Oceaneering Robotics: Parallels to Satellite Servicing

Presented by:
Todd Colangelo

3/25/10

OCEANEERING®
www.oceaneering.com

Company Background

Oceaneering International, Inc. *is an industry leader in enabling humans to perform work safely and effectively in harsh environments ranging from depths of the sea to the outer reaches of space.*

- Oceaneering is a large company traded on the NYSE with 8000 employees, 66 locations in 18 countries.
- 89% of our work is oilfield and 11% is non-oilfield

Oceaneering Performance Facts

Subsea Facts:

- With 248 Remotely Operated Vehicles (ROV) in use, Oceaneering has on average over 5700 days of ROV operations every month and 888 hrs of teleoperation time per day.
- We have virtual simulation capabilities, and have used them to support training, uncover design issues and risks prior to the operation, and overlay the work environment real time to eliminate lag issues.

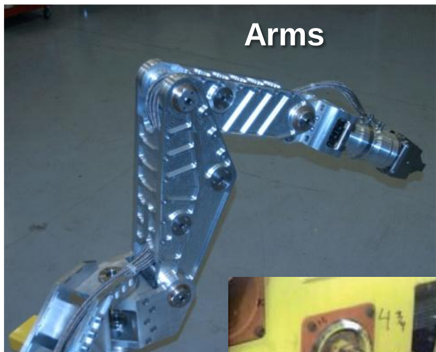
Space Facts:

- We have developed and flown tools for capturing and servicing satellites
- Oceaneering has been developing EVA tools since 1978. On the One EVA contract, Oceaneering has delivered and is providing sustaining engineering for 3659 EVA flight tools since 2005.

Oceaneering Robotics

Subsea ⟷ **Land** ⟷ **Space**

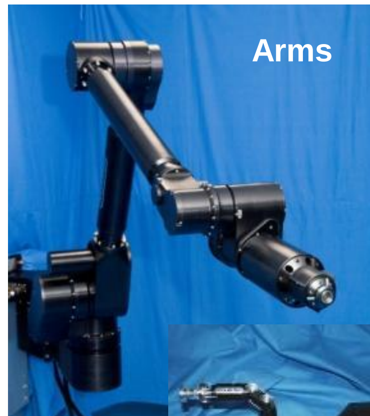
Subsea


Arms


Subsea Robot Tools

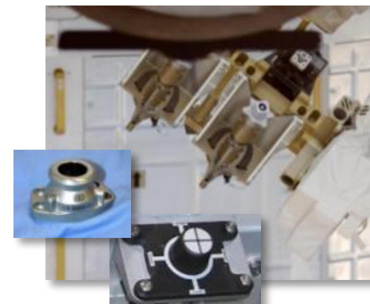

ROVs

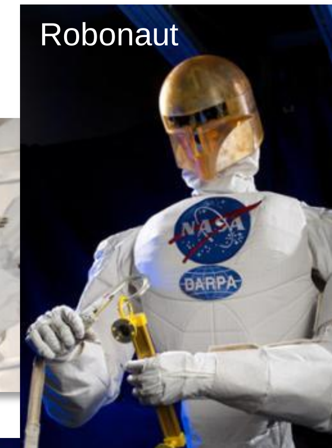
Land


Arms

Space

End Effectors and interfaces



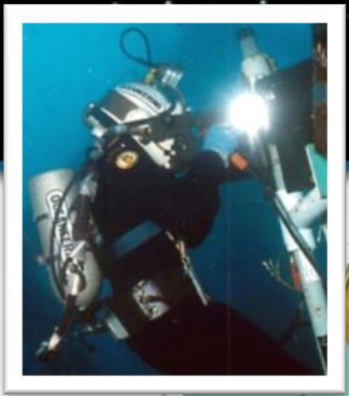

Robonaut


R2

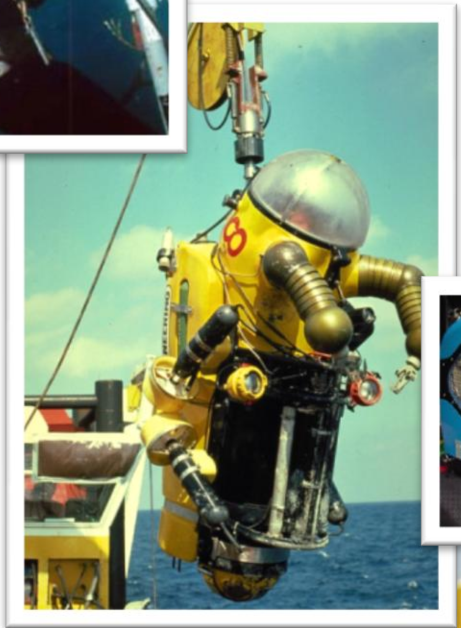
Subsea Architecture

- Servicing vehicle is taken out to sea by ship with operators on board
- Winch drops servicing vehicle within gross proximity of the work
- A servicing vehicle / Remotely Operated Vehicle (ROV) is used for fine positioning and dexterous robotic operations
- A work package is used for similar tasks or for similar work areas.
- Tools and interfaces have been standardized for robotic servicing

Subsea Robotic Evolution



- Human Servicing Saturation diving 1000 ft depth



- Human Servicing Atmospheric diving 2100 ft depth requiring special tooling and interface changes

- Telerobotic inspection 20,000 ft

- Telerobotic Delivery System selected based on torque and hp requirements 20,000 ft

Cost and Safety were drivers for the evolution

- Telerobotic delivery and variety of work packages

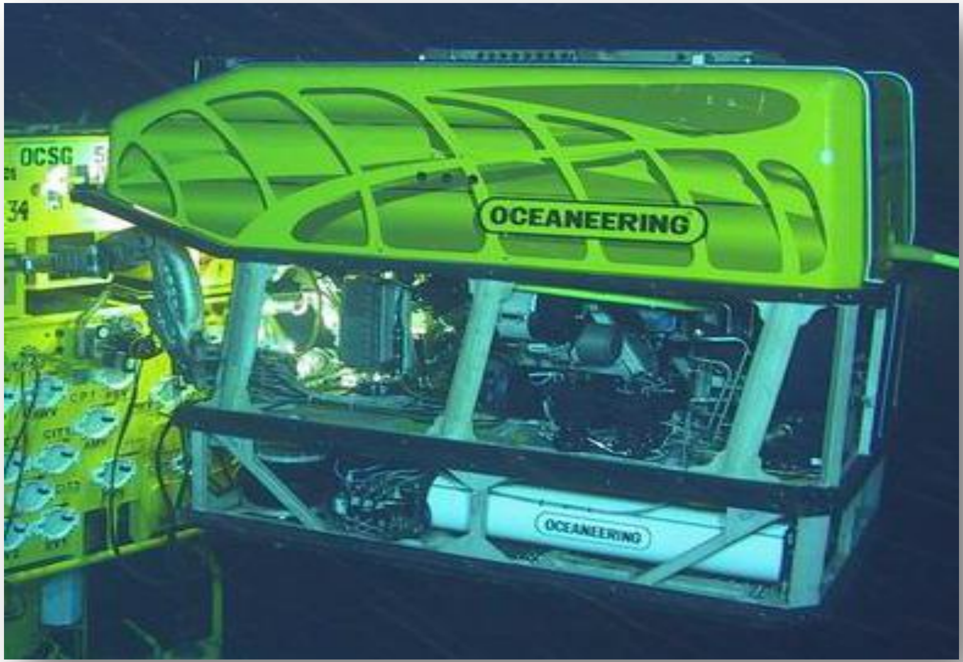
ROV Features

Cameras and Lighting

Station Keeping Ability

Two Manipulators

On-board Tool Packaging



Neutrally Buoyant

Power and Communication

Thruster Propulsion

Electronic Navigation and Control

Subsea Work Packages

Work package skids are predefined sets of tools packaged together for ease of operation on a set of like tasks.

- Fluid Storage and Injection Skids
- Assembly Skids
- Test Skids
- Power and Communication Skids
- Tool Storage Skids
- Salvage Skid

Subsea Robotic Tasks

- Seeing eyeball/ inspection
- Remove and replace electronics
- Assemble electrical, mechanical and fluid connections
- Valve operations, troubleshooting and monitoring
- Leak detection, sealing, fluid insertion
- In-situ testing and commissioning
- Jacket removal, jumper/flow line cuts and installation
- Decommissioning and debris removal
- Salvage

Other Subsea Similarities

- Mission Scenario Planning
- Simulation Software
- Training and Human Factors
- Situational Awareness
- Controls w/ Time Lag and Human Factors

Subsea Servicing Parallels to Satellite Servicing

Offshore Oil and gas required life support and special tooling for operations and servicing.	Astronauts are used to capture and repair satellites both on the ground and with special tooling on-orbit.
As oil wells moved beyond the reach of human capability, robotics were necessary for servicing.	As satellite servicing moves from LEO to GEO, robotics are going to be needed for servicing.
Operations on oil field assets never intended to be robotically serviced underwater.	Satellites needing refurbishment or refueling were never intended to be robotically serviced on orbit.
Historically the architecture has gone from one ROV per platform to one ROV for multiple wells joined together	Past: one satellite serviced in one mission Future: multiple satellites serviced in the same mission.
Robotic Standardization of interfaces and tooling for future well operations and services	ISS has standardization of robotic interfaces and tooling but no robotic standardization on Satellites
Autonomous tasking has been considered but environmental liability for failure too great	Autonomous docking and fluid transfer demonstration –Orbital Express

Satellites built before Servicing Standardization

- A humanoid Robot is the answer to servicing existing satellites now.
- Satellites on orbit were originally built using humans.
- Human-like scale and dexterity allows use of heritage EVA tools thereby saving tool development costs
- Operator training is intuitive
- Operation procedures become easier to develop
- A humanoid has the flexibility to adapt to unknown satellite configurations
- R2 is being configured to launch to ISS September 2010 for IVA usage.

Robotic Considerations for Future Satellite Fleet

Lessons Learned from Servicing Missions – Sea & Space

- Design tasks for single arm operations
- Minimize fasteners and complexity of mechanism actuations
- Provide clear access (visual and physical)
- Minimize motion requirements (i.e., simple, single axis actuation)
- Provide alignment guides and targets
- Provide adequate visual cues
- Maintain loose tolerances between parts
- Limit / minimize forces required to operate mechanisms
- Provide status indicators for all activated functions
- Provide clear identification of objects and directional cues
- Provide operational margins (design tasks for the mid-range of servicer system capabilities – provide redundant capabilities)

Conclusion

- Deep water robotic servicing is a mature industry that has evolved continuously over the past 30 years.
- Robotic servicing in space is an industry in the earliest stages and would benefit significantly from leveraging the lessons of the deep water industry.
- Contact information:
  - Todd Colangelo 443-459-3774