SMART Underwater Robot (SUR)
Application & Mining

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Outline

(1) Undersea Resources and Mining

- Facts
- Undersea Mining Procedure
- Undersea Mining Vessels
- Difficulties in Undersea Mining

(2) Smart Underwater Robot Technology

- Why SMART Underwater Robot (SUR)?
- Ingredients of Smartness
- SMART Underwater Robot System
- Future Prospective for Undersea Mining
(1) Undersea Resources and Mining
Facts

Undersea Resources and Mining

Land Resources

Land resources are depleted and vanished

Marine environment covers more than 70% of the Earth

Future for the mankind
Rare earth element deposits in the Pacific Ocean less than 2 km deep
(University of Tokyo, 2007)
### Minerals and Related Depths

<table>
<thead>
<tr>
<th>Type of Mineral Deposit</th>
<th>Average Depth</th>
<th>Resources Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymetallic Nodules</td>
<td>4,000 - 6,000 m</td>
<td>Nickel, Copper, Cobalt, and Manganese</td>
</tr>
<tr>
<td>Manganese Crusts</td>
<td>800 - 2,400 m</td>
<td>Mainly Cobalt, some Vanadium, Molybdenum and Platinum</td>
</tr>
<tr>
<td>Sulfide Deposits</td>
<td>1,400 - 3,700 m</td>
<td>Copper, Lead and Zinc some <strong>Gold and Silver</strong></td>
</tr>
</tbody>
</table>
Hydrothermal Vent Formation & the Formation of Seafloor Massive Sulfides
(Birney et al., 2007)
Ocean Resources

Surface

- 1,000 m
- 2,000 m
- 3,000 m
- 4,000 m
Active hydrothermal vents at Roman Ruins vent in the PACMANUS vent field, eastern Manus Basin. (Photo courtesy M. Tivey and WHOI Deep Submergence Lab, Cruise Manus 2006 with ROV Jason II)
Search/Explore
Location of Resourced Site, Sampling
Effectiveness Study
Start Mining/ Confirmation
Excavation
Operation/ Expansions
Figure 2
BISMARCK SEA AREA, PAPUA NEW GUINEA
LOCATION OF TENEMENTS
March 2009 © Nautilus Minerals

Exploration Licences
- Granted, 100% Nautilus
- Granted, Teck (transfer to Nautilus pending)
- Surrendered, 100% Nautilus
- SMS system

Exploration Licence Applications
- 100% Nautilus

Dyual Island

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Location of Resourced Site, Sampling
Excavation, Operation/Expansions
Deep Sea Mining Vessels
GPS: Global Positioning System
MBES: Multi Beam Echo Sounder
NBS: Narrow Beam Sounder
PDR: Precision Depth Recorder
nSBP: narrow-beam Sub Bottom Profiler
BMS: Benthic Multi-coring System
(Large-gravity Corer
MC: Multiple Corer
FDC: Finder-installed Deep-sea Camera
FG: Free fall Grab
FPG: Finder-mounted Power Grab
DB: Dredge Bucket

GPS (D-GPS)

n-SBP

LC

MC

DB

FDC

FPG

BMS

MBES, NBS, PDR

FG

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Underwater Robot System
Difficulties in Undersea Mining

Deep water/ Darkness/ Current/ Unknown Environment
Extra High Water Pressure
Exploration/ Search difficulties
Detection/ Sampling of Resources
Approaching to the Underwater Sites
No Human Allowed Environments
Mining Method/ What Kind of Tools to Use...
Etc......
Current Undersea Mining Technology

Undersea Drilling
Human Operated Submersible
Remotely Operated Underwater Vehicle
Mixed with Man-Machine Operations
Very Few options for Disaster (Oil Spill in 2011)
Future Directions

SMART Underwater Robot

Safe Underwater Oil Drilling
Accidents/ Disaster Prevention Measures
Sustainability and Effectiveness of Operation
(2) Smart Underwater Robot (SUR) Technology
Why?

- Entering a hostile or deep area (man cannot go) and gathering much information
- Quickly identifying possible mining areas and safe paths gathering, transmitting
- Continuous operations at the ocean floor
- Avoid any human related accidents
- High efficiency in operations
Definition of Smartness

From *Dictionary*

* Intelligent, Clever/Expert
* Machines uses computer technology to make them effective.
* Wisdom, 智慧/知慧
* 지혜는 이치를 깨우치고 사물을 정확하게 처리하는 정신적 능력
Ingredients of Smartness

• Agile Body/Vehicle Structure
• Mission Management System (Vehicle Management)
• Intelligent Navigation System (Obstacle Avoidance)
• Simultaneous Location and Mapping (SLAM) → Perception of Environment
• Target/ Object Recognitions
• Effective Mission Accomplishment
• Effective Networked/ Communication
• Swarm/Cooperative Operation? Maneuvering
• Cost Effectiveness
Undersea Mining Characteristics

• Effective Search/ Confirming the Site
• Excavation and Development Stability
• Delivery of Ore and Resource
• Mining System/Complex Operation
• Sensitivity in Environmental Issues
• Disaster Prevention and Recovery
• Networked Communications
• System of Systems Management
SMART Underwater Robot

• Intelligent/Effective Performances
• Overall Mission Management System
• Smart Vehicle Operations
• Obstacle Avoidance/Management
• Intelligent Perception of Environment
• High Probability in Recognition of Target/Object
• Sustainability/Interoperability
System Autonomy

Rule #1 → Gain information about the environment
Rule #2 → Work for an extended period without human intervention
Rule #3 → Move either all or part of itself throughout its operating environment without human assistance
Rule #4 → Avoid situations that are harmful to people, property, or itself
Rule #5 → Maintain its own survival at the expense of the previous rules (Sentient Robot Mandate)
Rule #6 → Learn or gain new capabilities like adjusting strategies for accomplishing its task(s) or adapting to changing surroundings.
Endurance and Sustainability

Unmanned Air Vehicle Power
- Long endurance fuel cell power (26 hr flight Nov 2009)
- Low noise & heat signature
- Affordable ($80K/vehicle)

Unmanned Undersea Vehicle Power
- Lithium-ion battery safety
- Air independent power systems: fuel cell, hybrid electric, Al-water

Unmanned Surface Vehicles
- Advanced platform designs
- Launch & recovery
- Autonomous operation
Networked Communication Systems

Network-Centric architecture overview.
System Mission Management Systems

• **Improved Performance**
• **Informed Decisions**
• **Smarter Control**
• **Better Resource Efficiencies**
• **Superior Responsiveness**
• **Reduced communication Requirements**
Behavioral Autonomous Vehicle Control as Implemented in the Pennsylvania State University Applied Research Laboratory Intelligent Control Architecture (After: Lewis and Weiss, 04)
Intelligent Navigation
Smart Mission Management System
Future Prospective for Undersea Mining

Shallow Water Zone
Medium Depth Sea Mining
Medium and Deep Sea Mining
Deep Sea Explorer

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Sea Floor Unmanned Excavation Vehicle
Nautilus has investigated the use of proven subsea technology for mining the SMS deposits. This 900HP ROV assisted pipeline trenching machine is as powerful as a D11 bulldozer.
Questions and Future Cooperation?

Thank you for your attention.