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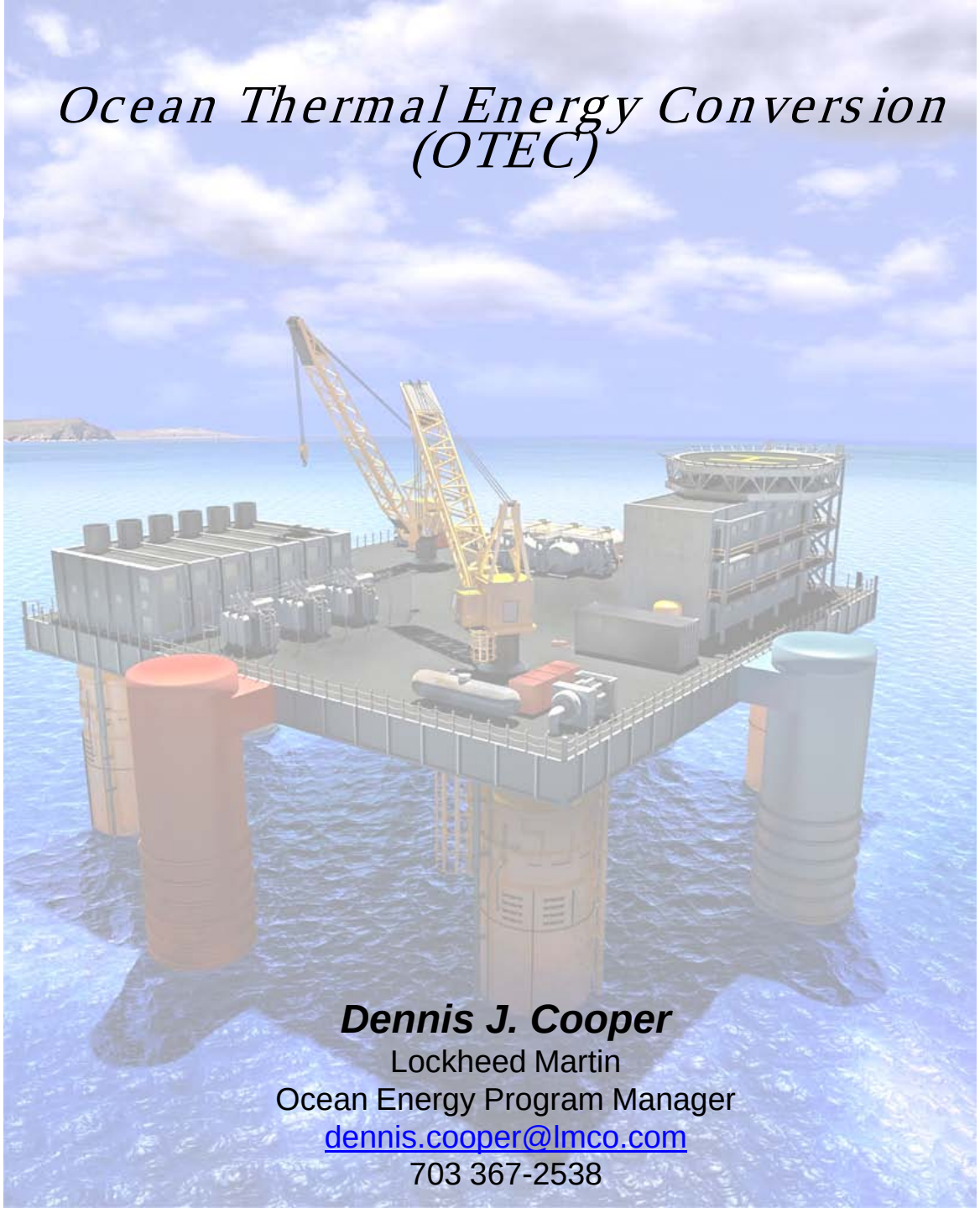
· August 15-18, 2010 · Dallas, Texas ·
· Dallas Convention Center ·

OTEC
Ocean Thermal Energy Conversion

Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion (OTEC)



Dennis J. Cooper
Lockheed Martin
Ocean Energy Program Manager
dennis.cooper@lmco.com
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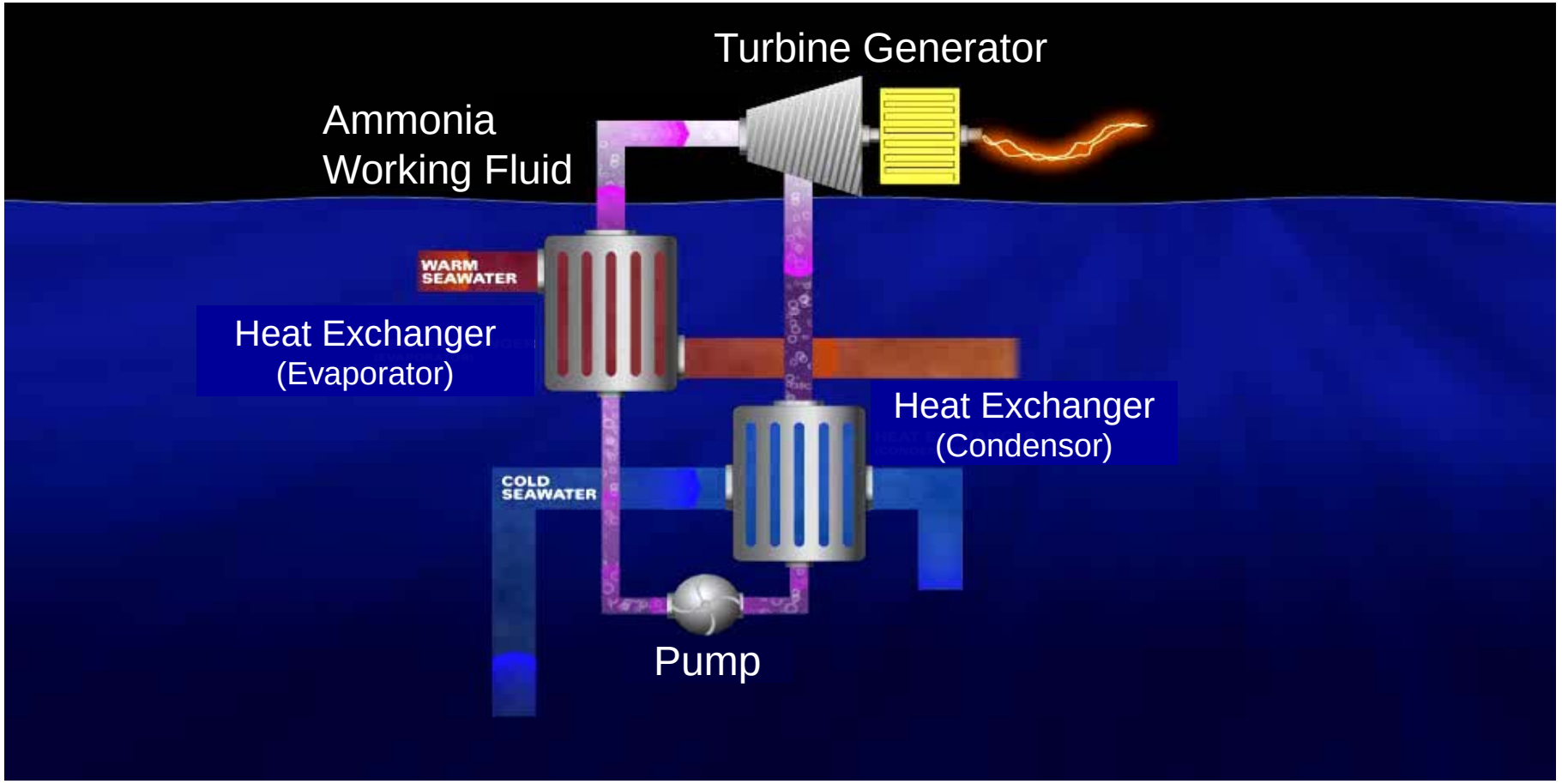
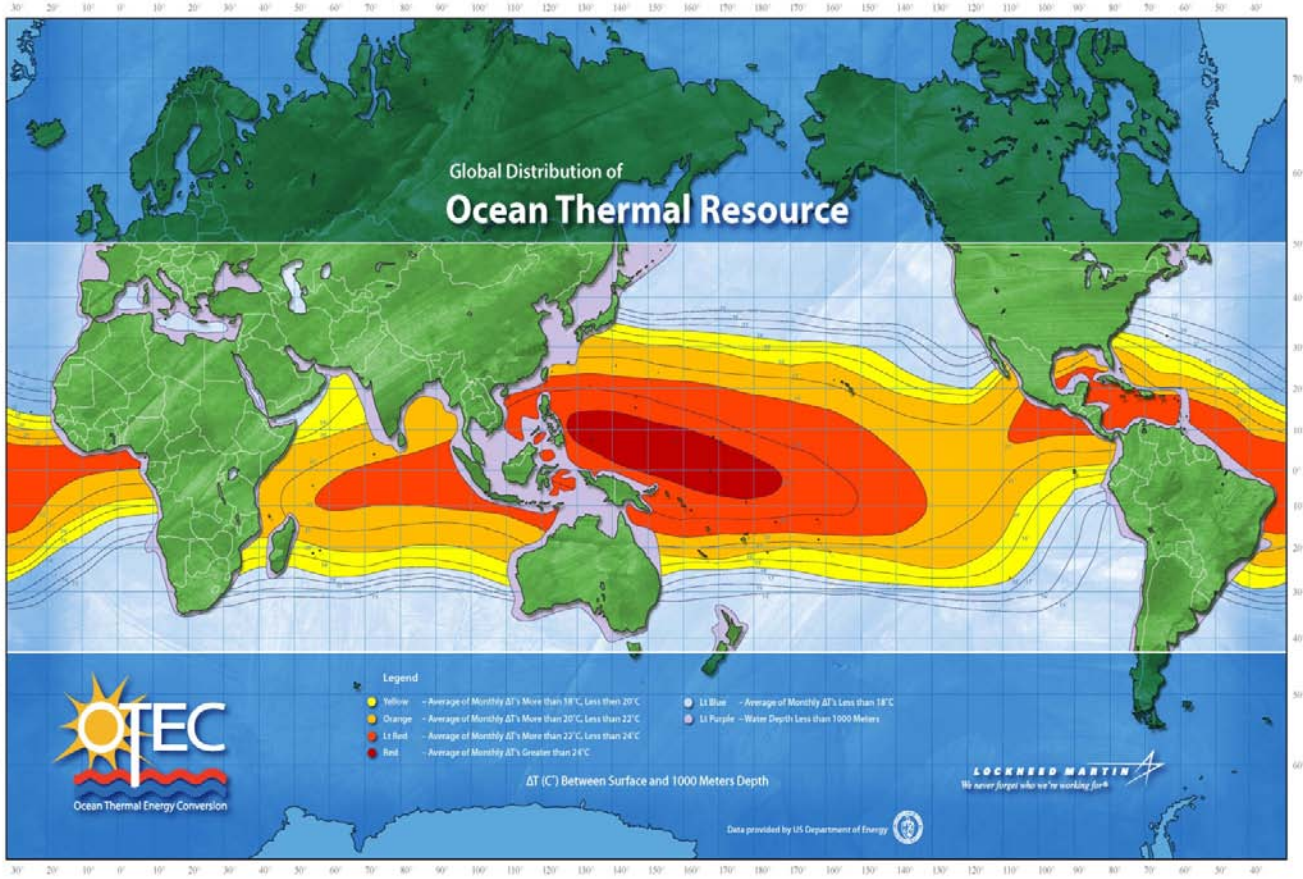
Ocean Thermal Energy Conversion (OTEC) Process



A Standard Rankine Cycle

The OTEC Resource

- ✓**Large Renewable Energy Source**
  - At least 3-5 Terawatts*
- ✓**Base Load Power**
  - Available 24/7
- ✓**Energy Security**
  - A Secure Energy Source
- ✓**Climate Friendly**
  - No Fossil Fuel Emissions
- ✓**Facilitates Water Desalination**



* **A Preliminary Assessment of OTEC Resources ASME 3/2007**

A New Clean Renewable 24/7 Energy Source

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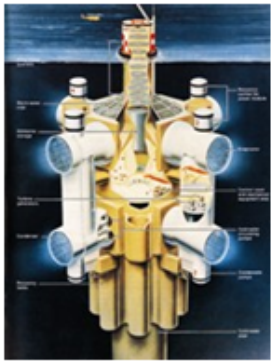
OTEC History

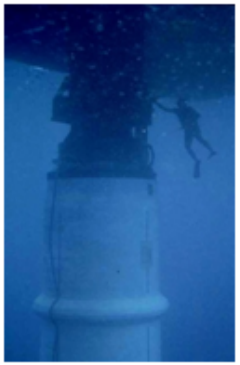
1974: Hawaii established Natural Energy Laboratory (NELHA)

1975: NSF OTEC Scientific Study (Lockheed Martin)



1979: 50 kW Mini-OTEC (Lockheed Martin & Makai)

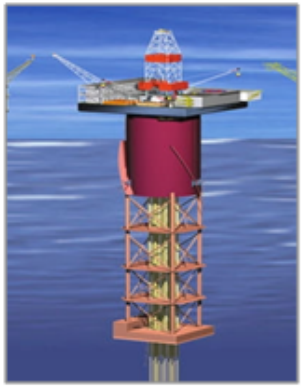
1983: 8ft Pipe At Sea Test (TRW for DOE)



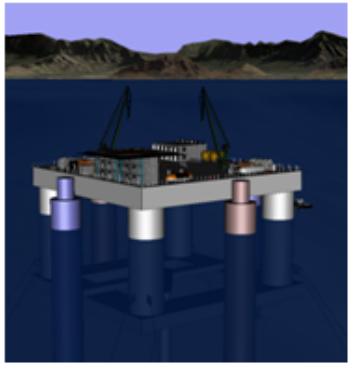
1993: 250kW Open Cycle (NELHA)

1996-2000: 50KW Hx testing (NELHA)

2005: Diego Garcia Feasibility (OCEES SBIR)



2006: OTEC Study (Makai SBIR)



2007-present: Pilot Plant Design (Lockheed Martin Team)

Georges Claude built the first OTEC plant, in Cuba in 1930

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What has Changed

30 YEARS AGO	TODAY
➢ Global warming, energy security not in public consciousness	➢ Energy security serious concern ➢ Growing concern for air pollution & global warming ➢ Widespread renewable mandates
➢ Different economic and political environment	➢ Current political focus on new jobs, energy, and environment
➢ Large capital construction cost	➢ New composite materials and construction techniques address high-cost components (Cold water pipe and heat exchanger)
➢ Offshore technology not mature at requisite scale	➢ Mature offshore technology at requisite scales in deep water

"We know the country that harnesses the power of clean, renewable energy will lead the 21st century." – President Obama

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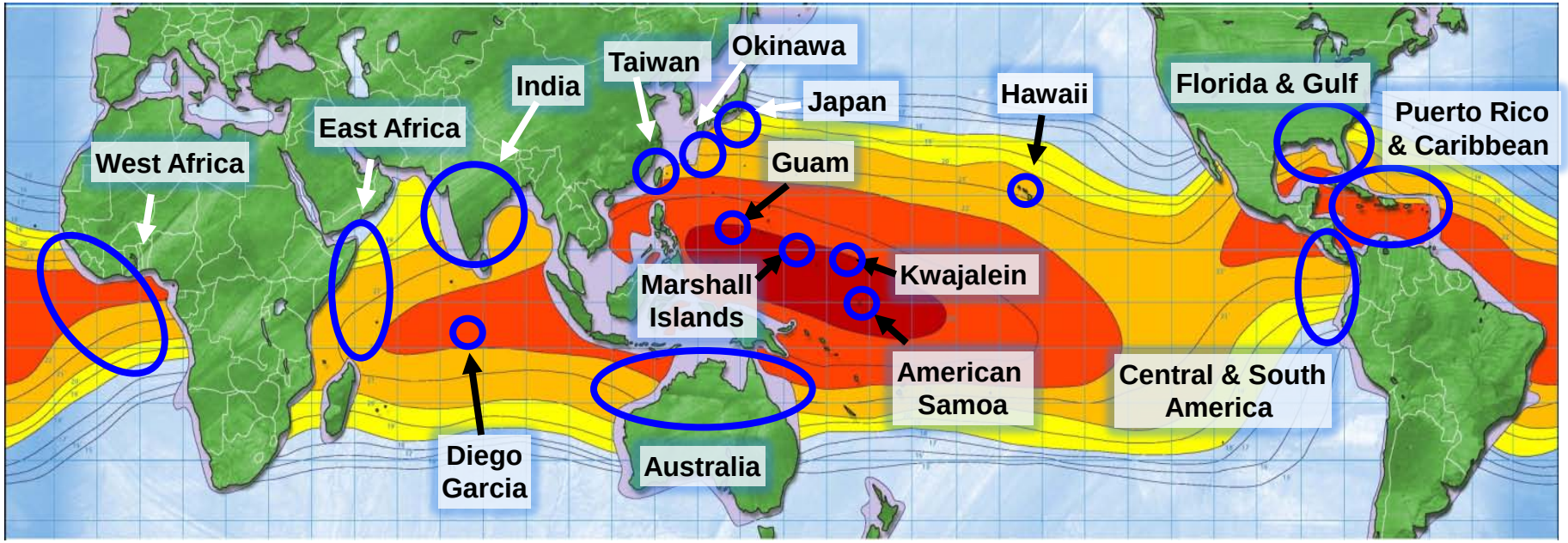
OTEC is a Solution for

A New Secure Renewable Energy Source
For Defense and Commercial Applications



Over 84 Countries have access to the OTEC Resource

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OTEC Benefits for the DoD/US Navy

Electricity & Fresh Water for DoD Bases

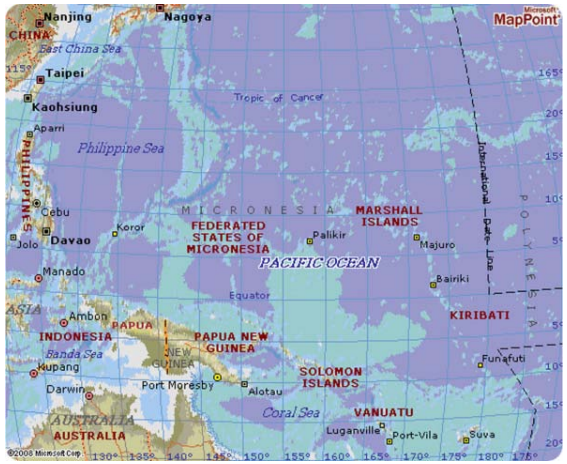
- OTEC can generate clean ***secure*** electrical power plus potable water source for isolated DoD bases
  - DoD/Oahu
  - Diego Garcia
  - Kauai (PMRF)
  - Guam
  - Kwajalein

Pacific Missile Range Facility (PMRF)

Diego Garcia

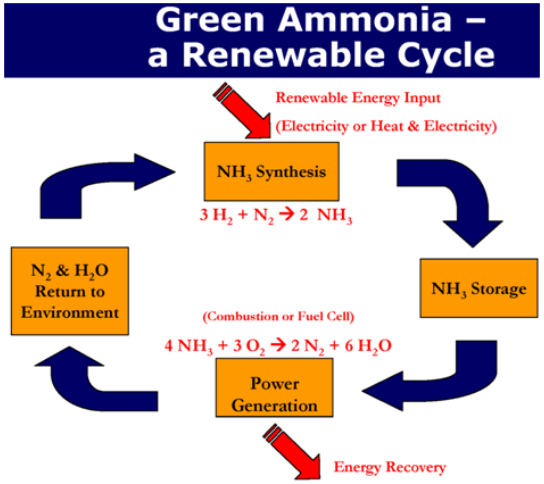
Expanded DoD Mission: Nation Building

- OTEC can generate power and water to assist developing economies
  - 84 Nations "touch" the OTEC Resource



Fuel Production

- **Fuel Production**
  - Ammonia
  - Hydrogen
  - Synthetic Fuels



All Naval facilities to be powered by 50% renewable energy by 2020

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Why OTEC

Each 100MW OTEC Plant

SAVES

1.3M Barrels Oil / Yr

$130M / Yr

($100 / Barrel)

0.5M Tons CO_2 / Yr

$15M / Yr

($30 / Ton Carbon Credit)

A Game Changer

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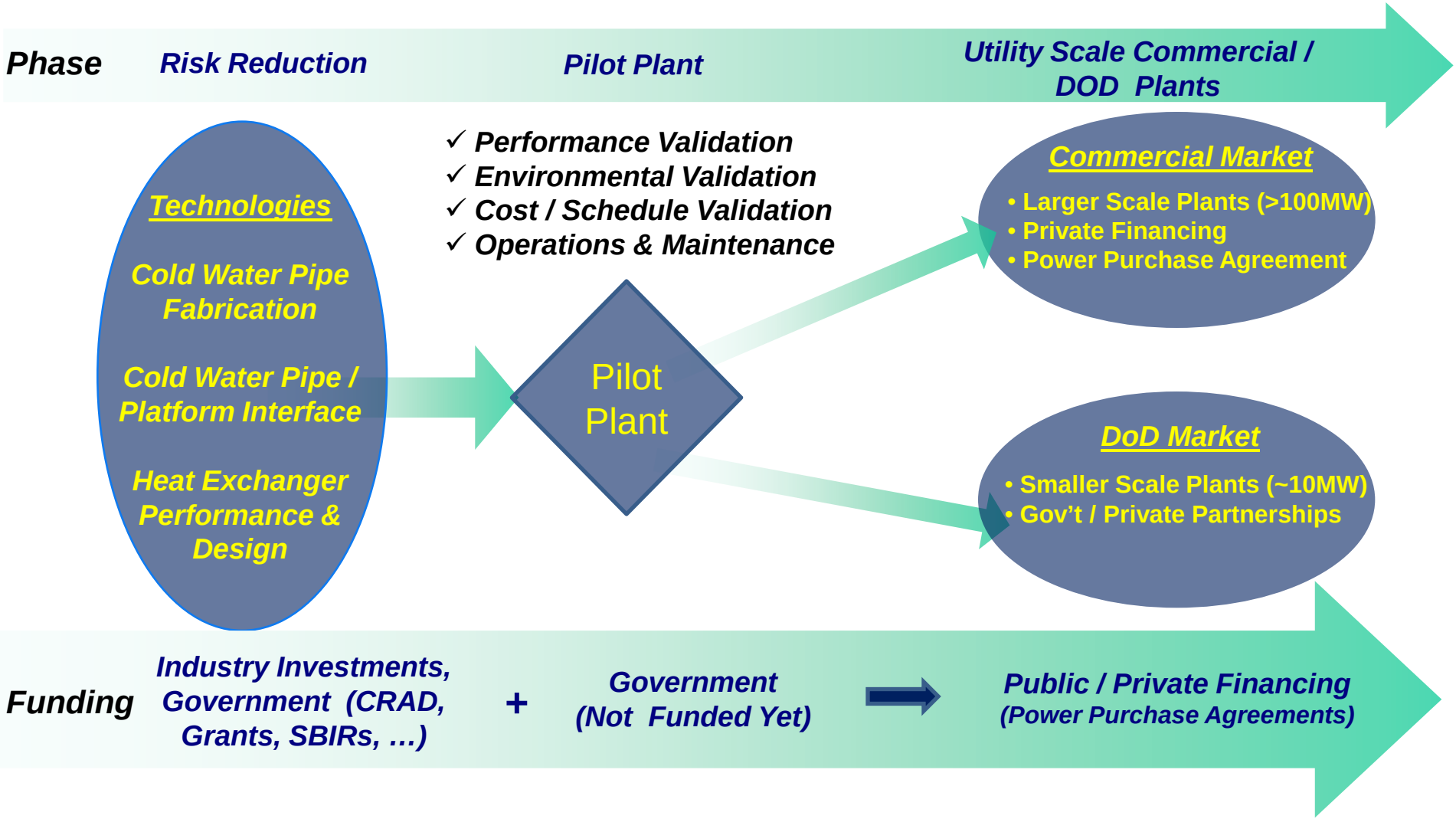
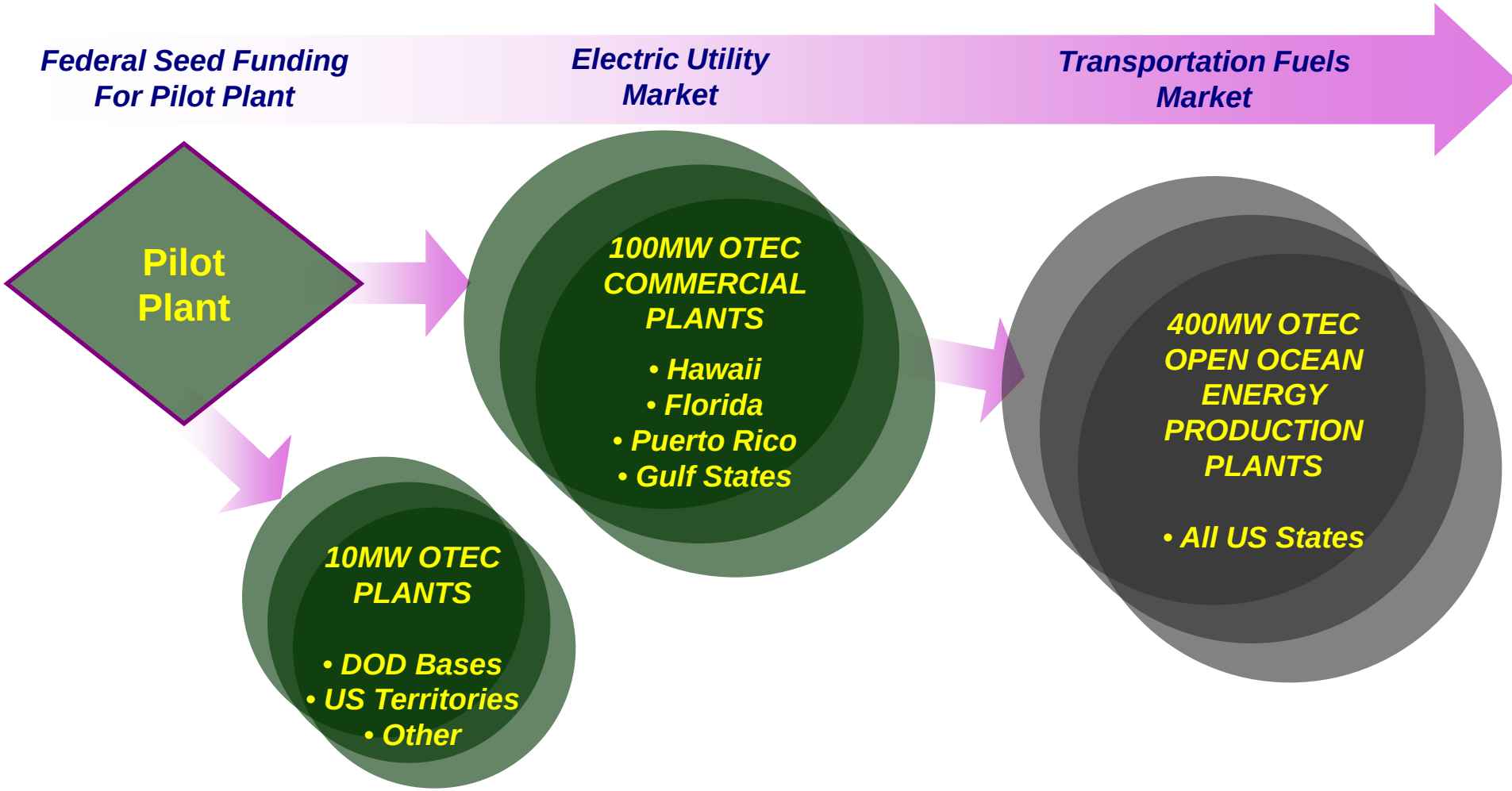
Commercialization Roadmap



Pilot Plant Support Needed for Commercialization

OTEC Vision



OTEC is Poised to be a Global Energy Resource

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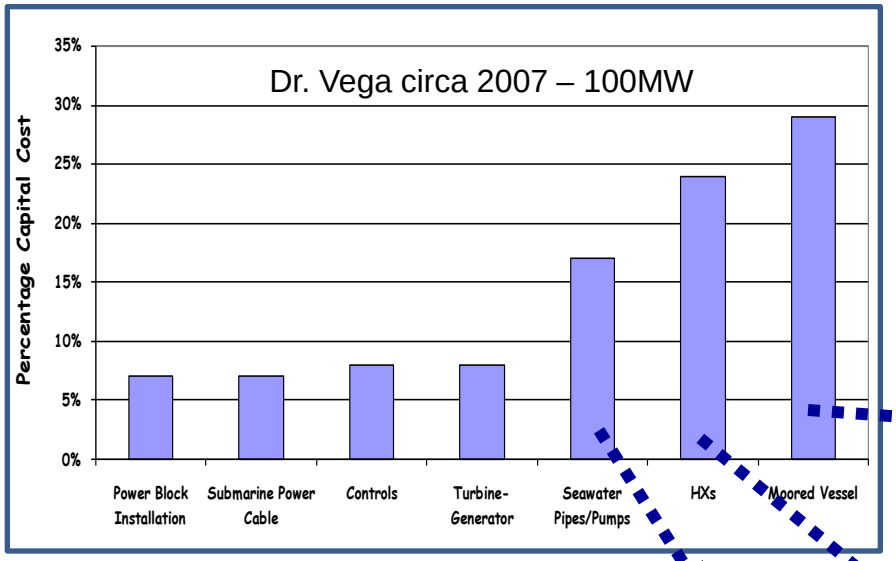
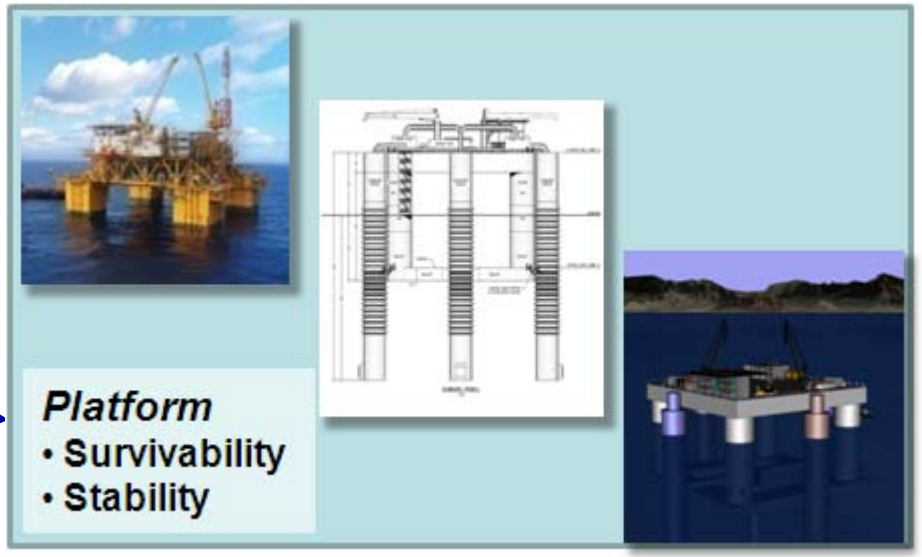
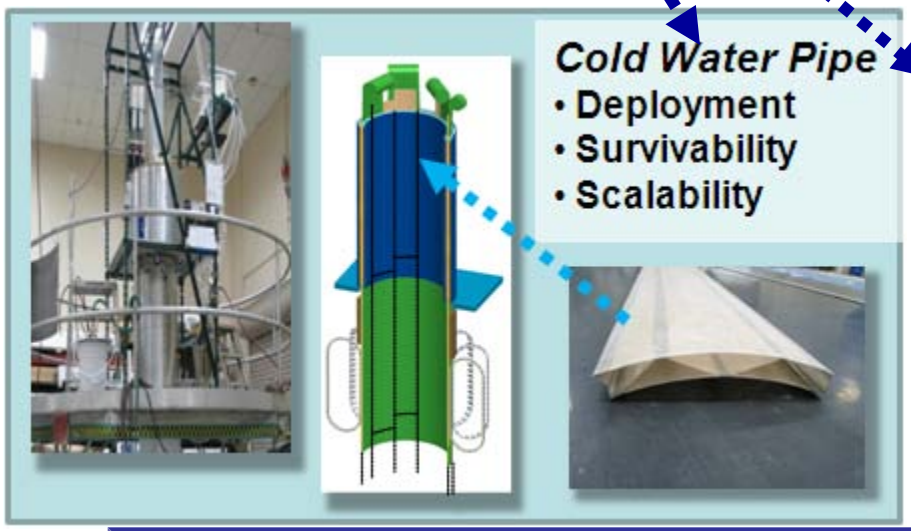
OTEC Technology Challenges

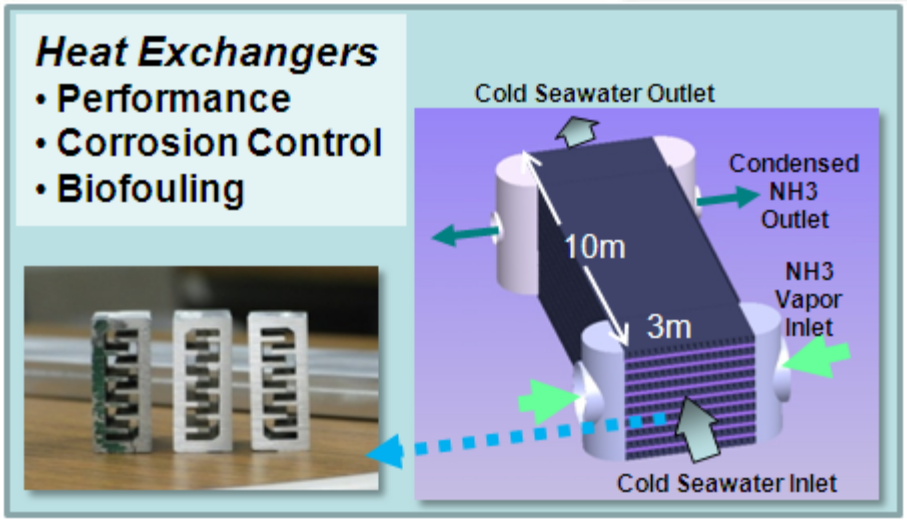




Platform
- Survivability
- Stability



Cold Water Pipe
- Deployment
- Survivability
- Scalability



Heat Exchangers
- Performance
- Corrosion Control
- Biofouling

Focused on Addressing Key Costs and Technical Challenges

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LM OTEC Team

LOCKHEED MARTIN

J Halkyard & Assoc

Houston Offshore ENGINEERING

THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

Horton Wison Deepwater
Reinventing Deepwater Solutions

E 3Tec

University of Hawaii at Manoa
Hawaii Natural Energy Institute

SBM OFFSHORE SBM Atlantia

CELLULA ROBOTICS

STRESS ENGINEERING SERVICES INC.

geo marine

PLANNING SOLUTIONS

G Noland & Assoc

NAVATEK

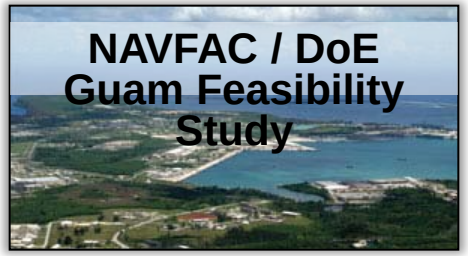
OCEES
Ocean Engineering & Energy Systems

FAU
CENTER FOR OCEAN ENERGY TECHNOLOGY
College of Engineering & Computer Science
Florida Atlantic University

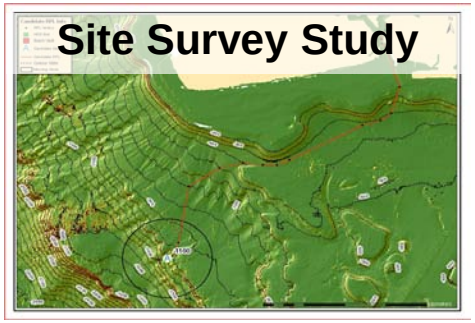
JANICKI INDUSTRIES

Strong Team with International Recognized Expertise

Risk Reduction OTEC Activities

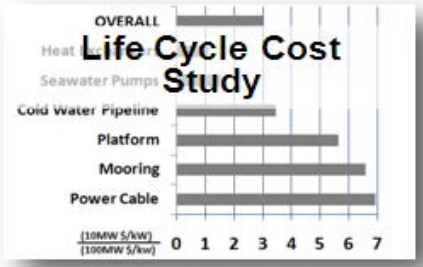


NAVFAC - $0.15M

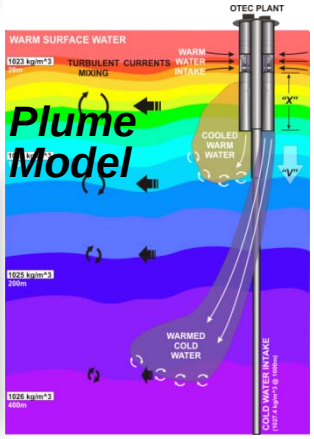


NAVFAC - $1.0M

NAVFAC - $8.12M

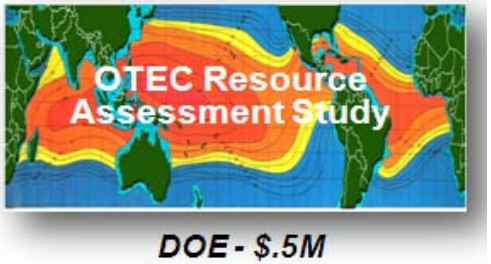


DOE - $.5M

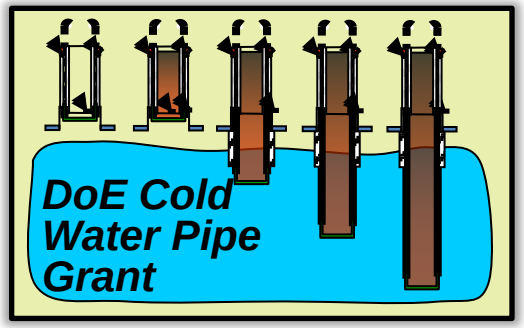


CEROS - $0.5M

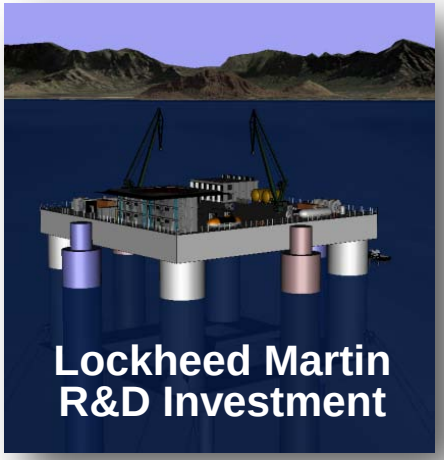
ONR - $5.0M
DOE - $0.9M
NAVFAC - $1.7M



DOE - $.5M



DOE - $1.2M



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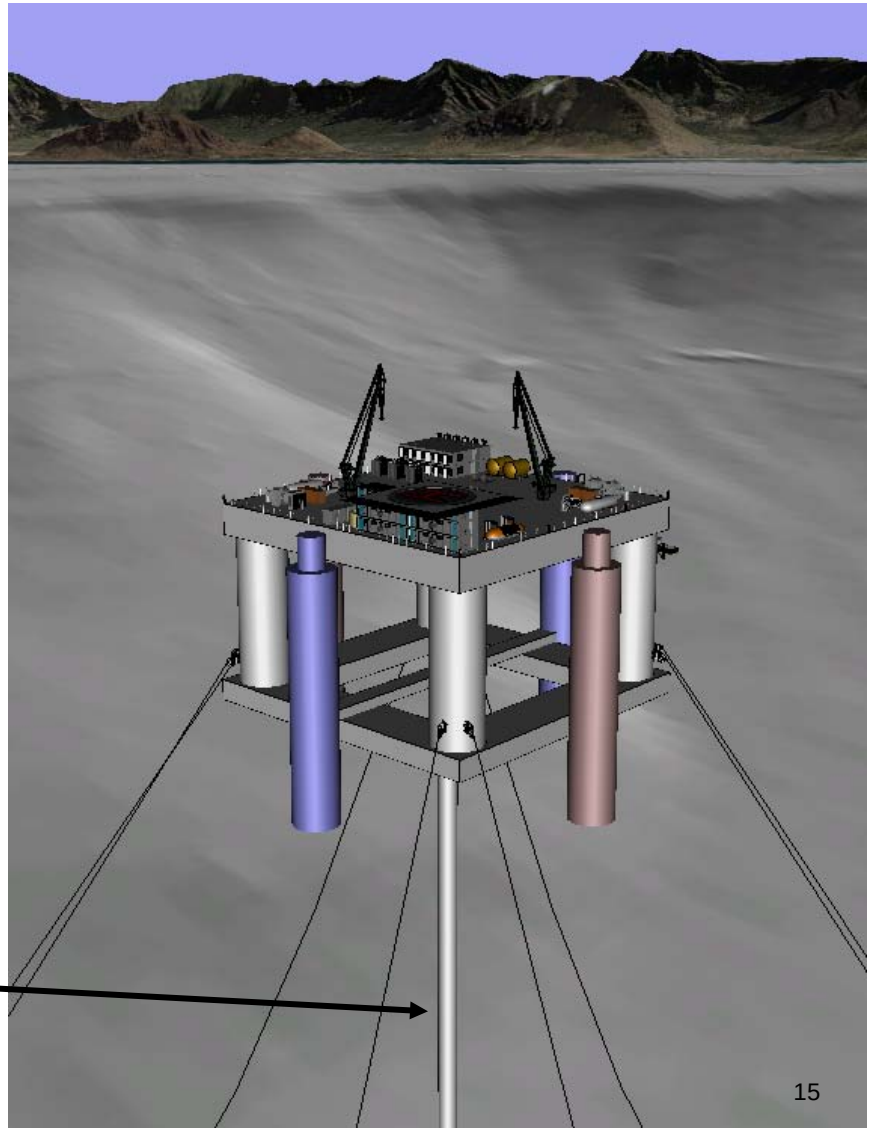
Getting a Feel for a Hawaii OTEC Plant

10 MW SYSTEM PARAMETERS

Cold Water Intake Velocity(m/s)	**2.6**
Cold Water Pipe Flow (gallon / sec)	**4,200**
Warm Water Intake Depth (m)	**20**
Warm Water Intake Velocity(m/s)	**0.15**
Water Discharge Depth(m)	**50**
Warm Water Flow (gallon / sec)	**6,100**
Hull Size (m x m)	**55 x 55**



4m diameter x 1,000m long Cold Water Pipe

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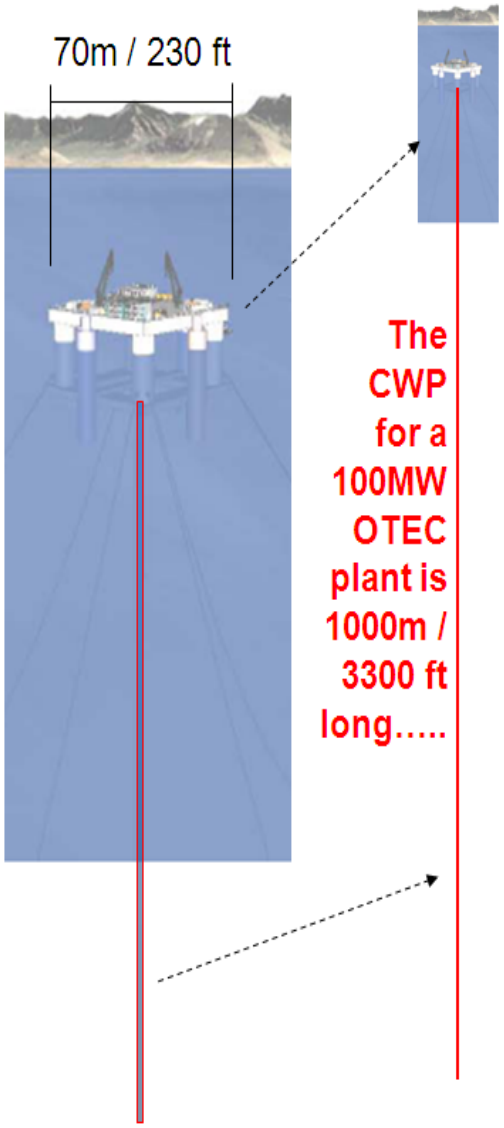
The Cold Water Pipe

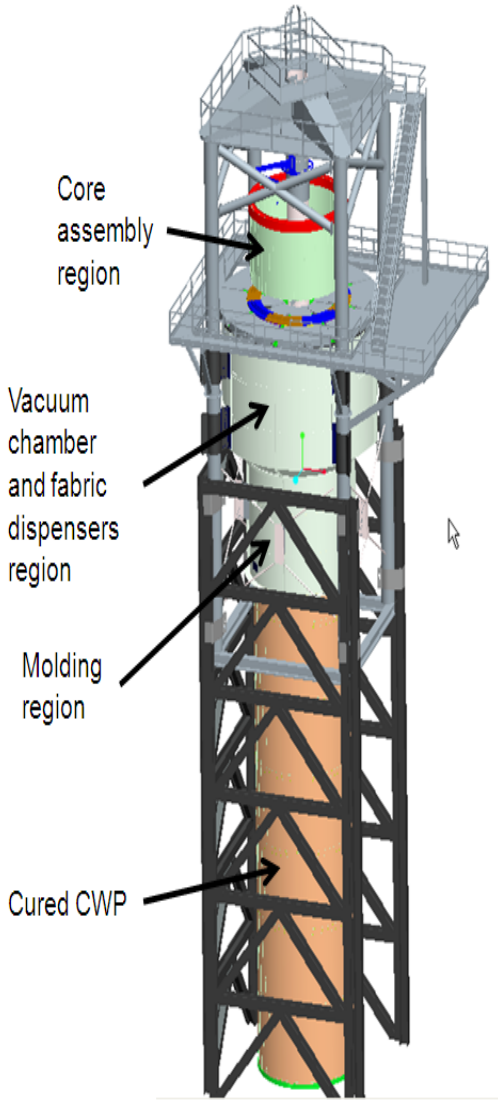


The CWP for a 100MW OTEC plant is 1000m / 3300 ft long.....

Empire State Bldg is 1472 ft. to top of antenna

.....by 10m / 33 ft in diameter

10m / 33 ft is about the width of a modest 2-story house



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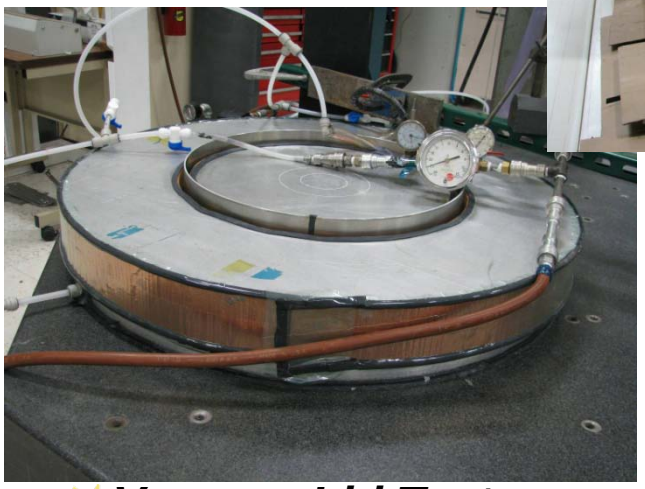
OTEC Cold Water Pipe

Inner & Outer Face Sheet

Protrusion

Inner Face Sheet



Vacuum Lid Test

Shear Key Ring

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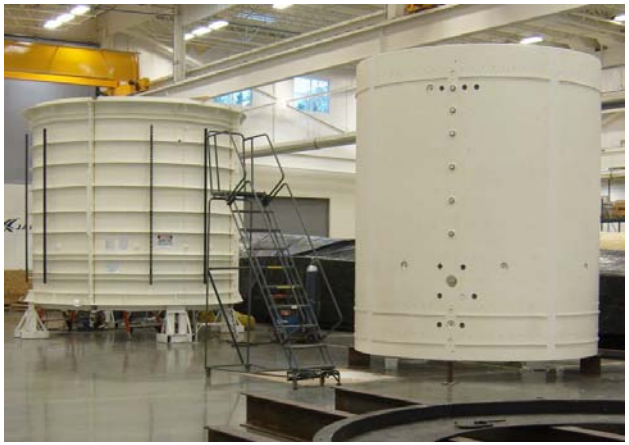
OTEC Cold Water Pipe



Inner and Outer Molding Region

Installing inner soft tool onto inner hard shell

Installing inner hard shell with soft tool into the outer hard shell

Completed Assembly

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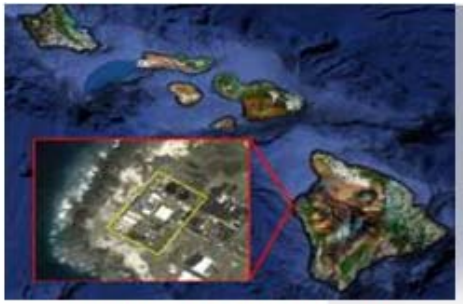
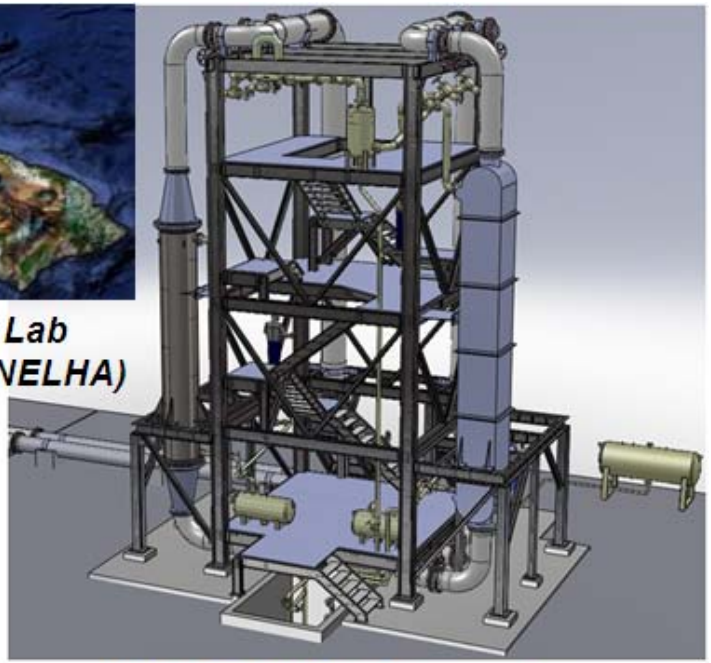
OTEC Heat Exchangers

LM Manassas 1KW Hx Test Stand

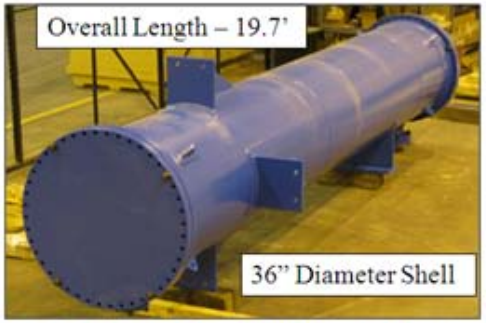


Natural Energy Lab
Hawaii Authority (NELHA)



NELHA 40KW Hx Test Stand

Friction Stir Welding (FSW)



Heat Exchanger Test Article

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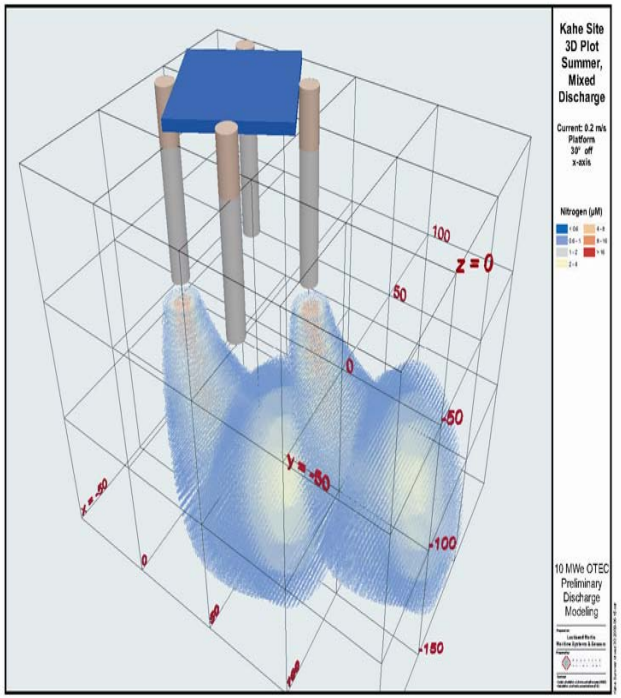
License/Permitting Strategy for Pilot Plant

1. **Identify & Meet with Stakeholders early & often**
2. **Pursue "Demonstration Project" designation from DoE for Pilot Plant**
   - **OTEC Act of 1980 allows for a demonstration plant to proceed without commercial license**
3. **Model plume discharges and gather baseline data**
4. **Monitor Pilot Plant Operation**
   - **Monitor impact to baseline environmental data**
   - **Develop commercial plant impact predictions**



Address Environmental Impacts Early in the Design Process

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OTEC Benefit Summary

ENERGY

- Baseload power source
  Continuous power (24/7)
- No storage/backup generation
  Fewer grid integration issues
- Unexploited resource

NATIONAL SECURITY

- Reduce dependence on unstable sources of oil
- Provides military bases with secure electricity and fresh water
- Power/water to developing nations

ENVIRONMENTAL

- Minimal CO_2 emissions
- Sea-based plant reduces land needs
- Designed to minimize impact on ocean environment
- Fresh water production

ECONOMIC

- Commercial products (fresh water, air conditioning, fuels)
- Leveraging and advancing existing technology
- Create new industry; green jobs
- Significant export opportunity
- Cost Competitive Electricity

OTEC Summary

- *OTEC is a Large, Clean, Renewable, Baseload Energy Resource*
- *Strong Industry team making excellent progress on Risk Reduction Activities*
- *A OTEC Pilot Plant would provide Navy Baseload Power and enable OTEC DoD and Commercial development*
- *Government support enables industry transition to privately competed utility scale OTEC plants*
  - *Green Industry and New Jobs*