Challenges of Integrating Human and Robotic Work Systems

Lessons learned from the Subsea Industry

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First generation of subsea oil production equipment –
Triply redundant, aerospace derived, “diverless systems”

- Early generations of sub sea equipment were not designed for serviceability - influence from aerospace industry
- Required the superior perception, judgment and dexterity of hands on diver
- Ushered in the era of saturation diving in the offshore oil fields.
Saturation Diving from Sea Lab to Offshore Oilfields

Diving bell provides means to transfer under pressure from habitat to ocean depth

Transfer lock: contains shower and toilet

6 person living chamber
Potentially dangerous operations and the utility equation

Utility = (Probability of Success * Reward) – (Probability of Failure * Cost)

• Commercial diving is potentially a very dangerous business.

• As a professional it is important to continually balance the utility equation to have a positive outcome.

• If the cost of failure is human life then every effort should be applied to reducing the probability of failure and/or pull the human back from the worksite to a safer environment.
Darwinian Evolution of Subsea Work Systems To Reduce Dependency on Complex and Expensive Saturation Diving
Early Attempts at Robotic Servicing were oversold and failed miserably
One Atmosphere Diving Suits

• Taking the human a step back from the hands on environment
• Necessitated redesign of the subsea equipment to operate within the capabilities of the atmospheric diving suit work system.
Another Step Back from the Worksite

GE Force Reflecting Manipulator
Evolving ROVs to be less complex and more reliable
New Generation of ROV Compatible Tools

T/O Gate Valve Tool
Subsea production complex analogous to a Lunar or Mars Base
PLACID SUBSEA PRODUCTION SYSTEM
Physical and Visual Accessibility

If you can’t see it and touch it you can’t complete the task.
Worksite Design: ROV Accessible Valves

- Put the simplest part in the hostile environment
  - No need to have actuators with umbilicals on every valve
- Design the facility with robotic access and the robot becomes the actuator saving mass, complexity, and expense.
Re-engineering the Sub-Sea Equipment
Standard Interfaces Compatible with Robotic and Astronaut Tooling

Micro-conical interfaces

Robot compatible tool

Astronaut compatible tool
UPR Tanker Scouts Path Between the Lander and the MAV
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UPR Transferring Propellant from Lander to MAV

Propellant transfer and power charging port is integrated with a landing leg at ground level
UPR Transferring Propellant From Tanker Package to MAV

- Assumes arrays not deployed during traverse and that charging occurs during the ~4hrs of propellant transfer.
Don’t build a robot and ask what can I do with it? Start with the tasks and determine which tasks are candidates for a robot then iterate engineering of interfaces to develop the robotic work systems.

Integrating a parametric understanding of the task and work system (humans or robots) with the operational environment.