Asia Pacific Clean Energy Summit

Ocean Energy Panel

Tim Fuhr
Director, Ocean Energy

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Lockheed Martin

- A Global Security Company
  - Focus on research, design, development, manufacture, integration and sustainment of advanced technology systems, products and services
- 126,000 Employees
- 63,000 Scientists, Engineers and IT Professionals
- Operations in 1,000 Facilities, 500 Cities, 50 States and 75 Countries
  - More than 300 Partnerships Across the Globe

We Do What Hasn’t Been Done... A Passion for Innovation
Lockheed Martin Ocean Energy

Ocean Thermal Energy Conversion
Exploits existing ocean thermal gradients to drive a heat engine to produce electricity

- Long-Term Focus
- OTEC Plant Designs
- Discriminating Technology
  - Heat Exchangers
  - Coldwater Pipe
- Significant Technology Investments with Broader Commercialization Potential

Tidal Energy
Captures energy from tidal flows to rotate submerged turbine-generators to produce electricity

- Atlantis Resources Relationship
- Yaw Drive Development
- ETI and Turbine Engineering Programs
- Canada Bay of Fundy Project
- Supply and Support of Tidal Turbine Systems

Wave Energy
Transforms wave motion to electricity from device arrays near the coasts

- Ocean Power Technologies (OPT) Relationship
- Product Design Support
- DOE contract
- Supply and Support of Wave Energy Converters (WEC)
  - Victoria, Australia & Reedsport, OR projects

Operating Across the Ocean Energy Sector
Why Lockheed Martin in Ocean Energy?

Experience & Innovation
• Proven Marine Design Expertise
• Advanced Modeling and Simulation
• Research & Development
• Technology Innovations
• Design for Manufacturing

Marine Engineering Domains: 10,000+ SMEs

Proven Performance
■ Large Scale, Complex Systems Integration
■ Ocean Based Products with Proven System Performance
■ Experienced Program Management
■ Global Footprint and Ability to Achieve Scale
■ Design - Production - Operations and Support

Bringing Experience to Deliver Ocean Energy Solutions
LM OTEC Progression

Many Years of Research… 5+ Years Focused Development Ready for Transition to Deployment
# OTEC Offshore Pilot Plant

<table>
<thead>
<tr>
<th>Major Component</th>
<th>Pilot Plant Approach</th>
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<tbody>
<tr>
<td>Platform</td>
<td>Modified Standard Offshore Config</td>
</tr>
<tr>
<td>Turbine/Generator</td>
<td>Non-Developmental</td>
</tr>
<tr>
<td>Pumps</td>
<td>Non-Developmental</td>
</tr>
<tr>
<td>Power Cable</td>
<td>Non-Developmental</td>
</tr>
<tr>
<td>Instrumentation &amp; Control (I&amp;C)</td>
<td>Modified Commercial</td>
</tr>
<tr>
<td>Heat Exchangers (HX)</td>
<td>Technology Scale-Up</td>
</tr>
<tr>
<td>Composite Cold Water Pipe (CWP)</td>
<td>Finalize Development and Deployment</td>
</tr>
<tr>
<td>CWP System Elements</td>
<td>Detailed Design &amp; Technology Scale-Up</td>
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</table>

**Power Module**  
HX; Seawater & Ammonia Pumps

**Turbine/Generator Set**

**Semi-Submersible Platform**

**CWP**

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**R&D Focused on HX and CWP … Pilot Plant Build is Next Step**
Wave Energy Program in Hawaii

• PB-40 early prototype installed off Marine Corps Base Hawaii (MCBH)
  • First grid-connected wave energy system in the U.S.
  • Survived severe storms & confirmed models
  • Validated design for scale-up to higher power buoys

– Now deploying larger devices to better capture available wave energy resources
PB150 Deployment in Scotland

- PB150 Float Assembly
- PB150 Bridge Assembly

PB150 assembled on wharf

Rated power output: 150 kw
Peak power output: 866 kw

PB150 Unit Deployed in Scotland and 2\textsuperscript{nd} Unit Ready for Deployment in Oregon
Portland, Victoria, Australia
Wave Power Demonstration Project

- Approvals, licences and funding during 2012 / 2013
- 19 MW in 3 development stages
  - Stage 1 – 0.5 MW – 2013 / 2014
  - Stage 2 – 5.0 MW – 2014 / 2015
  - Stage 3 – 13.5 MW – 2016/ 2017
- Supported by Federal grant - $66.5M max
- Grid connected; 25 year operating life
- Located within State waters
- Sufficient power to fulfill energy needs of approximately 10,000 homes

- **Role of OPT**: Power Buoy Design; Provide Power Buoy technology, Provide Power Take-Off (PTO), Underwater Substation
- **Role of LM**: Power Buoy Design Support; Buoy Component Production; System Integration & Test; Program Management
Atlantis – LM Tidal Energy Efforts

**Engineering**
- Turbine Design and Analysis
- Performance Modeling
- Yaw Drive Development
- UK Energy Technology Institute (ETI) Tidal Energy Converter (TEC) Project

**Testbeds**
- EMEC, Scotland [AR-1000]
- FORCE, Canada [Test Berth]
- NAREC, UK [AR-1000]

**Focus Projects**
- **MeyGen**, Scotland: 400MW project with 85 MW Stage 1, FEED in Progress, Construction 2014
- **Mundra, India**: 250MW project, FEED in progress
- **Projects in planning** - Canada, Bay of Fundy; others

*L O C K H E E D M A R T I N*
Atlantis Resources 1 MW Horizontal Axis Tidal Turbine

- Designed for very rough offshore wave exposed locations (high survival state)
- ARC/ABB designed power conditions system full UK & European grid compliant
- Full onboard health monitoring system with fiber telemetry remote link

Key Statistics

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<thead>
<tr>
<th>Water Speed</th>
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<tbody>
<tr>
<td>Rated operational</td>
<td>2.65 m/s</td>
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<tr>
<td>Maximum operational</td>
<td>3.4 m/s</td>
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<table>
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<tr>
<th>Output</th>
<th></th>
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<tbody>
<tr>
<td>Rated output</td>
<td>1,000 kW @ 2.65 m/s</td>
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<tr>
<td>Expected capacity factor range</td>
<td>35-50%</td>
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<tr>
<td>Shaft speed</td>
<td>6-15 rpm</td>
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<tr>
<th>Operating Conditions</th>
<th></th>
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<tr>
<td>Design depth of operation</td>
<td>25-60m (max)</td>
</tr>
<tr>
<td>Minimum clearance from surface (LAT)</td>
<td>7m</td>
</tr>
<tr>
<td>Expected life of turbine nacelle</td>
<td>20 years (structural)</td>
</tr>
<tr>
<td>Maintenance cycle</td>
<td>Overhaul every 5 years</td>
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<th>Deployment and Support</th>
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<tr>
<td>Method</td>
<td>Gravity Base (GBS) or mono-pylon</td>
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Source: Atlantis Resources
Advantages of Ocean Power

• Close to Population centers on the coast, with minimal land usage and sight impact
  – Transmission costs and losses minimized
  – Perfect for islands and coastal land

• Predictable Power
  – OTEC is baseload, Wave and Tidal are periodic/predictable
    • Not prone to short-term variations like solar/wind
  – Able to predict output with high accuracy, often days in advance
Challenges

• Transition from Research / Pre-Commercial to Commercialization
  – Recognizing and leveraging the tipping points

• Testbeds that Advance Industry toward Commercialization

• Support for technology development and initial projects
  – Incentives and government support
  – Risk sharing