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Section 4

Rates & Factors

Direct Labor Calculations-Time Phased
Base Dollars for Overhead, Fringe
Fringe, G&A, Service Centers, and Cost of Money

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Section 5

Priced Bill of Materials (PBOM)

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Section 6

Basis of Estimate (BOE)

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Table 4. Expertise and Responsibilities of Team Members

		Expertise	Responsibilities
Hota GangaRao, Prof. CEE	PI	Composites and structures design, aging, fatigue	Leadership, direction, coordination, management, technical guidance in design & manufacturing
Ruifeng Liang, Prof. ChE	co-PI	Composite manufacturing, testing, durability	Production and testing related activities, including aging
Mark Skidmore, Engg Scientist	co-PI	Dynamics, data acquisition, construction	Construction and field coordination, including vibration tests and analysis
John Zondlo, Prof. ChE	co-PI	Thermal energy conversion, thermophysics	Thermal measurements and analysis
Udaya Halabe, Prof. CEE		Non-destructive evaluation	Monitoring pipe quality and detecting any damages during production and testing
Engineering Scientist (New Hire)		Materials Science and Engineering	Technical and managing assistance in all subtasks, including day-to-day work
Technician (s), CFC-WVU			Machining, set-up testing frame, instrumentation, supervising students in lab
Office manager, CFC-WVU			Accounting, meeting arrangement, paperwork, follow procedures
GRA Students, MS /PhD		Civil, Chemical and Mechanical Engineering	Technical assistance in all subtasks
Hourly Workers			Field aid workers

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ADVANCED COMPOSITE OTEC COLD WATER PIPE PROJECT

Advanced Water Power Projects Funding Opportunity Announcement Number DE-PS36-08GO98030

CFDA Number: 81.087

Proposed under FOA Topic Area #1: Advanced Water Power Renewable Energy In-water Testing and Development Projects

Proposal Submitted By:

Lockheed Martin
Maritime Systems & Sensors
Undersea Systems
9500 Godwin Drive
Manassas, VA 20110-4157

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1 EXECUTIVE SUMMARY & PROJECT OBJECTIVES

The Advanced Composite OTEC Cold Water Pipe Project validates a unique in-situ manufacturing process to simultaneously construct and deploy the large cold water pipe needed to commercialize OTEC systems at a substantial cost savings over previous designs and deployment concepts.

1.1 Background

Ocean thermal energy conversion (OTEC) systems hold great promise for large base-load environmentally sustainable power for the US. The thermal energy contained in the temperature difference between the warm ocean surface waters and deep cold waters within tropical waters represent at least a 3 TW resource[1].

OTEC systems have been shown to be technically viable but the high capital cost has thwarted commercialization to date. The Lockheed Martin (LM) team is investigating commercializing OTEC and is therefore focused on reducing the cost of critical system components such as the cold water pipe (CWP). Providing large flow of deep cold water to a floating OTEC plant requires a pipe of large diameter (~10m for a 100 MWe plant) that extends from near the ocean surface to a depth of 700m to 1,000m. This CWP must be strong enough to withstand wave induced motions (WIM) and vortex induced vibrations (VIV) and operate in the ocean with as little to no maintenance for at least 30 years to limit maintenance costs. In addition, the weight of the CWP should be as light as possible to minimize the floating platform size and buoyancy needs but must also be heavy enough to maintain stability.

1.2 Low Cost Cold Water Pipe

Using advanced composite materials and innovative fabrication tooling and methods, the LM team has developed a unique approach to simultaneously manufacture and deploy OTEC CWPs at lower cost than previous concepts. The approach uses pre-pultruded segments as sandwich core, molded between outer and inner layers of fatigue-resistant composite fiber with seawater-resistant vinyl ester resin forming an integrated structure.

Construction uses an innovative step-wise process whereby ~20m segments of CWP are infused with resin and cured, with the infused fabric continuous with the supply roll; the cured section is then lowered below the apparatus for the next segment to be fabricated contiguously. Thus, the operation represents simultaneous fabrication and deployment of the CWP with lower costs for both operations. Conversely, a steel CWP designed with telescoping segments constructed ashore and towed to the deployment site was estimated by the offshore construction firm Technip to cost ~ $100M. The LM CWP of the same internal diameter and length has been estimated using commercial material cost quotes to be ~ $35M, a savings of 65% for a CWP with superior life and less weight. The reduced overall system cost helps make Levelized Cost of Electricity (LCE) from OTEC plants competitive with other renewable energy systems.

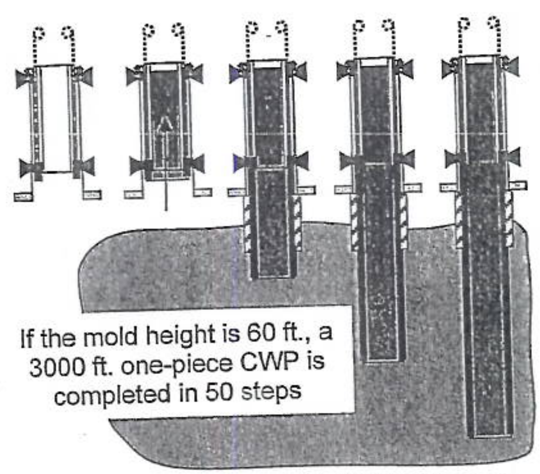

Figure 1-1. Artist Concept of LM's Unique Stepwise Molding Process

[1] ASME Paper by Dr. Gerard Nihous, **An Order-of-Magnitude Estimate of Ocean Thermal Energy Conversion Resources,** Vol. 127, December 2005, p 328 - 333

1.3 Project Objectives

The objectives of the Advanced Manufacture & Deployment of Composite OTEC Cold Water Pipe Project are to:

1. Validate the LM CWP design at prototype and Pilot Plant scales,
2. Validate the advanced tooling designs, construction methods, and associated projected cost savings, and
3. Validate the simultaneous construction and deployment concept for a 70m length of 4m diameter CWP into the marine environment.

1.4 Project Plan

Our plans for the Advanced Composite OTEC Cold Water Pipe Project are to construct the required tooling and fixtures needed for the innovative LM fabrication method. We use this tooling and associated fixtures to fabricate sections of CWP in the laboratory to ensure proper operation. The LM team then fabricates a full segment of CWP that is then lowered below the fabrication tooling on an assembly platform as if being lowered into the water at the OTEC construction site. The next contiguous section of CPW is then fabricated directly onto the preceding section in the planned step-wise fashion with complete fiber continuity. This operation repeats three more times and checks out the entire fabrication and deployment approach.

Upon completing the laboratory checkout of the tooling and processes, the fabrication tooling is disassembled and sent to West Virginia University where it is re-assembled for demonstration of the simultaneous construction and deployment operation at Summerville Lake, a location under management by the Army Corp of Engineers. CWP fabrication and deployment are demonstrated in a marine environment while gathering actual construction labor and material costs for use in projecting full-scale commercial plant costs.

The LM team then performs non destructive testing of test coupons and full diameter pipe segments to validate mechanical properties and ocean environment sustainability.

The LM team and their responsibilities are summarized in the following table:

Organization	Responsibility
LM, Maritime Systems & Sensors	Prime Contractor
LM Space Systems	Process, Tooling Design & Construction
Makai Ocean Engineering	Design Review & Comment
West Virginia Univ.	In-water
Glasforms, Inc.	Pultrusions

1.5 Benefits of Project Results

Significant benefits result from achieving the stated objectives to assist the LM team with OTEC commercialization while also supporting DOE's objectives as defined in the Advanced Water Power Projects FOA.

Successfully accomplishing the objectives demonstrates a major advancement toward commercializing OTEC systems by reducing the fabrication and deployment cost of very large diameter cold water pipes thereby enabling power from OTEC systems to be competitive with other renewable energy technologies. The data gathered during the marine demonstrations provides important cost information for large diameter composite OTEC cold water pipes for effective use in ocean systems applications.

1.6 Future Plans

The LM team believes that viable near-term business opportunities exist for OTEC plants providing electrical power to consumers ashore via marine power cables to the grid. Hawaii Electric Company has expressed interest in this concept and the Department of Defense has a need for power and potable water for island bases in the Pacific and elsewhere. At some future date, mid-ocean OTEC plants may well produce hydrogen or a synthetic sustainable liquid fuel substitute for petroleum for transportation and even stationary power plants, with no C02 emissions.

1.7 Conclusions

The LM team is eager to again work with DOE to advance OTEC technology. We have a sound technical approach, a qualified team, our cost match exceeds the minimum requirements, and our R&D investments leverage directly into the AWPP work.

2 MERIT REVIEW CRITERIA DISCUSSION

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2.1.2 Impacts on Levelized Cost of Electricity

There are major cost reductions as a direct result of the new CWP concept. For a 100 MW plant, there is a reduction in CWP cost from the $100 m that was assumed most recently (based on ONR SBIR OTEC plant designs using a steel CWP) to $35m for the one-piece stepwise fabricated fiberglass CWP, based on actual material and fabrication costs from the wind turbine blade industry. The $65m savings will have a substantial impact on the levelized cost of electricity produced by OTEC plants. LM calculations based on Dr. Luis Vega's presentation May 2007 show a projected levelized cost for electricity from a 100 MW net power OTEC plant to be 9.13 cents/kw-hr. The LM CWP helps make such a plant possible at the $800M cost projected by Dr. Vega.

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2.1.3 Impacts on Energy Generation Efficiency

Some OTEC CWP designs have been based on bundles of HDPE pipe. Since high-quality extruded HDPE is available only up to 2m in diameter, many individual small pipes are required for a 100MW or even a 10MW sized OTEC plant. For the same mass flow rate, the increased surface area causes higher frictional pumping losses compared to a single large CWP. For a 100 MW plant with a given flow cross-section, the decrease in plant efficiency is about 6%. Thus the new fiberglass CWP design has a beneficial impact estimated to be at the 6% level, compared to a bundle of HDPE tubes. While it is possible to use more HDPE tubes to gain a larger flow area to compensate for the greater wall area, substantial assembly and deployment challenges remain with this concept.

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2.1.6 Impacts on Commercialization

The reduction in capital cost (current estimate of savings is $65m on each CWP) should contribute considerably to making OTEC more cost competitive and will help lower the main barrier to commercialization, namely cost of the plant.

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2.2 Technical Approach and Project Research Plan

2.2.1 Plan to achieve FOA objectives

FOA objectives focus on (1) development, in-water testing, and deployment of advanced water power technologies, and (2) reductions in manufacturing and operational costs of advanced water power technologies. The proposed work addresses both categories. With respect to category 2, and as described in previous sections, the new in-situ fabricated and deployed fiberglass CWP saves $65m initial cost per 100MW plant, and the absence of joints eliminates what are often multiple expensive-to-maintain and risky maintenance items in conventional construction.

With respect to category 1, successful deployment of an OTEC CWP has always been a critical and sometimes unmet challenge in the history of OTEC demonstrations. Quite a number of would-be OTEC CWP's have been lost at sea during deployment. In all cases, these were externally-fabricated CWP's that had to undergo risky operations consisting of transport to location and rotation into position. The new CWP concept described in this proposal makes a major contribution to retiring the risk of OTEC CWP deployment, in as much as the CWP is fabricated directly from the platform already in the vertical position. Deployment will consist simply of removing the fabrication tooling and replacing it with the cold water pump intake manifold.

Our program plan (see timeline for details) includes on-water testing under Task 5 to validate that the new fabrication process can be performed successfully on the water.

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Benefits of the one-piece CWP with no joints

Another major risk factor which is retired by our CWP design is the total elimination of joints in the composite CWP, which enhances its long-term reliability greatly. Mechanical joints, with their inevitable need for bolts, fittings, seals, and other components, have an inherent degree of non-reliability associated with corrosion and other degradation mechanisms, especially over the required service life of 40 years in seawater. Having portions of the CWP at depths up to 3000 ft. makes inspection, maintenance, and repair of such components very expensive. In fiber composites, joints are even more of a challenge, because the anisotropic mechanical properties make transfer of load through mechanical joints difficult and generally increase the required size, weight, and cost of the component considerably as it is "beefed up" at joints to handle bearing and other stresses.

These considerations played a strong role in our decision to focus on a one-piece CWP without any joints, and should greatly reduce its in-service technical risk, cost risk, and maintenance expense compared to traditional multi-segment piping having mechanical joints.

Bonded joints (e.g. doublers over the face sheets) are often a solution in composites when permanent assembly of discrete components is required. However the required 40-year life in seawater with inaccessibility for repair makes even bonded joints risky. All loads must transfer through the adhesive, which does not contain any continuous fibers and therefore has mechanical properties far lower than the base composite. Any degradation of the joint adhesive during the service life in seawater could be disastrous.

In this first on-the-water demonstration, fabrication will take place at the US Army Corps of Engineers Summerville Lake facility under Task 5. The risk of ocean storms impeding this initial demonstration is zero. As the technology matures and available budget grows, experienced personnel from the offshore industry will be engaged for transition of the same process to ocean platforms.

2.2.4 Decision Points & Deliverables

Decision point at end of year one: Successful dry fabrication of CWP section

The proposed two-year program provides a very logical decision point at the end of the first year, by which we will have completed Task 4, checkout fabrication of a length of CWP on dry land, using four steps of the fabrication process for a total of about 30 ft. Successful completion of Task 4 (producing a CWP section having an overall configuration, fiber placement accuracy, and other features in accordance with expectations) provides the go/no-go decision point for year 2. Assuming that task 4 is successful, we then move the prototype tooling onto the on-water platform at Lake Summerville, and operate the same process during Task 5, ultimately fabricating about 200 ft. of CWP on the water.

Leading up to the key decision point at the end of year one is a series of other tasks and subtasks with a specific schedule and budget. Progress during the program will be monitored using the normal methods (progress reports, budget reports, etc.) providing an intermediate means of verifying that the program is on-schedule and on-budget, even prior to the key decision point at year one end. Details of these intermediate progress indicators are contained in Section 3.

Deliverables

Deliverables will include reports with all of the plans, fabrication and test results, and recommendations. Section 3.3 describes the tests to be run. These include non-destructive evaluation of the dry fabricated and on–the-water fabricated CWP. The "on-water-fabricated" CWP will measure about 200 ft. length and about 13 ft. in diameter. The CWP will be available for other purposes if the DoE so desires.

2.3 Qualifications and Resources

2.3.1 Team Member Credentials

Lockheed Martin

In 1979, a team of Lockheed and Makai Ocean Engineering successfully designed and built the Mini-OTEC system. To date it is still the only successful floating OTEC system. Based on this record of success and experience, Lockheed Martin and Makai have reconstituted the team to assess the commercial potential for OTEC. Technology has advanced in the many of the areas needed to make OTEC more affordable. One of those areas is composite materials. Lockheed Martin Maritime Systems and Sensors (MS2) has teamed up with our Space Systems division in Palto Alto and Sunnyvale, CA which is a leader in composite material development for both commercial and military applications.

Makai Ocean Engineering

Makai is recognized as an expert on CWP and has been committed to the research and development of ocean-based renewable energy sources since the 1970's. Makai has applied theoretical research to real life projects in the areas of sea water air conditioning (SWAC) and ocean thermal energy conversion (OTEC). Makai designed the CWP and mooring for the original Mini OTEC.

West Virginia University

The Constructed Facilities Center (CFC) at West Virginia University is a unique research and development center. The CFC's ability to adapt rapidly to changing research needs, allows emerging technologies to create new products such as fiber composite materials, diagnostic tools, design procedures, and structural components. Summersville Lake is located near the CFC and has a spot near the dam where an extended portion of the CWP can be fabricated and deployed.

Glasforms, Inc

Glasforms, Inc is one of the world's most respected manufacturers of fiber reinforced polymers (FRP) and advanced composite products. Glasforms designs, formulates and produces carbon fiber and fiberglass reinforced composites utilizing continuous molding processes. Glasforms has a large base of experience, facilities, and expertise producing hollow-core pultrusions of the type and fiber orientations to be utilized in this program.

Key Individuals

Principal Investigator – Alan Miller, Ph.D from Lockheed Martin Space Systems is the Principal Investigator. He has expertise in processing and manufacturing of fiber composites, predicting and optimizing CTE and other properties of composites from a knowledge of their constituents, VARTM (Vacuum-Assisted Resin Transfer Molding) of composites, moisture absorption/desorption in composites, honeycomb-core and foam-core sandwich structures, "spring-in" of anisotropic composites and sandwiches, and compliant adhesives for structures containing materials with dissimilar coefficients of thermal expansion. He led the LM OTEC CWP Trade Study providing the basis for the CWP approach described herein.

Steve Bailey from Lockheed Martin MS2 has over 25 years of aerospace and marine experience in mechanical design, test and systems engineering disciplines. Currently, he is the Engineering lead for the platform subsystem of conceptual Ocean Thermal Energy Conversion (OTEC) design. Developments for the platform involve novel arrangements of OTEC energy producing equipment within tension leg and semisubmersible platform arrangements.

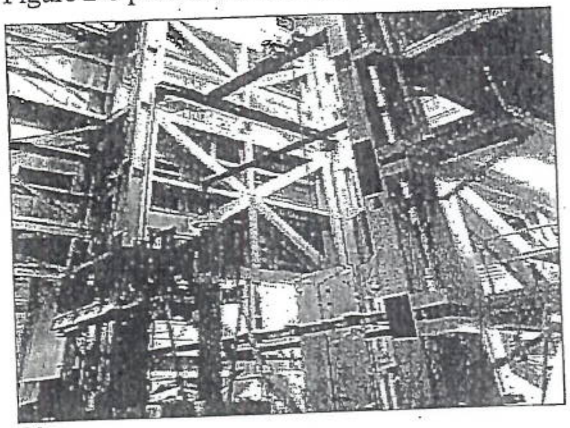
Joe Van Ryzin, Ph.D., P.E., from Makai Ocean Engineering was a principal member of the Mini-OTEC design team responsible for its Cold Water Pipe (CWP) design and deployment. Dr. Van Ryzin was also Principal Investigator on a recent Office of Naval Research sponsored OTEC SBIR study.

Professor Hota Gangarao is the director of the CFC and a world recognized technical expert in composites for large industrial and infrastructure applications.

2.3.2 Availability of Required Equipment

Lockheed Martin Space Systems High Bay Test Facility

The High Bay Test stands facility in Building 156G in Sunnyvale is fully equipped and available to handle the fabrication of large composite structures. The High Bay facility will be used to do the initial fabrication and testing on dry land. Figure 2-6 provides a description of the facility.



Size:
18 ft. wide x 18 ft. deep x 80 ft high
Six work levels with removable work platforms.
Reaction Capacity:
3 x 106 lbs
axial – 1 x 106 lbs. lateral
Crane:
15 ton capacity
74 ft. hook height from outside building into test stand.
Stand Access:
Dock unload area and
85 ft. high roll-up door.
Test Head:
Steel plate with machined flatness and finish.

Figure 2-6. LM Space Systems High Bay at Sunnyvale

Summersville Lake

Summersville Lake is a man-made lake constrùcted by the Army Corp Engineers. Near the dam the lake is 300 feet deep. The lake also provides excellent visibility (25 ft at 40 ft depth) for good in water working conditions. This provides a convenient and excellent location near the CFC for fabricating and testing the CWP in a marine environment. The Army of Corp of Engineers has already given permission to the CFC for the CWP research and development work. Figure 2-7 shows Summersville Lake. The test site for the CWP on water fabrication will be located just in front of the dam. The dam is located in the middle of the picture.

Figure 2-7. Summersville Lake in West Virginia

2.3.3 Private Industry Level of Involvement

Lockheed Martin has put together a strong team of experts to address the challenges of the CWP. The team is made up of large business, small business and academia. Lockheed Martin over the past 2 years has invested internal R&D funds to advance the technology for OTEC. This investment is being leveraged as the starting point for this demonstration. In addition, our cost share for this demonstration exceeds the minimum required. The cost share will be a combination of Research & Development and Capital funds. Capital is being used since the resulting tooling is expected to be used for a future pilot plant development. Lockheed Martin is committed to determining the feasibility and cost effectiveness of advanced composite materials and fabrication method for the CWP.

2.3.4 Team Member's Commitment and Participation

Lockheed Martin Role

Lockheed Martin is functioning as the lead of the project and will be solely responsible for the cost share.

Lockheed Martin Maritime Systems & Sensors

The Maritime Systems and Sensors (MS2) division will be the lead LM organization. As such, MS2 will be responsible for overall program management and oversight. In addition, the cost share will be supplied and managed by the MS2. MS2 will also have a lead role in the test program for the CWP.

Lockheed Martin Space Systems

Lockheed Martin Space Systems (Space) will supply the principal investigator for the task and he is fully dedicated to this task. Dr. Miller will leverage LM's significant expertise in innovative, low cost fabrication methods for large composite material tooling and structures. As PI, Dr. Miller will direct the CWP fabrication plans, procedures, tooling development and land checkout of the CWP manufacturing process in the High Bay facility, as well as provide general direction for the remaining tasks.

Makai Ocean Engineering Role

Makai Ocean Engineering is a recognized expert in the industry for the design of cold water pipes for both OTEC and Sea Water A/C applications. Makai will be providing subject matter expertise in the design reviews of the construction, manufacture, and test of the CWP.

West Virginia University Role

The Constructed Facilities Center (CFC) at West Virginia University (WVU) will be responsible for the in water fabrication program of the CWP. WVU will be providing the facilities and personnel to perform the fabrication at Summersville Lake. WVU is to design and perform the following tests:

- Non-destructive forced vibration and vortex-induced vibration tests of prototype CWP
- Non-destructive fatigue validation of entire CWP section.

In addition, WVU has already worked with the Army Corps of Engineers to provide access to Summersville Lake, where testing and verification of at-sea fabrication process will take place, demonstrating their early commitment to the program.

Glasforms, Inc Role

Glasforms will bring its years of experience in composite construction to design and prove techniques required for this project. This opportunity will continue to build Glasforms' repertoire in the composites industry, especially in large-form hollow composites.

2.4 Commercialization Plan

2.4.1 Planned In-Water Demonstration

The key feature of our proposal is a demonstration of our innovative manufacturing process to construct on-site a large cold water pipe. Our partner, West Virginia University (WVU) and their Constructed Facilities Center, will support this effort for a demonstration on Summersville Lake near the WVU campus. Summersville Lake is under the control of the Army Corp of Engineers (Corp). Based on prior collaborations with the Corp and because minimal environmental issues exist with CWP fabrication (we will not be moving water), WVU will obtain the necessary Corp approval for lake use.

2.4.2 Scale-up Plan for Commercialization

Our legacy Lockheed Missiles & Space Company, Sunnyvale, CA, conducted design studies for an OTEC plant in the mid 1970's for the National Science Foundation. Following that study, Lockheed partnered with Makai Ocean Engineering and others, to compose a hardware demonstration of net power production on a floating barge titled Mini-OTEC, generating electricity at the modest level of 50 KW gross, 10 KW net.

In 2007, LM MS2, Undersea Systems, restarted tasks to assess commercial potential for OTEC and reconstitute the earlier OTEC team with Makai. We began OTEC investigations, identifying specific business opportunities, and initiated independent research & development (IR&D) activities focused on a technical and cost solution. As of 2008, we have determined a significant OTEC market exists and we continue our IR&D efforts to develop technical and cost information.

Our commercialization plan can be summarized into four parallel efforts as shown in Figure 2-8.

OTEC has only been demonstrated at the kilowatt scale. Financing for utility scale OTEC plants requires understanding of technical and cost risks at the requisite commercial scales. Cost risks include the ability to identify the capital construction costs and estimate operation & maintenance (O&M) costs over the life of long term, fixed price power purchase agreements. We therefore believe a pilot plant with a generation capacity on the order of 10 MW must be built and deployed to validate capital costs and provide necessary O&M data.

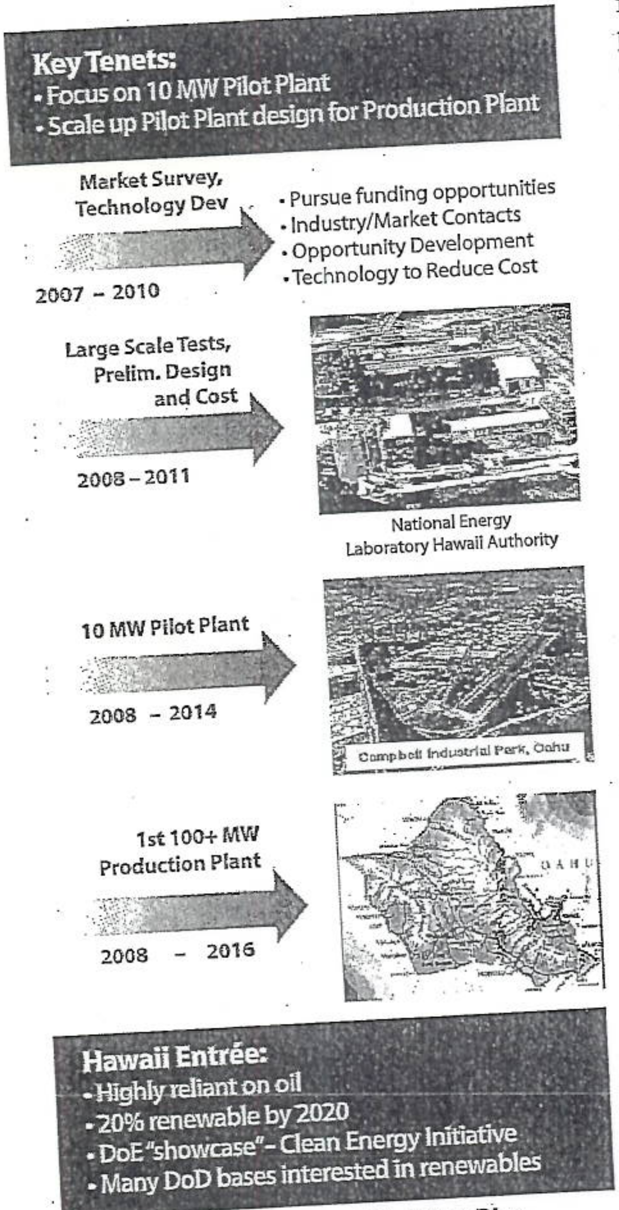


Figure 2-8. LM Commercialization Plan

Our market survey clearly shows multiple and significant OTEC opportunities exist for applications providing both electricity generation and water production cabled/piped to locations where thermal resources are close to shore. Future grazing OTEC plants can be sited farther out to sea to produce energy carriers such as hydrogen and ammonia that can be shipped to US ports. We also believe OTEC can provide the energy resource for synthetic fuel generation to provide transportation fuels for those applications, i.e. military, that require the higher energy content fuels. Our technology development effort shows potential for new approaches that can reduce the capital cost for OTEC plants. One such topic has resulted in this proposal to demonstrate our CWP approach.

We are therefore developing our preliminary pilot plant design package with our team members. We have knowledge of other companies with OTEC designs, but believe most, if not all, are not of sufficient technical maturity to address the cost risks. Key to a successful pilot plant design is large scale subsystem tests of which this CWP proposal is one of several critical tests. Successful demonstration of our ability to construct low cost CWPs for a pilot plant retires technical risk and provides data for cost estimates.

Tests and designs of these scale subsystems leads directly to construction and deployment of a pilot plant. Successful pilot plant deployment leads directly to the ability to replicate the design for markets needing small MW capacities and to the ability to scale up to utility MW capacities. Based on discussions we have had directly with the Hawaiian Electric Company and with Florida Power & Light, commercialization of OTEC generated electricity is of interest and has a market.

2.4.3 Plan to Disseminate Results

The results of this effort will be presented at future EnergyOcean conventions. It is anticipated that an interim first year status report will be provided in the June 2009 time frame. Completion of first year efforts and, if funded, the status of 2nd year efforts will be presented at EnergyOcean 2010 followed by final results presented in 2011.

2.4.4 Likelihood of Commercialization by 2015

The prototype tooling fabricated under this program is being designed to become the production tooling for 10 MW Pilot Plant and larger follow-on plants. This will assist commercialization in terms of retiring risk, reducing tooling costs, and establishing credible fabrication labor cost and time estimates for OTEC plant proposals.

Discussions have already been held with interested customers for OTEC Pilot Plants, and successful completion of this prototyping program will help them (and investors) decide to move forward with construction of Pilot and Full-scale plants. Depending on funding and financing, our plan is to complete pilot plant contract design, build and deploy the pilot plant by 2014. We further plan to scale up to utility scale and get hardware into the water by 2016.

2.4.5 Technology Penetration at Full Commercialization

OTEC can provide baseload, environmentally benign electricity generation to Hawaii, Puerto Rico, multiple DOD bases, Florida, potentially other Gulf coast states, and many international locations. Recent investigations by the Hawaii Natural Energy Institute, University of Hawaii, suggest the lower global bound for environmentally benign extraction of OTEC energy is at least 3 terawatts (TW). Such a resource approaches or exceeds the current consumption of the US and at full commercialization, is a significant market. Our estimates of ultimate cost per kilowatt-hour will be made as our pilot plant design matures this fall and into next year.

3 PROJECT TIMETABLE

3.1 Programmatic Tasks and Milestones

In laying out the schedule (Figure 3–1) for design of the Cold Water Pipe the team has elected to divide tasks into two years by a Go/No Go Milestone. The Go/No Go decision will evaluate work completed to date and design evaluations to ensure that construction and testing after that point is both viable and productive.

Throughout the schedule the LM team has included two efforts for Project Management that include *Overall Technical Oversight* that will ensure continuity and coordination of technical tasks as well as *Technical Schedule and Cost Monitoring* to ensure that programmatic schedule and cost targets are maintained. In addition to these two ongoing tasks Progress Briefings are scheduled quarterly to ensure that the entire team maintains on task with aligned objectives, and the DOE customer is kept informed.

3.2 Year 1 Activity Summary

Task 2 – During the first year, we further refine and develop the CWP Fabrication Plans, Procedures & Tooling (Task 2.1), starting with the point of departure described herein. This work is done primarily by the PI, consulting with the rest of the team. Then the actual prototype tooling is designed and drawn in Sunnyvale (2.2) using Pro-Engineer, which allows for electronic transmittal to LM Manassas for collaboration. The tooling is fabricated in the Materials and Processes Engineering Development Lab in Sunnyvale (2.3) and checked out by a small run in that same facility (putting the tooling up on a safe 8' high equipment platform which is available from a past program).

Task 3 – At the same time, we place the subcontract under which Glasforms designs, fabricates, and proves out the pultrusion setup for the prototype size hollow core segments and supplies pultrusions for Task 4.

Task 4 – This is the capstone work for the first year: We move the prototype tooling to a manufacturing platform providing sufficient "runout" space underneath it for fabrication of a 30' long section of prototype CWP. This platform is in Sunnyvale in one of two B156G test stands, which actually are capable of much more than 30' if desired. (An alternative consisting of using a surplus tall building at W. Va. U. was investigated and priced but is not competitive.) We integrate the prototype tooling onto the platform (4.2). In parallel (4.3), we order all of the other materials necessary for the fabrication, including WindStrand fiberglass as stitched fabric from Owens Corning, 8084 vinyl ester resin from Ashland, promoters and other chemicals for controlled cure of the resin, and other needed materials. Then we perform the dry fabrication trials (4.4) allowing any necessary improvements to be discovered and incorporated, followed by the actual demonstration fabrication (4.5). During the trials and the demo, we (4.6) collect labor time data which we expect will be of great value later in credibly estimating the cost of future CWP's. During this demo, the crew that conducts the on-water demo during the second year participates in training (4.7) for their subsequent duties.

3.3 Go / No Go Criteria

Successful dry fabrication of the prototype CWP is the go/no-go milestone and criterion for continuation into year 2.

3.4 Year 2 Activity Summary

Task 5 – West Va. Univ. makes arrangements (5.1) with the Army Corps of Engineers to use their Lake Summerville nearby, and an appropriate number of barges to make up a suitable and safe Marine Construction Platform. The marine platform is outfitted with the prototype tooling and support equipment (5.2, 5.3). At the same time (5.4), we place the subcontract under which Glasforms supplies the pultruded core for Task 5. Then we operate the prototype tooling at dockside (5.5), conduct CWP Fabrication Trials At Sea (5.6), and perform the capstone second-year activity, namely on-water (into-the-water) fabrication of 200' of CWP. Again, labor time data is collected for future estimates of on-water CWP fabrication for OTEC plants.

Task 6 – Also during year 2, we evaluate the CWP demo pieces and coupons cut from them. Non-destructive evaluation (6.1) includes NDT inspection by ultrasonic and X-ray.

3.5 Plans Beyond Year 2

Additional testing can be performed after year 2 to determine other mechanical, performance and corrosion characteristics. Successful on-water fabrication of the CWP during year 2, along with establishing a credible cost estimate based on the actual measured labor times and number of workers, is expected to fully retire any technical and cost risks associated with the CWP for the Pilot Plant. One or more successful 10 MW plant CWP's will in turn do the same with respect to full 100 MW plants, which will then enable the utilities or investors to fund and construct them. LM expects to stay fully involved in these technical, business, and environmental mitigation opportunities.

We truly hope that the DOE AWP program concurs with this view and supports our work towards these goals.

3.6 Project Schedule

WBS	Task Name
1	⊟ **Program Management**
1.1	Overall technical direction
1.2	Technical, Cost, Schedule Monitoring
1.3	⊞ **LM Mgt & DOE Progress Briefings**
1.4	Deliverable Documentation Preparation and Submission
2	⊟ **CWP Fabrication Plans, Procedures & Tooling**
2.1	Develop Fab Plans & Procedures
2.2	Design Tooling and Fixtures
2.3	Tooling & Fixtures Fab, Assy and Checkout
3	⊟ **Pultruded Core**
3.1	Pultrusion Setup
3.2	Supply Prototype size pultruded core for Task 4
3.3	Supply Prototype size pultruded core for Task 5
4	⊟ **Land Checkout and Test of CWP Manufacturing Process**
4.1	Find or Construct Manufacturing Platform
4.2	Integrate Fixtures & Tooling onto Platform
4.3	Procure & Stage Composite Mtls & Core Segments
4.4	Perform Fabrication Trials
4.5	Fabrication Demonstration
4.6	Collect labor time data suitable for estimating costs of full-scale CWP
4.7	Training for at-sea demonstration
5	⊟ **At-sea Demonstration of CWP**
5.1	Obtain Suitable Marine Construction Platform (MCP)
5.2	Outfit MCP with Fixtures & Tooling
5.3	Outift MCP with Support Equipment, Tools, and Spares
5.4	Stage CWP Materials on MCP
5.5	Conduct Dockside CWP Fabrication Trials At Sea
5.6	Perform CWP Fabrication Trials At Sea
5.7	Perform CWP Fabrication At Sea for Record
5.8	Collect labor time data suitable for estimating costs of full-scale CWP
6	⊟ **CWP Test, Evaluation, and Comparison of At-Sea vs. On-Land results**
6.1	Non-destructive evaluation of fabricated CWP demo pieces

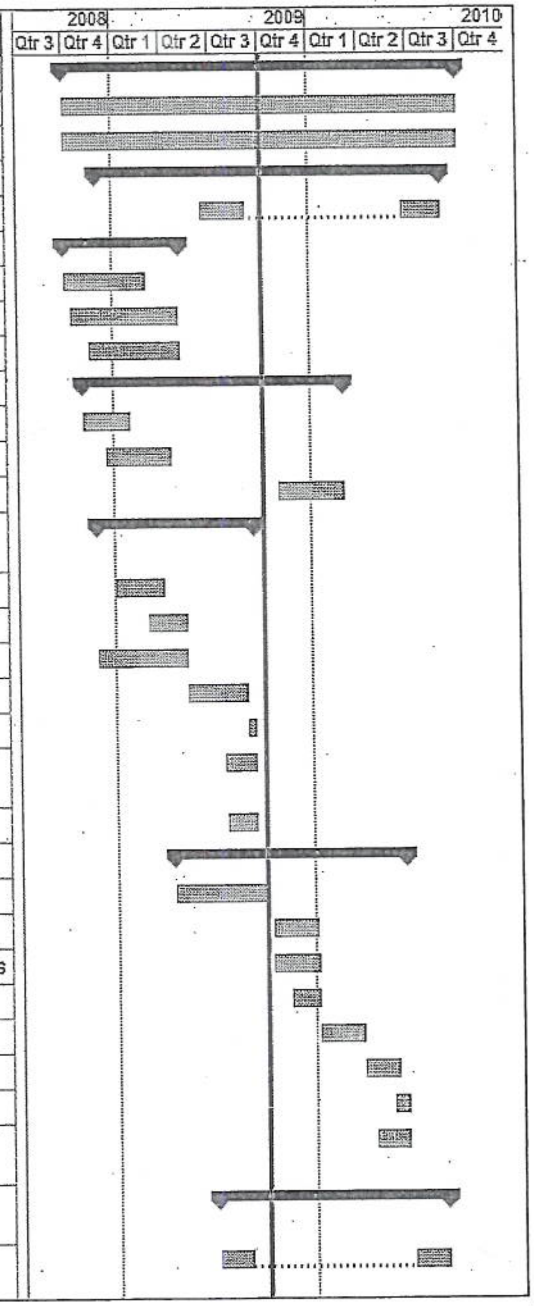


Figure 3-1. Advanced Composite OTEC Cold Water Pipe Project Schedule

Applicant Name: Lockheed Martin MS2

Award Number: ____________

Budget Information - Non Construction Programs

Section A - Budget Summary

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds: Federal (c)	Estimated Unobligated Funds: Non-Federal (d)	New or Revised Budget: Federal (1st Yr) (e)	New or Revised Budget: Non-Federal LM Cost Share (1st Yr) (f)
1. Cold Water Pipe				601,537	1,392,709
2.					
3.					
4.					
5. Totals		$0	$0	$601,537	$1,392,709

Section B - Budget Categories

6. Object Class Categories	Grant Program, Function or Activity: Cold Water Pipe	(2)	(3)	(4)
a. Personnel				
b. Fringe Benefits				
c. Travel				
d. Equipment	REDACTED EXEMPTION4			
e. Supplies				
f. Contractual (Intra company Work Agreements, Subcontr				
g. Construction				
h. Other				
i. Total Direct Charges (sum of 6a-6h)		$0	$0	$0
j. Indirect Charges				
k. **Totals** (sum of 6i-6j)		$0	$0	$0
7. Program Income				

Pre

Previous Edition Usable

Section C - Non-Federal Resources			
(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources
8. Cold Water Pipe - LM Cost Share	1,392,709		
9.			
10.			
11.			
12. **Total** (sum of lines 8 - 11)	$1,392,709	$0	$0

Section D - Forecasted Cash Needs	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter
13. Federal	$601,537	41,851	171,160	46,666
14. Non-Federal (LM Cost Share)	$1,392,709	160,643	500,379	311,636
15. **Total** (sum of lines 13 and 14)	$1,994,247	$202,493	$671,539	$358,303

Section E - Budget Estimates of Federal Funds Needed for Balance of the Project	Future Funding Periods (Years)		
(a) Grant Program	(b) First additional Year	(c) Second	(d) Third
16. Cold Water Pipe - 2nd Year	594,221		
17.			
18.			
19.			
20. **Total** (sum of lines 16-19)	$594,221	$0	$0

Section F - Other Budget Information

21. Direct Charges

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

As a for-profit organization, MS2 is governed by the Federal Regulation Acquisition (FAR) part 31 as stated in the FOA and 10 CFR 600.31 31 does not include costs of efforts sponsored by a grant, MS2 must condition our submittal on an award that would allow MS2 to use its IR performing work on the project and recommends a single case deviation to 10 CFR 600.317 as may be allowed under 10CFR 600.4 or the av Transaction Agreement or Technology Investment Agreement (TIA) for this project.

Instructions for the SF-424A

Public Reporting Burden for this collection of information is estimated to average 3.0 hours per response, including the time for reviewing instructions, searching existing data source maintaining the data needed, and completing and reviewing the collection of information. Please do not return your completed form to the Office of Management and Budget; send i provided by the sponsoring agency.

General Instructions
This form is designed so that application can be made for funds from one or more grant programs. In preparing the budget, adhere to any existing Federal grantor agency guidelines which prescribe how and whether budgeted amounts should be separately shown for different functions or activities within the program. For some programs, grantor agencies may require budgets to be separately shown by function or activity. For other programs, grantor agencies may require a breakdown by function or activity. Sections A, B, C, and D should include budget estimates for the whole project except when applying for assistance which requires Federal authorization in annual or other funding period increments. In the later case, Sections A, B, C, and D should provide the budget for the first budget period (usually a year) and Section E should present the need for Federal assistance in the subsequent budget periods. All applications should contain a breakdown by the object class categories shown in Lines a-k of Section B.

Section A. Budget Summary Lines 1-4 Columns (a) and (b)
For applications pertaining to a **single** Federal grant program (Federal Domestic Assistance Catalog number) and **not requiring** a functional or activity breakdown, enter on Line 1 under Column (a) the catalog program title and the catalog number in Column (b).

For applications pertaining to a **single** program **requiring** budget amounts by multiple functions or activities, enter the name of each activity or function on each line in Column (a), and enter the catalog number in Column (b). For applications pertaining to multiple programs where none of the programs require a breakdown by function or activity, enter the catalog program title on each line in **Column** (a) and the respective catalog number on each line in Column (b).
For applications pertaining to **multiple** programs where one or more programs **require** a breakdown by function or activity, prepare a separate sheet for each program requiring the breakdown. Additional sheets should be used when one form does not provide adequate space for all breakdown of data required. However, when more than one sheet is used, the first page should provide the summary totals by programs.

For continuing grant program applications, submit these forms b each funding period as required by the grantor agency. Enter in Colu estimated amounts of funds which will remain unobligated at the enc period only if the Federal grantor agency instructions provide for this these columns blank. Enter in columns (e) and (f) the amounts of fu upcoming period. The amount(s) in Column (g) should be the sum o Columns (e) and (f).

For supplemental grants and changes to existing grants, do not u and (d). Enter in Column (e) the amount of the increase or decrease and enter in Column (f) the amount of the increase or decrease of n Column (g) enter the new total budgeted amount (Federal and non-F includes the total previous authorized budgeted amounts plus or mir the amounts shown in Columns (e) and (f). The amount(s) in Colum equal the sum of amounts in Columns (e) and (f).

Line 5—Show the totals for all columns used.

Section B. Budget Categories
In the column headings (a) through (4), enter the titles of the same p functions, and activities shown on Lines 1-4, Column (a), Section A. additional sheets are prepared for Section A, provide similar column sheet. For each program, function or activity, fill in the total requirem Federal and non-Federal) by object class categories.

Lines 6a-i—Show the totals of Lines 6a to 6h in each column.

Line 6j—Show the amount of indirect cost.

Line 6k—Enter the total of amounts on Lines 6i and 6j. For all applic grants and continuation grants the total amount in column (5), Line 6 same as the total amount shown in Section A, Column (g), Line 5. F