WHITE PAPER ADVOCATING A NIST ADVANCED TECHNOLOGY PROGRAM FOCUSED ON THE DEVELOPMENT OF ADVANCED COMPOSITES TECHNOLOGY TO ENABLE ECONOMICAL DEVELOPMENT OF ULTRA DEEPWATER GULF OF MEXICO PETROLEUM RESOURCES

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EXECUTIVE SUMMARY

The discovery of large reserves of oil in deepwater Gulf of Mexico (GOM) combined with wells which produce at rates in excess of 10,000 barrels per day has created high interest in the oil industry to develop this valuable United States resource. In response, the Minerals Management Service has opened large blocks of the GOM for leasing including blocks in water depths up to 13,000 feet and the bidding response by both U.S. and foreign oil companies has been very aggressive. Deepwater development poses many new technical and economic challenges, and the oil and oil service industry is aggressively responding to meet these challenges. Although the oil industry is a complex, high-tech industry, it essentially produces a commodity product where the price is controlled by the law of supply and demand. In the first half of 1998, over supply has caused oil prices to be lower than have been typical of recent years. If low oil prices continue, they can be expected to impose a restraining effect on the rate of development of deepwater resources. On the other hand, industry experts indicate the worldwide demand for oil will grow at 2% to 2.5% annually[1] and a strong case can be made that the world is rapidly approaching the point of consuming half the original resource of oil and a supply side deficit is likely to emerge within the next ten years.[2,3]

In spite of price uncertainties, the U.S. oil industry continues to develop deepwater resources with the expectation of improving markets. For the United States, deepwater GOM is the only large new source for petroleum currently available. The United States currently imports approximately 56 percent of the oil consumed internally. Without GOM deepwater development, United States oil production will continue to decline making dependence on imported oil even larger. In the interest of economic and national security, the U.S. government is expected to continue to encourage new oil and gas development to prevent dependence on imported oil from going even higher. The Department of Energy recently published a document called *Comprehensive National Energy Strategy*[4] in which Secretary of Energy Federico F. Pena made the following statement, "Our national security depends on affordable and abundant supply of energy. Under every conceivable scenario projected by energy analysis, natural gas and oil will remain a central part of our Nation's energy future. As the world demand for oil grows, the United States does not want to rely on any particular region of the world for imported oil. Moreover, our own dependence on imported oil is expected to grow from 50 percent today to 60 percent by 2010." [4] One of the five goals of the Department of Energy is to "ensure against energy disruptions by reducing the threat of supply interruption and

increasing the security and reliability of our energy infrastructure".[4] One of the DOE strategies to achieve this goal is to stop the decline in domestic oil production by the year 2005. Development of Gulf of Mexico deepwater resources clearly will have a significant role in achievement of this goal.

The technology needed to safely and economically develop deepwater petroleum bearing reservoirs is extremely complex and will require advancements in several different disciplines. Technology is playing a vital role in reducing the cost of finding and producing oil and gas. Important advancements have been made in seismic technology, directional drilling, multiple completions, subsea systems, and production techniques. Composite materials is another technology which could provide important enabling solutions for safe, affordable deepwater development. Floating platforms are the only practical configurations for deepwater and are commonly used in combination with subsea wells. Floating platforms are tied to the ocean floor by moorings or tethers, or for drilling can be dynamically positioned using thrusters. Saving weight is an important design consideration for floating platforms with more cost benefit for some configurations such as Tension Leg Platforms (TLPs) than others and corrosion prevention is also important. Successful introduction of secondary composites on recent GOM TLPs and NIST ATP research programs have positioned the oil industry to be receptive to composite components. Low-cost manufacturing methods and utilization of hybrid materials to minimize cost are two examples of ways composites manufacturers are addressing the cost issue.

The ATP program initiated by NIST in 1995, which focused on composite manufacturing for the oil industry, provided significant stimulus to get composites acceptability within the broader petroleum industry. Products such as composite production risers, drilling risers, and spoolable pipe are being considered in project planning exercises. A significant amount of scientific technology has also been developed under these programs such as complex metal to composite joints, hybrid material design methods, and composite structure reliability analytical methods.

The oil industry is currently developing the deepwater solutions which will be implemented in the 1st decade of the 21st century. Many issues are multi-disciplinary in which a solution for one problem affects the design of many related components. Weight savings fall into this category and if composites are not considered in the early planning stage, the benefits will not be captured and the industry will become entrenched in an alternative inefficient solution. Advanced composites technology needs to be developed now and be ready for application during the introductory window of opportunity which for ultra deepwater GOM will be during the next five years.

NIST sponsored a meeting on January 29, 1998 to assess the oil and civil infrastructure industry needs and their interest for another ATP focus program on composites. A summary of the breakout session discussion of composite applications for the oil industry is presented in Appendix A. Projects were prioritized with regard to the four criteria established by NIST.

1. Potential U.S. Economic Benefit
2. Good Technical Merit
3. Strong Industry Commitment
4. Opportunity for ATP to Make A Difference

A list of the potential candidate projects related to composites for the oil industry which might be appropriate topics for an Advanced Technology Program is presented below. The priority of a fit with ATP criteria was ascribed a value of 1-5 with 1 - low and 5 - high.

Potential Candidate Projects for NIST ATP Co-Sponsorship

1.	Tubular Tendons for Floating Production Systems	5
2.	Other Mooring Systems	5
3.	Choke and Kill Lines, 4.5", 7500 - 15,000 psi	5
4.	Continuous Tubulars, D>4", Pressure > 4,000 psi	4
5.	Thermoplastic, Spoolable, Continuous Tubulars	4
6.	Deck Structure for Floating Production Systems. Spacer beams, Main Girders, Fabricated Shapes, Attachment Methods	3-4
7.	Analytical Methods for Qualification of Alternative Designs	3
8.	Drilling Derricks & Flare Booms	3
9.	Fiber Over-Wrapped Steel Pipelines	3
10.	Real Time, Performance Monitoring Sensors and Inspection Tools	2
11.	NDE Methods for Qualification of Products (Incorporate into 1 & 3)	2
12.	Composite Pressure Vessels	2
13.	Down Hole Tubulars	2

The January 29 meeting served as background for the current report which provides additional information on these and other applications which could be productive topics for development under NIST ATP joint venture programs. A condensed version of this report was submitted to NIST as a White Paper advocating a new Advanced Technology Program focused on composites for the oil industry[5]. In preparing this document, representatives of the oil, oil service, and composites manufacturing industries were consulted and the report reflects their input. Many of the proposed applications are highly-loaded primary structure with high performance reliability requirements. The user (oil / oil service companies) and composites manufacturer all assume risk in adopting composite materials solutions. The oil company's primary risk is associated with reliability and the expense associated with failure including delays in production should components not meet expectations. The engineering service companies are not experienced in designing or servicing composite components and are skeptical of unknown risks and foresee additional costs in preparing to efficiently design and install composite products. The manufacturer's risks involve being able to precisely understand the requirements and then being able to design and manufacture successful products at a profit. All these risks are formidable barriers to developing composite products, especially without external stimulus such as the NIST ATP program. It was therefore recommended to NIST, that a new ATP program be initiated which would focus on addressing the needs of the oil industry for composite structure solutions for ultra deepwater development.

The benefit to the United States of a new focus program on composites for ultra deepwater petroleum development would be:

1. Provide the technology assistance needed to help make successful the GOM thrust into ultra deepwater.
2. Help increase the domestic production of oil and gas.
3. Improve the international trade balance of payments.
4. Create new U.S. based jobs in oil service and composites manufacturing.
5. Develop composite products for overseas markets.

Such a program is consistent with the November 1997 recommendations of a panel of energy experts appointed by President Clinton which strongly urged the administration to increase funding for energy research by $1 billion over the next five years. The benefit of the program to the petroleum and composites industry will be to provide the stimulus to overcome current technology barriers and reduce economic risks, thus allowing highly-loaded primary structure components to be developed in time to be deployed on the next generation of platforms in ultra deepwater in the GOM and exported to deepwater development in the rest of the world.

INTRODUCTION:

Approximately 65% of United States energy needs are supplied by petroleum. Domestic oil and gas production, however, is declining and in 1998 the United States will import approximately 4 billion barrels of oil accounting for 56% of consumption and add approximately $63 billion annually to the international trade deficit. In 1972, just prior to the oil embargo, the United States imported 1.7 billion barrels of oil, which was only 29% of total consumption. One promising new source for petroleum in the United States is from reservoirs located beneath deepwater in the Gulf of Mexico (GOM). It will be a significant challenge to produce petroleum from reservoirs located beneath ultra-deepwater (up to13,000 feet of water depth). Lightweight, corrosion-resistant composite materials could provide an important contribution to the safe, economical development of deepwater petroleum resources. In addition, if composite products are developed by U.S. manufacturers rather than overseas, they could be deployed in deepwater basins in other parts of the world to provide a valuable market for U.S. products. The export of composite products for the oil industry will help make U.S. oil and service companies more competitive in international exploration and production services and have a significant positive impact on the U.S. balance of payments.

In January 1994, representatives of the petroleum industry submitted a white paper[5] to the National Institute of Standards and Technology (NIST) advocating a program to encourage development of composites technology directed toward petroleum industry applications. Based on the needs and opportunities identified, NIST established a focused program on manufacturing composite structures for the oil industry and six programs addressing oil exploration and production applications were initiated in 1995 (see Table 1). These programs will finish their third year of development in 1998 and several programs have made sufficient progress to move toward commercialization. The technology developed is also being used to develop alternative oil application products based on current market demands. NIST support helped create a critical mass of interested parties involving all the stake holders, the end users (oil companies), technology developers (industry and universities), and potential suppliers (materials and manufacturers). These interdisciplinary teams worked together to define the functional requirements, resolve critical technology barriers, conduct validation tests and establish specifications in preparation for the introduction of new products into service. Without NIST support, the oil industry would be much less prepared to accept and apply composite materials.

The Composites Engineering and Applications Center for Petroleum Exploration and Production (CEAC) in October 1997 sponsored an international conference focused on composites for petroleum applications.[6] The conference highlighted progress that had been made in composite applications since a similar International Conference held in October 1994. One of the highlights of the meeting was a presentation by the Mars

Tension Leg Platform (TLP) project manager in which he gave strong endorsement for the numerous secondary composite applications being used on the current class of deepwater TLPs. The Mars TLP was installed in 1996 in 2940 ft. of water. Composite applications include large quantities of low pressure pipe used to transport seawater including fire protection water, as well as secondary structures such as gratings, hand rails, and ladders. Also highlighted in the Conference were research efforts on more advanced composite applications such as drilling and production risers and small diameter spoolable pipe currently under development. These advanced applications are expected to make significant economic and enabling contributions as the oil industry moves into ultra deepwater. More advanced composite applications such as deck structures, synthetic fiber moorings, large-diameter long-length pipe, thick-walled tubulars for ultra high pressure service, extended reach smart drill pipe, corrosion resistant process vessels, and TLP tendons could also contribute to the development of ultra deepwater, but these applications will require significantly more research and development activity to develop the high level of reliability required for highly loaded, safety critical applications.

Several factors have converged in the last few years to make composite materials attractive solutions for primary structural applications on offshore platforms. First, large reserves of oil and gas have been discovered beneath deepwater basins in the GOM and in other parts of the world. World wide, deepwater is estimated to contain over 150 billion barrels of oil of which approximately 18.5 billion barrels are estimated to be located in deepwater GOM[7]. Saving weight on deepwater platforms and the supporting infrastructure could provide significant cost savings and enabling advantages in deepwater developments. Second, the success achieved in applying secondary composites in the last four years in the new generation of deepwater platforms has demonstrated the advantages of composites and opened the door for more challenging applications. For example, high performance components such as high-pressure accumulator vessels used to support riser tensioners were introduced into service on the Mars TLP platform. Successful performance, safety enhancements and significant cost savings for these applications have helped erase industry skepticism and caused a paradigm shift toward accepting broader applications of composite materials offshore. Third, the composites industry has started to mobilize and develop the infrastructure needed to be able to supply products. The NIST ATP focused program on oil industry applications has played a significant role in helping assemble a critical mass of responsible parties focused on development of the required critical technology. Oil operators and service companies are now seriously considering ways to utilize lightweight, corrosion-resistant composites during the planning stage of new projects.

The development cycle for an offshore platform takes about five years from exploratory discovery of oil to development of the necessary infrastructure to allow production. Significant emphasis is being made in new projects to shorten this development time, especially the time from project approval to first oil where expenditures in excess of a billion dollars are typical of deepwater projects. With such large capital expenditures, the time value of money is one of the most important factors impacting the profitability of a project. The long lead-time in developing composites is part of the risk factor that inhibits oil companies from committing to composites. Oil companies are most receptive to consider new ideas during the early planning stage of a field development driven by the goal to lower cost or overcome technology barriers. Project managers are driven to accomplish the project on schedule and in budget and are more comfortable with conventional solutions. In most cases to be seriously considered for a project, the technology must be ready for use or require only minor enhancements. This makes it important to have the technology ready while the window of opportunity is open. The industry is currently very active in addressing the challenge to develop ultra deepwater oil and gas resources and solutions formulated during the next few years will become the standard for the industry for many years to come. The oil industry thinks "metals", but on balance has changed paradigm in the last few years from negative to neutral relative to accepting composites. If composites technology is to be utilized, it is critical that the technology be ready while the window of opportunity is open. This window of opportunity is believed to be the first decade of the 21st century during which the oil industry will develop the framework for exploiting ultra deepwater resources worldwide.

DEFINITION OF DEEPWATER

The oil industry definition of deepwater continues to escalate. The Minerals Management Service (MMS) defines deepwater as water depths greater than 1312 feet (400 meters). The Ram Powell TLP platform installed in the 1997 is located in 3251 ft. of water and the Ursa platform is scheduled to be installed in 1998 in 3928 ft. of water. The Kings Peak platform is anticipated to begin production in 6800 feet of water in 1999. Exploratory drilling has already taken place in over 7600 ft. of water and companies hold GOM leases at water depths as great as 13,000 ft. For the purposes of this paper, *ultra deepwater* is defined as water depths greater than 4000 ft. Water depths up to 13,000 ft. are believed to hold oil reserves, and it is the greater than 4000 ft. depths where major technical challenges exist and where composite materials are expected to provide significant enabling capabilities

ECONOMIC INCENTIVE UNCERTAINTIES

Highly successful exploration and production of oil and gas in recent years from deepwater Gulf of Mexico (GOM) resources provided the incentive for the current intense level of activity in leasing, exploring and developing United States deepwater resources. Figure 1 illustrates the rapid growth rate in recent years in leasing deepwater (greater than 2625 feet) GOM tracts.[8] Not only are tracts being leased, but oil and gas are being discovered and production projects are being launched as indicated in Figure 2 which provides a summary of current deepwater development projects in the GOM.[8] The high economic potential for the GOM coupled with restrictions on access to other potential development areas such as the east and west coasts and Alaska have positioned the GOM to be the major region for U.S. oil and gas development for the first part of the 21st century.

It is generally accepted that light-weight, fiber-reinforced, composite materials could play a major role in facilitating the safe, reliable, economical production of oil and gas from deepwater reservoirs; however, significant work needs to be done to make the technology ready. Steel is the primary material used in the construction of offshore platforms and infrastructure and tubulars are the most common structural element. Steel is relatively inexpensive, but heavy and susceptible to corrosion. Low density and corrosion resistance are the primary properties which make composites attractive for offshore developments. In deepwater, the value credited to saving weight increases and composites become more economically attractive.

Unlike the aerospace area, the oil industry does not have a strong sponsor for development work in the materials area, either within oil companies or the oil service industry. In the modern highly competitive commodity market driven by stockholder expectations of ever increasing profits, most oil companies have in the last 5 years reduced or eliminated in-house research in the materials area. Oil companies have downsized or closed materials laboratories with the expectation that the oil service industry and universities would fill the need. The net result is that in the last five years much less research has been sponsored in the materials area. Fortunately for composite materials, the NIST ATP programs have helped keep active a critical level of research and development activity in support of oil E&P applications.

By the time project engineers enter the planning stage to develop the supporting infrastructure of field developments, it is usually too late to develop new technology unless it is impossible to accomplish the objective otherwise. Project teams focus their attention on existing technology, even if it is more expensive or less efficient. The uncertainty of changing development scenarios during such long lead times is a primary concern for product manufacturers and becomes one of the primary reasons government support is needed to help accelerate the pace of development and ensure that products are available when they are needed.

GOM DEVELOPMENT IMPORTANCE TO NATIONAL ECONOMY AND REDUCING FOREIGN ENERGY DEPENDENCE

The petroleum industry is a major component of the U.S. economy. During the last decade, U.S. oil production has steadily declined while gas production has shown only a modest increase. At the same time domestic consumption of oil and gas has steadily risen with current oil imports of 10.8 million barrels per day which accounts for over fifty-six percent of consumption. At $16 per barrel, this accounts for a foreign trade deficit of $63 billion. The percent of oil imported when the first NIST white paper[5] was written in 1994 was 49.2%. No major new onshore oil and gas discoveries are expected in the lower forty-eight states, and East and West Coast offshore resources and the Alaskan Naval Petroleum Reserve are currently not available for development. This leaves the development of deepwater GOM resources as the major source of U.S. development for the first part of the 21st century.

Oil companies have been very active in recent years in leasing deepwater GOM properties from the U.S. government. "There are a total of 4875 active leases issued in all water depths across the US Gulf OCS in the 1992-1997 leasing period, of which 2221 (45%) lie in water depths greater than 1,500 ft. Of the 2221, 1032 (46%) are in water depths greater than 4,999 ft. and 746 (34%) are in water depths ranging between 2,999 ft. and 4,999 ft."[9] "More than 25 percent of new discoveries in the U.S. Gulf are in deepwater. As of January 1998, 104 deepwater prospects have been announced in the GOM of which sixteen are located in water depths ranging from 2,000-2,999 ft., 21 in the 3,000-3,999 ft. depth range, and 18 in 4,000 ft. plus ultra-deepwater."[10] Exploratory drilling activities have been conducted in waters as deep as 7620 ft.[11] The Minerals Management Service estimate of the water depth from which U.S. offshore oil will be produced in future years[11] is presented in Table 2. The data shows a clear government expectation that future offshore production will primarily come from deepwater with 69% coming from water depths greater than 2600 feet by the year 2007 versus only 28% in 1997.

Production from deepwater reservoirs in the GOM can help fill the need for oil from domestic rather than foreign sources. Accelerated production of oil and gas from deepwater reserves will also contribute to the economic growth and prosperity of the United States by creating additional jobs in the oil and gas service industries while federal and state governments will benefit from the growth through lease and royalty payments. In FY 1998, the Minerals Management Service (MMS) expects to collect $5.5 billion in revenue from the Outer Continental Shelf and the amount is expected to grow as production in the GOM expands.

Composites is one of several technologies which could make a big difference in enabling economical ultra deepwater petroleum production. Lacking a support base like the aerospace industry, manufactures of composite products for the oil industry must assume unusually high risk to develop products. The NIST ATP program could provide the stimulus to the oil industry to unite to support the development of the necessary technology to insure that products are available in time to be applied in the 1st decade of the 21st century window of opportunity.

PROMISING NEW COMPOSITE APPLICATIONS

In preparation for this paper, representatives of the oil and composites industries were contacted to identify potential new applications for composites and to determine if there was sufficient technical merit and interest to form project teams to conduct the necessary development. A positive response was received and the ideas expressed below reflect the topics around which projects could be expected to be formulated. The production of oil and gas in ultra deepwater demands creative thinking and the topics expressed below capture some of the solutions being considered utilizing composite materials and structures.

A listing of some of the components which could provide significant enabling capabilities if constructed of composites rather than steel is provided in Table 3. If a NIST ATP program focused on deepwater oil needs is advertised, these are the topics on which proposals for support could be expected. In addition an estimate is provided of the quantity and market value of projected utilization of these composite components during the first decade of the 21st century. The last column highlights the advantages of using composites as seen from the perspective of the oil company end user. Large quantities of composites are forecast to be used if the technology can be demonstrated to meet the requirements at an affordable price and are developed in time to be applied when needed. This includes approximately one-half billion pounds of composite materials with estimated value over $5 billion. This scenario is for new composite products currently not available and does not include the use of composite products such as low-pressure fiberglass pipe, gratings and other products already baselined on new TLPs designed for the GOM. Even though additional work will be required to extend the capabilities of composite production and drilling risers to meet ultra deepwater requirements, the technology developed under the current NIST ATP program is believed to be adequate to permit the development of new products. It is not anticipated that additional ATP programs would be requested in these two areas.

The values in Table 3 assume a total of 40 field developments in the time period 2000-2010 utilizing bottom anchored platforms including 10 TLPs and 30 Floating Production Systems (FPS). In addition, it is assumed 10 Mobil Offshore Drilling Units (MODU) will be outfitted with drilling risers and 20 MODUs with drilling riser support lines (choke and kill, hydraulic, and mud boost lines). It is assumed that the 40 field developments will make the indicated utilization of composites. In addition, existing composite products such as low-pressure fiberglass pipe, composite gratings, etc. deployed on current generation deepwater platforms will continue to be utilized. However, these applications are not included in the total because the table is intended to reflect the impact a new NIST ATP program might have on composites utilization.

The 485-million pounds of composite weight utilization forecast in Table 3 includes composites constructed of carbon, aramid and glass fibers. Large portions of the material will be carbon to meet the high performance requirements of strength and stiffness for primary structure. As indicated above, the demand for advanced composite components will be greater at the end of ten years than at the beginning while fiberglass components will show an earlier growth history. The values forecast in Table 3 for composite components are based on offshore needs for the Gulf of Mexico including subsea pipelines, but do not include additional markets expected from deepwater developments in other parts of the world which could be even larger. Exploration in ultra deepwater with discovers is also taking place in the North Sea, off the West Coast of Africa and in Asia.

IMPORTANCE OF ATP FOCUSED PROGRAM

How important are composites to the development of Gulf of Mexico petroleum resources and how important is NIST ATP funding to help make the technology ready for use in the first decade of the 21st century?

Perhaps an answer to the first half of the question is by analogy. Could you fly a steel aircraft or put a man in space without aluminum? The answer is yes, but why would you want to and certainly you couldn't fly as many passengers for the same energy costs. Likewise for ultra deepwater developments, oil will be produced with or without composites. Probably not as much oil because marginal fields may be uneconomical and also with less efficiency. For example, producing a field for 30 years from a dynamically positioned platform would appear to be very inefficient, but it could be done.

The answer to the second half of the question concerning the need for another focused NIST ATP program and whether it would make a difference contain two elements. First, are there sufficient good technical ideas to warrant a program? The discussion of problems and potential composite solutions provided above is believed to support an affirmative answer. The second question to ask is, would a NIST ATP program be subscribed with good proposals? This question is more difficult to answer. If a NIST ATP focus program is offered, it is anticipated that proposals would be submitted on at least six of the topics described above and maybe all. However, some preparatory coordination work would be required to assemble the right skill mix to ensure that good projects with high probability of success were formulated. Composite manufacturers have the highest invested interest, but oil and oil service company participation is essential to insure that the requirements are completely defined with buy-in for their utilization, and a place needs to be reserved for university participation to develop and coordinate the supporting advanced technology.

A successful development program spurred by a NIST ATP initiative will have a significant impact on the economic development of ultra deepwater in the GOM. The increased utilization of composites will have an extensive impact on the composites supply and manufacturing industries. An expansion of the composites industry will result in a large net increase in needs for skilled labor in the U.S. to supply materials and products. A new market for composite materials will be developed. The increase in the market for carbon fiber over the next ten years, for example, could be on the order of 250 million pounds. This market will also consume large quantities of aramid fiber, glass fiber, matrix resins and other associated materials used in the manufacture of composite structure. The potential market for new components for the GOM offshore market over the next ten years could exceed $5 billion. The global market could be even larger.

Realistically, however, the composites industry has little capital to invest in new product development and oil companies allocate little resources to the materials development area. Without a NIST ATP or other external stimulus, only a portion of the needed development will occur and such efforts will not be at the pace needed to meet the window of opportunity concurrent with the early development of ultra deepwater resources.

CONCLUDING REMARKS

The results of this survey on opportunities to use composites in ultra deepwater petroleum field development suggest that the timing is right for a new NIST ATP focus program. NIST support for the program will benefit the United States in the following ways.

1. The U.S. needs the oil expected from ultra deepwater resources in the GOM to help reduce the financial burden of imported oil and maintain an acceptable level of energy independence.
2. Composites technology is needed for efficient development of future ultra deepwater Gulf of Mexico petroleum resources.
3. NIST ATP financial support would enable U.S. composites industry manufacturers to reduce their financial risk and accelerate the pace of development to meet the upcoming window of opportunity to use composite products in ultra deepwater developments.
4. Once composite products are demonstrated in the GOM, significant overseas sales could be expected to support ultra deepwater developments overseas thus helping the international trade balance of payments.

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TABLE 1. - NATIONAL INSTITUTE OF STANDARDS & TECHNOLOGY ADVANCED TECHNOLOGY PROGRAMS CONDUCTED WITH EMPHASIS ON OIL INDUSTRY EXPLORATION AND PRODUCTION.

Program	Goal	Manufacturing Sponsor	Supporting Sponsors	Funding, $	Start / years
Composite Production Riser	R & D program to design, analyze, manufacture and test composite production riser for floating production platform.	Lincoln Composites Inc.	NIST, Brown and Root USA Inc., Conoco Inc., Hercules Inc., Hydril Company, Shell Development Company, Stress Engineering Services Inc., University of Houston.	$7,168,000	1995 / 5
Manufacturing Composite Structures for Offshore Oil Industry	Develop cost-effective manufacturing methods with emphasis on a composite drilling riser.	Westinghouse Electric Corporation, Marine Division	NIST, ABB Vetco Gray Inc., Hercules Inc., Offshore Technology Research Center, Reading & Bates Development Company, Texaco Inc./Deepstar Project.	$4,814,000	1995 / 5
Spoolable Composite Tubing	Develop long continuous lengths of composite tubulars for oil production operations including coiled tubing and flowlines.	Hydril Company	NIST, Amoco Corp., Dowell Schlumberger Inc., Elf Atochem North America Inc., Mobil E&P Service, Phillips Petroleum Co., Shell Chemical Co., Shell Development Co., Dow Chemical Co., University of Houston.	$5,015,000	1995 / 5
Innovative Joining/Fitting Technology for Advanced Composite Piping	Develop innovative composite joining and fitting technologies to enable and stimulate the use of composites in offshore oil/gas production pipelines.	Specialty Plastics, Inc.	NIST, NASA	$2,867,000	1995 / 3
Light-Weight /High Strength Composite Intelligent Flexible Pipe	Develop and validate flexible composite pipe with built-in performance monitoring for use in oil /gas production.	Wellstream Inc.	NIST	$5,760,000	1995 / 2
Composite Drill Pipe	Design, manufacture, test, and demonstrate affordable composite drill pipes for use in offshore oil drilling.	Spyro Tech Corporation	NIST, Phillips Petroleum Company, Amoco Exploration and Production Technology Group, University of Houston.	$2,770,000	1995 / 4
Development of Innovative Manuf. Techniques to Prod. A Large Phenolic Composite Shape.	Optimize a 36-inch deep composite structural beam element using phenolic resin and glass/carbon fiber which has a modulus of 6 million psi	Strongwell	NIST, Georgia Tech Note: This project has application to the oil industry but was funded under the infrastructure program.	$2,000,000	1995 / 3

Table 2. - MMS Estimate of Future Offshore Oil Production.

Water Depth, ft	1997 %	2002 %	2007 %
0 - 650	59	39	17
650 - 2600	13	14	14
> 2600	28	47	69

TABLE 3.- GULF OF MEXICO DEEPWATER OFFSHORE OIL INDUSTRY ESTIMATED COMPOSITE APPLICATIONS YEARS 2000-2010.

COMPOSITE COMPONENT	QUANTITY	COMPOSITE WEIGHT, MILLION LB	COMPONENT COST, $MILLION	ADVANTAGE COMPARED TO STEEL, $MILLION
TLP Tendon	10 TLPs[1] 18 Risers Per TLP	127 (composite) including 76 (carbon)	1,000	Large Cost Savings Enabling[5]
TLP Production Riser		29 (composite)	286	$98 Cost Savings
FPS Mooring Rope	30 FPSs[2] 16 Lines Each	97 (polyester)	485	Large Cost Savings Enabling[6]
Thick-Walled Tubulars for Ultra High Pressure[3]	Tubing Inside 180 TLP Risers	7	147	Enabling[7]
	Non-Vertical Risers On FPSs 18 each FPS	40	888	Cost Saving[8]
	Choke & Kill, Hydraulic, Mud Boost Lines, On 20 MODU	7	100	Enabling[9]
	Riserless Drilling Mud Return Lines[4]	5	106	Enabling[10]
Drilling Riser	10 MODU	6	128	Enabling[11]
Double-Wall Insulated Subsea Pipe	300 Miles 6"-8" I.D.	31	546	Enabling[12]
Long Length, Large Diameter Tubulars	400 Miles 10" I.D.	25	494	Cost Savings
Extended Reach Smart Drill Pipe	300,000 ft	2	63	Enabling[13]
Linerless High Performance Thermoplastic Pipe	Special Products Including CoiledTubing			Enabling[14]
Platform Primary Structure	Topside, Hull	100	800	Cost Savings
Process Vessels and Tanks	Storage, Processing	8	64	Cost Savings
Buoyancy Modules	Large Number			Cost Savings
Metal/Composite Hybrid Structures	Pipe, Tanks, Primary Structure			Cost Savings
	TOTAL	**485 million lbs**	**$5,107 million**	

Estimated economic impact of oil produced from 10 TLPs and 30 FPSs utilizing advanced composite enabling technology is $525 billion.[15]

Table 3 Footnotes:

[1] 3 TLPs - 4000 ft, 3 TLPs - 5000 ft, 2 TLPs - 6000 ft, 2 TLPs - 7000 ft

[2] 6 FPS - 4000 ft, 6 FPS - 5000 ft, 6 FPS - 6000 ft, 5 FPS - 7000 ft, 3 PFS 8000 ft, 2 FPS - 9000 ft, 2 FPS - 10,000 ft

[3] High operating pressure (15,000 psi), 6-inch I.D.

[4] 30 systems, 10,000 ft, 6-in I.D. , 2 lines per MODU

[5] Enabling. TLP permits direct wellhead access from the platform providing immediate capability for remediation workover of wells and eliminates the need for support from expensive workover rigs.

[6] Enabling. Synthetic fiber moorings save significant weight versus steel which allows existing drill ships to work in deeper water. In ultra deepwater, steel is too heavy to be used and synthetic fiber ropes become the only alternative for mooring FPS platforms.

[7] Enabling. Light-weight composite risers provide significant advantage. Composite tubing will provide additional weight savings, but more importantly, composite tubing can be designed to match the thermal expansion coefficient of the riser to eliminate thermal expansion problems coming from the change in temperature of the hot oil.

[8] Cost Savings. It is believed that composite flexible risers could be constructed at significant cost savings to current flexible risers constructed with steel armor.

[9] Enabling. The drilling riser system includes lines for control of the well should high gas pockets be discovered. The choke and kill, hydraulic and mud boost lines, if made of composite, would provide significant weight advantage.

[10] Enabling. Riserless drilling is a new concept being explored in which there is no riser outside the drill pipe for circulation of the mud. The mud return is a separate line which would is an ideal application for composites because of the difficulty in using a heavy steel line.

[11] Enabling. A light weight drilling riser opens new possibilities for cost efficient drilling operations through elimination of buoyancy material, corrosion resistance, storage volume reduction, and fatigue tolerance.

[12] Enabling. A common problem in deepwater is hydrate and paraffin depositing our of the produced fluid as temperature drops and plugging the line. By using a double-wall insulated pipe this significantly expensive event can be mitigated. In addition heaters can be integrated into the pipe wall.

[13] Enabling. A composite drill pipe with integral communication and reservoir testing lines opens new possibilities in exploration.

[14] Enabling: Availability of thermoplastic pipe would open the door to several applications and holds the possibility for making spoolable pipe without a liner.

[15] $525 billion is the estimated value of oil produced over 20 year life at $18/barrel, 100,000 barrel/day from 40 fields supported by 10 TLPs and 30 FPSs.

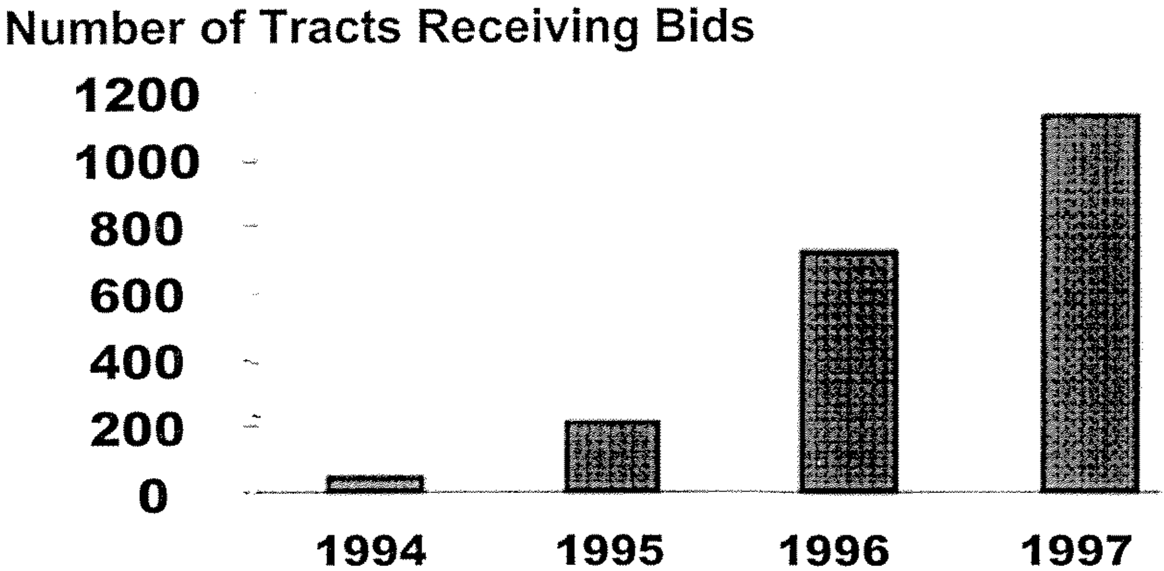

Figure 1. - Bids received by MMS for deepwater leases in Central and Western Gulf of Mexico regions in water deeper than 2650 feet.

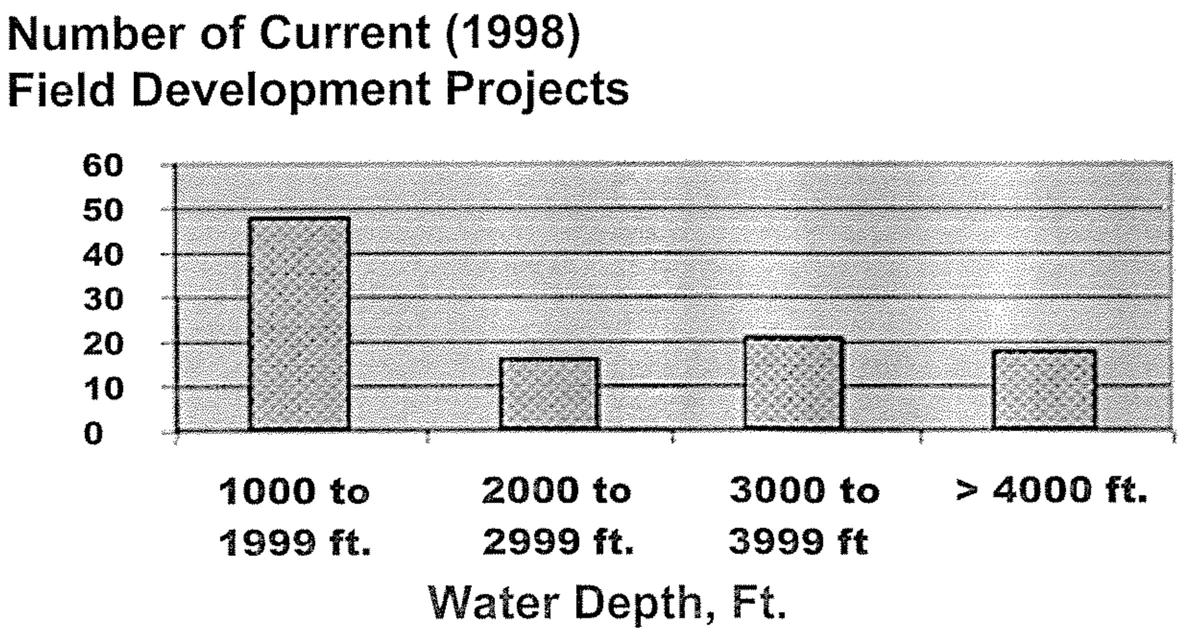

Figure 2. - Oil and gas projects currently under development in Gulf of Mexico at selected water depths.

APPENDIX A - SUMMARY OF PETROLEUM OFFSHORE E&P BREAKOUT SESSION

To: Felix Wu, NIST

From: Bill Cole, Amoco

Date: 2/4/98

Subject: NIST/ATP "Composites Infrastructure" Planning Meeting, 1/29/98
Summary of Petroleum Offshore E&P Breakout session

I. The group reviewed the criteria for NIST/ATP projects
1. Potential US Economic Benefit
2. Good technical merit
3. Strong industry commitment
4. Opportunity for ATP to make a difference

II. The group reviewed the barriers to more extensive use of composites in our industry. Most comments relate back to the barriers cited in the 1994 white paper: reliability, cost and complexity. However some of the specific barriers cited are listed below:

1 Long term durability (reliability)
2. Accelerated testing (")
3. Scaling from small sample test data to full scale structure performance (")
4. Materials availability (cost)
5. Manufacturing limitations (")
6. Installation of composite structure (complexity)
7. Products are not standard from alternate manufacturers (")
8. Complex design process (")
9. Extensive testing required to qualify new designs (")

III. Candidate Projects (proposals)	Fit with ATP Criteria (5 - high, I - low)
1. Tubular Tendons for floating production systems	5
2. Other mooring systems	5
3. Continuous tubulars, D > 4", Pressure > 4,000 psi	4
4. Analytical methods for qualification of alternative designs	3
5. Real time, performance monitoring sensors Inspection tools	2
6. Deck structure for floating production systems. Spacer beams, main girders, fabricated shapes, attachment methods	3-4
7. NDE methods for qualification of products (incorporate into 1. & 3)	2

8. Composite pressure vessels	2
9. Down hole tubulars	2
10. Drilling derricks & flare booms	3
11. Choke and kill lines, 4.5", 7500 - 15,000 psi	5
12. Fiber overwrapped steel pipelines	3
13. Thermoplastic, spoolable, continuous tubulars	4

IV. Proposals in response to a solicitation	Probability
1. Composite tendons, tubular design	High
2. Composite choke & kill lines, continuous tubulars	High
3. Composite tendons, strap design	High
4. Composite deck structure	Medium
5. Composite pressure vessels	Medium to low
6. Down hole tubulars	Medium to low
7. Fiber overwrapped steel piplines, onshore & offshore	High

V. Comments

There are several project ideas that have considerable merit, but do not align with the four four criteria for good ATP projects. Some have strong technical merit, but it is difficult to show benefit to the US economy. Others would have economic impact but are not as strong in technical merit. Some projects will probably occur with or without ATP funding.

A third solicitation under the existing focus program would result in several additional strong proposals.

A new focus program would also result in several new proposals if the existing focus program is not continued. The members of the planning group were able to identify four proposals that have high probability of occuring, and three additional proposals that might be developed. Additional participation can be expected from industry members that were not present.

In summary we see continued interest in the ATP program and would expect several additional strong proposals under the existing composites manufacturing program or with the proposed composites in infrastructure program. In fact industry would probably propose the same projects under either focus program.