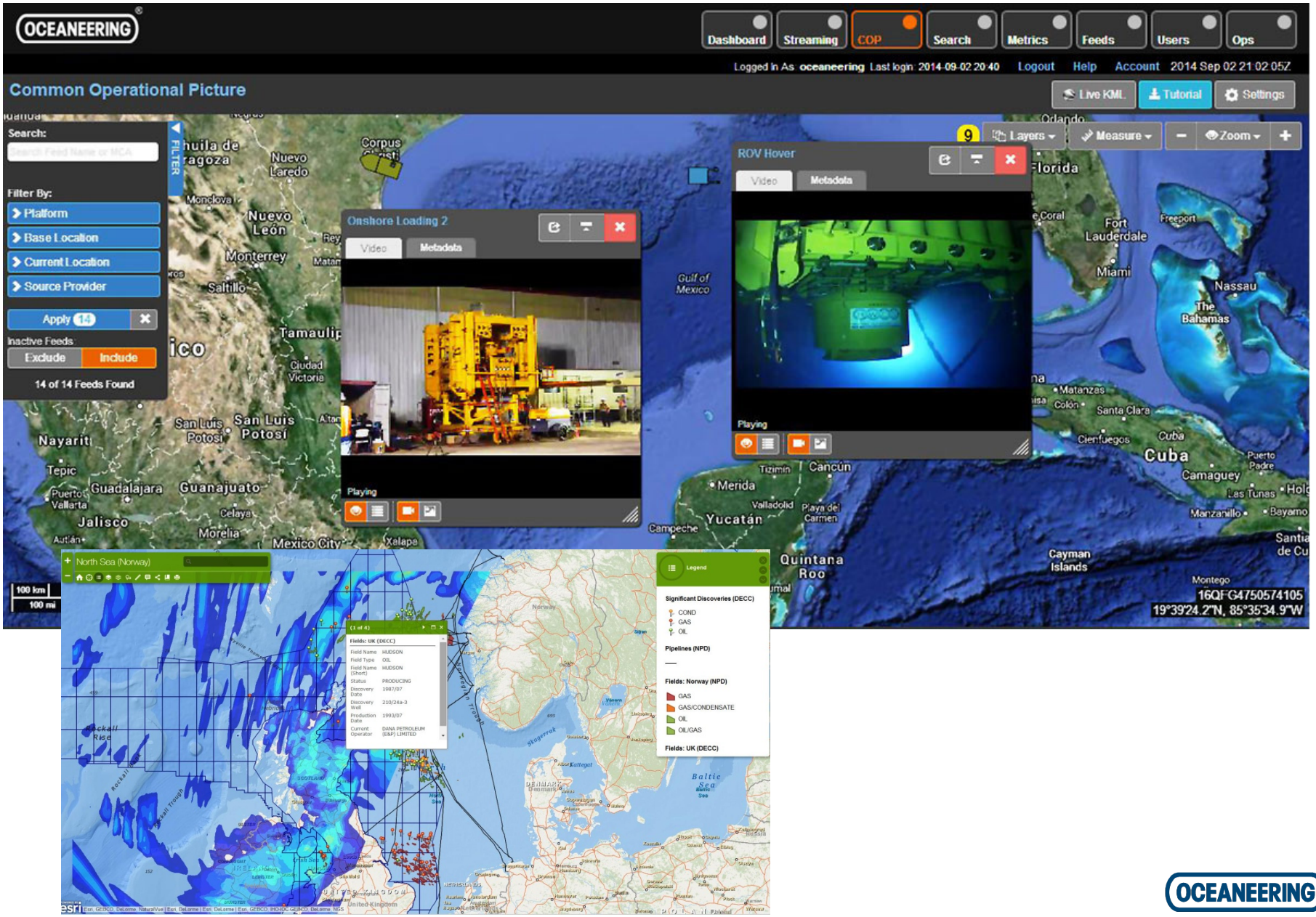
ASV Applications

- Unmanned vessel advantages
  - Cost Effective
  - Safer (regions)
- Applications
  - Remote transmission station
  - Support AUV survey applications
  - Deploy and operate vehicles (ROVs, AUVs)
  - Surveillance: environmental
  - Coastal Container shipping
  - …





Data Revolution



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The Future?

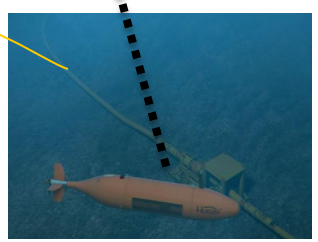
No personnel offshore

Onshore Monitoring and Control

Environmental

Infield IMR (Light and Heavy)

Pipeline Inspections



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The End

Questions?