Report to Congress

An Assessment of the Methane Hydrate Research Program

and

An Assessment of the 5-Year Research Plan of the Department of Energy

Prepared by the
Federal Methane Hydrate Advisory Committee

June 2007

Executive Summary

An adequate domestic supply of natural gas is a significant component of America's energy security. The National Methane Hydrate Program, established by the Methane Hydrate Research and Development Act of 2000, Public Law 106-193 (May 2, 2000) (Methane Hydrate R&D Act), as amended by Section 968 of the Energy Policy Act of 2005, Public Law 109-58 (August 8, 2005), presents a significant opportunity to determine the potential of methane hydrate as an important long-range domestic and international energy resource, as well as to identify and understand environmental concerns associated with this resource. Current estimates of the volume of natural gas trapped in hydrates within the United States are on the order of 200,000 trillion cubic feet (TCF). Even if only a small fraction of this volume is recoverable, this natural gas resource could provide an enormous contribution relative to the current domestic consumption level (22 TCF per year) and expected future growth in demand. Hydrates represent a potentially significant energy supply for the Nation.

However, estimates of the methane hydrate resource are poorly understood, and estimates of the portion of the gas that could ultimately be economically recovered are even less well understood. Production of natural gas from hydrates is pre-commercial and is not likely to be undertaken by industry alone due to the availability of other proven gas supplies and the long lead time necessary to prove the economic viability of this resource. A Federal-industry-academic partnership is required to advance the long-term goal of quantifying the resource and developing and testing options for commercial production.

Additionally, our ability to quantify the level of methane dissociating from hydrates in nature is poorly understood. Natural gas from hydrates is a potentially powerful source of greenhouse gas emissions that is not well documented in the scientific literature that forms the basis for the current policy debate related to climate change. Understanding this aspect of hydrate science is also an important part of the research funded by the Methane Hydrate R&D Act.

The Department of Energy budget for methane hydrate activity was flat at about $9 million per year from 2001 to 2005 and has received only a modest increase (to $12 million per year) in 2006 and 2007. Other energy-hungry countries, such as Japan, India, China, and South Korea, are each annually outspending the United States on hydrates-related research by up to a factor of ten. These countries are developing essential skills and knowledge that will enable them to take early advantage of whatever energy security the hydrate resource may provide. Unless significant increases in funding occur, the presently under-funded DOE program is unlikely to make the necessary gains in technology and understanding that will be required to advance our own national energy security goals within an acceptable time frame. This is a source of deep concern to the Committee.

Continued low levels of national funding, despite a mandate that the U.S. hydrate program remains comprehensive and well-managed, will relegate the program to a caretaking role rather than making it a principal force in worldwide methane hydrate research and development. As a result of prior Federal investment during the 1980s, as well as more recent R&D investments, the United States has maintained what is perhaps the world's most comprehensive and advanced methane hydrate science knowledge base. However, without an appropriate increase in funding, the United States will quickly lose this strategic advantage.

From a technical perspective, there are three critical needs that must be met in order to broaden the hydrate program:

1. ***Field testing of concepts and technologies for producing hydrates economically.*** Significant advancements have been achieved but remain at the conceptual or computer model stage.
2. ***An accurate assessment of the economic viability of marine hydrates, which exceeds the permafrost resource by several orders of magnitude.*** A reliable technique of remote hydrate detection must be developed.
3. ***A quantifiable assessment of the environmental impact of possible leakage of methane from uncontrolled hydrate decomposition.*** The environmental contribution of methane hydrates to the global carbon budget is an important unknown.

The Committee agrees that funding research at a level that will meet these needs is critically important. Additionally, the Committee makes the following findings relative to its assessments:

1. The goals of the Methane Hydrate R&D Act are important to the Nation and should be pursued;
2. These goals will not be reached without vigorous support from the Federal government;
3. The Committee fully endorses and believes feasible (given sufficient funds) the integrated interagency research plan that has been developed for both the near- and long-term time frames (the approved Interagency Five-Year Plan is provided in Appendix C).
4. The program's planning and management functions have actively addressed the assessment concerns of the National Research Council described in their 2004 report entitled "*Charting the Future of Methane Hydrate Research in the United States*" (National Research Council, Washington, DC, 2004) and others; and, most importantly,
5. Current funding levels are not sufficient to achieve the program goals.

The Committee therefore unanimously and strongly recommends that near-term appropriations honor the authorizations provided for by the Methane Hydrate R&D Act. If Congress agrees with the national and strategic importance of this work, increasing the funding beyond the current authorization will serve to accelerate the program commensurate with that importance on a global scale. Such funding is necessary to enable a full assessment and demonstration of the methane hydrate resource potential and of the environmental implications of developing that potential.

The Methane Hydrate Advisory Committee was established by the Secretary of Energy to assist in assessing progress toward program goals, evaluating program balance, and providing recommendations to enhance the quality of the program over time. As charged in the Methane Hydrate R&D Act (see Appendix A), the Committee submits to Congress this assessment of the methane hydrate research program, and of the 5-year research plan of the Department of Energy.

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I. What Are Gas Hydrates, and Why Are They Important?

A secure supply of natural gas is a vital goal of the U.S. national energy policy because natural gas is the cleanest and most widely used of all fossil fuels. The inherent cleanliness of natural gas, with the lowest CO_2 emission per unit of heat energy of any fossil fuel, means substituting gas for coal and fuel oil will reduce emissions that can exacerbate the greenhouse effect. Both a fuel and a feedstock, a secure and reasonably priced supply of natural gas is important to industry, electric power generators, large and small commercial enterprises, and homeowners.

Because each volume of solid gas hydrate contains as much as 164 standard volumes of methane, hydrates can be viewed as a concentrated form of natural gas equivalent to compressed gas but less concentrated than liquefied natural gas (LNG). Natural hydrate accumulations worldwide are estimated to contain 700,000 TCF of natural gas, of which 200,000 TCF are located within the United States. Compared with the current national annual consumption of 22 TCF, this estimate of in-place gas is enormous. Clearly, if only a fraction of the hydrated methane is recoverable, hydrates could constitute a substantial component of the future energy portfolio of the Nation (Figure 1). However, recovery poses a major technical and commercial challenge.

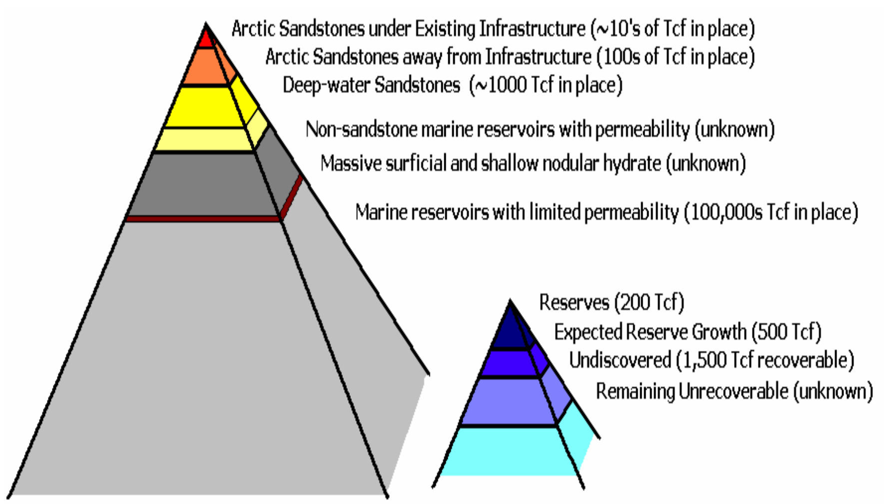


Figure 1. Hydrate resource (left) relative to the conventional natural gas resource (right) for the United States.

Such numbers have sparked interest in natural gas hydrates as a potential, long-term source of energy, as well as concerns about any potential impact the release of methane from hydrates might have on the environment. Energy-hungry countries such as India and Japan are outspending the United States on hydrate science and engineering R&D by a factor of 10, and may bring this resource to market as much as a decade before the United States.

What are hydrates? Gas hydrates found in nature are crystalline solids consisting of gas molecules, primarily methane (CH_4), each surrounded by a "cage" of water molecules. Gas hydrate forms when methane and water combine under conditions of elevated pressure and low temperature—conditions that occur in sediments in terrestrial arctic regions and in the subsea along continental margins.

The precise structure of the cage of water molecules in a hydrate can vary, depending on the size of the “guest” molecule and certain other conditions of formation. Three common hydrate structures found in nature (named sI, sII, and sH) are illustrated in Figure 2. The proximity of the cages causes the methane to be concentrated in a volume of hydrate, equivalent to a dense gas but with a lower energy density than LNG. A cubic foot of methane hydrate contains 164 cubic feet of methane gas measured at standard conditions of temperature and pressure.

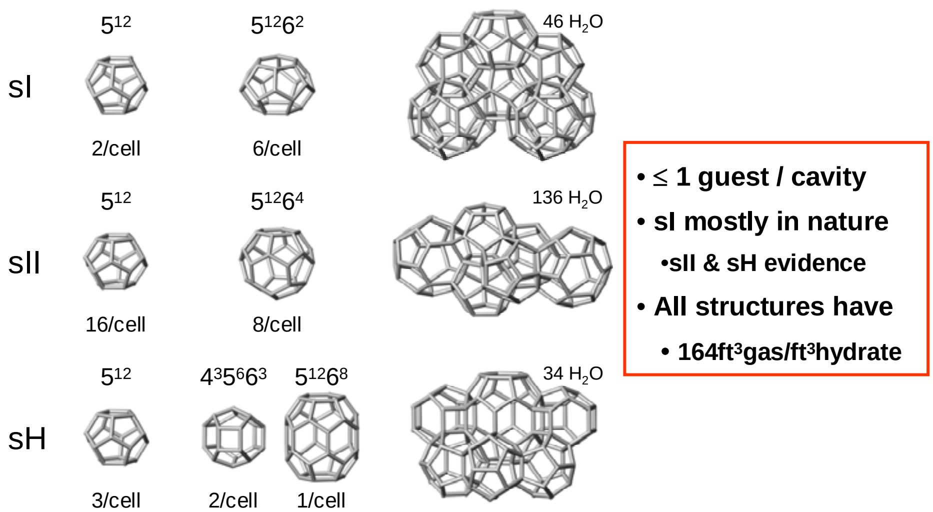


Figure 2. Three common hydrate structures found in nature, in which sI predominates (detailed by Sloan in *Clathrate Hydrates of Natural Gases*, 2nd Ed., Marcel-Dekker, New York, 1998).

With the potential of such a substantial energy resource at hand, the question arises as to why U.S. energy companies have not actively pursued hydrate exploration and recovery. The answer lies in the fact that, at present, ample global supplies of conventional natural gas at economically attractive prices allow the United States to meet its energy needs with a mix of domestically produced gas and gas imported from Canada and from overseas in the form of LNG. Furthermore, given the significant technological challenges of locating and producing gas from methane hydrate accumulations, its economic viability is currently beyond the energy industry’s horizon for financial consideration.

For example, at a meeting on March 16, 2007, managers from BP, ConocoPhillips, Chevron, ExxonMobil, and Shell independently offered these opinions about the hydrate resource:

- “Hydrates as a resource are too far out to be viably economically recoverable. We need government funding and leadership to establish needed science and engineering.”
- “Unless cost incentives are improved, hydrates in nature may remain untapped, awaiting excessive oil prices to become feasible.”
- “Our company critically evaluated work by Moridis, Collett, and Dallimore (acknowledged hydrates-in-nature experts). The conclusion was that natural gas hydrates ranked below all other hydrocarbon resources with regard to commercial value in the next decade.”
- “U.S. science and engineering significantly lag behind international government efforts.”
- “This effort needs leadership which will not be provided by the energy industry.”

These statements demonstrate that the energy industry is unlikely to focus resources in the near-term on developing gas hydrates, because hydrates are not expected to be economically viable in the next decade.

There are, however, several reasons why the Federal government should take the lead in this endeavor:

1. The science is new, and the occurrences of natural hydrates are complex and not yet well understood, leading to the need for substantial investments in basic science, data gathering, and theoretical validation—areas an industry focused on short-term returns is unlikely to finance;
2. Research in gas hydrate science requires specialized technologies, both to recreate hydrates in the laboratory and to study them in arctic or deepwater marine environments, and these technologies are expensive;
3. While the ultimate outcome of these investments is uncertain, the long-term potential benefit to the Nation is enormous, exactly the sort of high-risk/high-reward R&D where Federal funding has historically generated large public benefits.

However, due to funding shortfalls, the United States has scaled down its hydrate activity and is losing its leadership position in hydrate science and technology. This Committee believes that this trend must be reversed and that hydrate research and development investments now will generate significant benefits in future domestic energy supply. As leaders of the world's technological community, and as an energy-dependent nation, it is incumbent on the United States to increase funding for the development of this long-range energy source.

II. What Is the Current State-of-the-Art, and What Are the Shortfalls in Hydrate Science?

Hydrate developmental strategy is influenced by two facts:

1. The total amount of hydrates in the marine sediments is several orders of magnitude greater than the amount of hydrates in permafrost.
2. Hydrates in the permafrost often have the advantage of occurring in higher concentrations than in seafloor sediments and in several readily-accessible U.S. locations.

As a consequence, hydrates are first being accessed for exploration and production testing in the North Slope, Alaska, region permafrost. Technology transfer will then extend from these permafrost hydrates to the development of marine hydrates. The first U.S.-led effort to test hydrate exploration technology at Milne Point on Alaska's North Slope took place early in 2007.

However, the United States is beginning to lose its lead in hydrate science and technology to pioneers such as India and Japan, which are rapidly being followed by China and South Korea. Unless the United States increases its investment in hydrates, it will have to be satisfied with an "early-settler" role, rather than as a pioneer—hoping that knowledge developed by other countries will be made available. This "wait-and-adopt" strategy also relegates the United States to second place status in the pursuit of potentially valuable technology patents, and precludes the United States from establishing early standards to ensure that hydrate resources are accessed in a safe and environmentally responsible manner.

For example, Japan sponsored the first proof-of-concept hydrate energy recovery wells in the Canadian Arctic (the Mallik project). This project began in 1998 and culminated in a production test during the winter of 2006-2007. Japanese hydrate R&D expenditures were in excess of US$100 million in 2003, and US$68.5 million was spent on research in the Sea of Kumano off Japan alone during 2006-2007. The Japanese government has set a goal of commercial methane gas production from hydrates by 2017. It is estimated that Japan's production test well program at Mallik will cost Can$75 million. Beyond Japan's aggressive program, a 113-day Indian hydrate ocean expedition was undertaken during 2006 at a cost of US$36million. India's plans include a commitment for a production test well by 2009.

In contrast, Federal government hydrate research expenditures have averaged ~$10 million per year since 2001, and the first U.S. exploratory test well (an arctic test rather than a marine test) was drilled in February 2007. If funding levels are not increased, as recommended by this Committee, U.S. ocean hydrate production will not occur until substantially after production is realized in India and Japan.

As an extension to the unconventional oil and gas report of the National Petroleum Council's Global Oil and Gas Study (to be published in June 2007), the Committee has identified four principal R&D shortfalls related to hydrate development.

1. Long-Term Production Test Well for Arctic Hydrate Assessment

For an understanding of the potential of permafrost hydrates, a long-term production test well is needed to enable the testing of various recovery strategies and to provide for modeling verification.

Currently, there is no commercially proven way to recover methane gas from hydrates in permafrost, the most easily accessible location where hydrate is found. The gas from these hydrates is potentially producible today, given a pipeline or nearby commercial use for the gas. The Japanese performed a three-week well test at the Mallik site in Canada during the winter of 2006-2007, and DOE plans a similar production test on the Alaskan North Slope during the winter of 2007-2008, assuming sufficient funding.

Computer reservoir models are critical tools for the economic development of any conventional gas field. Hydrate reservoir models exist (e.g. TOUGH+Hydrate, STOMP, CMG-STARS, etc.), and they are currently being tested against each other to assess their reproducibility in the simulation of methane production from idealized hydrate reservoirs. However, the accuracy of these models can be verified only against data from a long-range, quasi-steady-state production test, with a minimum of the transient phenomena that can obscure observations of true reservoir behavior.

Hydrates can be decomposed to release trapped methane by reducing the ambient pressure, by heating to raise the ambient temperature, or by exposure to freezing-point reducers (anti-freezes) such as methanol. While there is no standard, proven method of hydrated gas production, it is believed that simple depressurization may cost less than thermal stimulation or inhibitor injection strategies. Prudent combinations of two or more of these approaches may be needed. In addition, other innovative techniques, such as geothermal stimulation or controlled oxidation, have yet to be attempted. A long-term, Alaskan Arctic testing facility could be constructed relatively inexpensively at a gravel pad on the North Slope of Alaska and would provide an opportunity to explore recovery techniques suitable for the permafrost. The results of such tests of permafrost technology (e.g., hydraulics, geomechanics, heat transfer, etc.) might then be transferable to inform the development of marine hydrate recovery techniques.

2. Remote Sensing Tools for Marine Hydrate Deposits

For marine hydrates, there is a need for remote sensing tools that can reliably locate and characterize gas hydrate deposits, integral steps required to assess the economic viability of the marine hydrate energy resource. An early remote sensing approach—using geophysics to search for what was believed to be seismic indicators of hydrate accumulations (bottom simulating reflectors, or BSRs)—has proven unreliable. A BSR is a subsurface reflection that appears on seismic cross-sections and parallels the sea bottom while crossing sedimentary boundaries, as an accumulation of hydrate might do.

Some large-scale hydrates discoveries have been made without any evidence of a BSR, and at the same time BSRs have been located, tested, and found to be devoid of hydrates. Two illustrations confirm this point. While the 113-day Indian hydrate expedition in 2006 drilled 22 sites where BSRs were detected, at one site off the west coast of India it was discovered that the BSR was in fact caused by a calcium carbonate deposit rather than hydrates.[1] Another example is

[1] Collett, personal communication to Sloan, February27, 2007.

the group of giant hydrate mounds found on the seafloor in Barkley Canyon west of Vancouver, BC. Here, seismic signals indicated that these hydrate deposits, with thin sediment cover, appeared geophysically equivalent to ocean bottom sand.[2]

In the future, the BSR will likely be coupled with a suite of remote detection methods, as has been noted by Mahajan and Somasundaran: "A thorough and cost-effective preliminary survey site protocol needs to be developed to include geochemical, heat flow, and electromagnetic (EM) characterization of deepwater-sediment hydrate beds. These data will be coupled with seismic surveys to determine deep drilling locations."[3]

The program is currently pursuing a number of other hydrate detection technologies, some of which were validated by the successful drilling of a test well at Mt. Elbert in Alaska during February 2007. However, the need for remote sensing hydrate tools that can reliably locate gas hydrate deposits is a critical one.

3. Multi-Well Drilling Expeditions in the Gulf of Mexico,

For marine hydrates, there is a need for multi-well drilling expeditions in the Gulf of Mexico, with coring and logging (similar to the 2006 Indian hydrate expedition) to characterize hydrate deposits and to validate emerging exploration technologies.

The cost estimate for a 30-day field program in the Gulf of Mexico will be roughly $10 million in ship rental fees alone. As a comparison, the Indian expedition in 2006 drilled 22 sites over a 3-month period at a cost of US$36 million. Multiwell expeditions like this provide some economies of scale relative to the inefficiencies of drilling at two or three sites at a time. This approach is also being taken by Japan, where the funding of well drilling during 2006-07 eclipses both that of the U.S. and India (Figure 3).

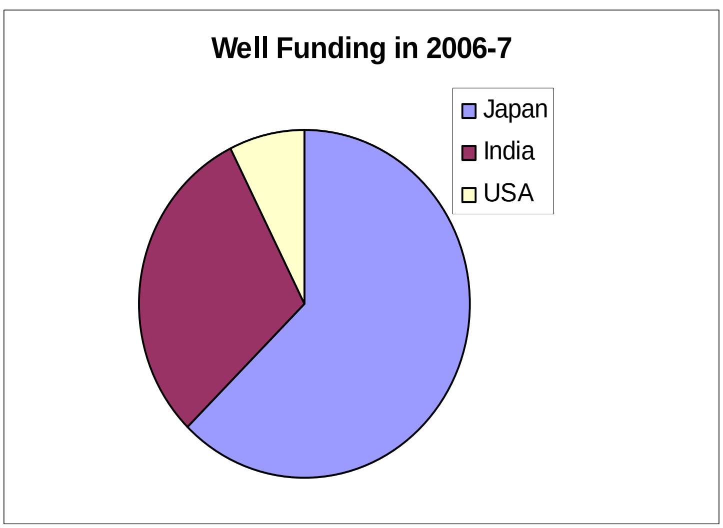


Figure 3. Relative Funding in 2006-2007 for Hydrate Wells by India, Japan, and the U.S.

[2] Brewer, personal communication to Sloan, March 22, 2007.
[3] Science and Technology Issues in Methane Hydrate R&D, 2006 Engineering Foundation Workshop, D. Mahajan and P. Somasundaran, Eds., March 2007.

4. Understanding of the Role of Hydrates in the Environment

The exact nature of what appears to be a dynamic relationship between methane hydrates and the environment remains a significant unknown. The most recent review of hydrate in the environment states, "The methane contribution from hydrate decomposition is an important unknown in the global methane budget."[4]

In their controversial book, *Methane Hydrates and Quaternary Climate Change: The Clathrate Gun Hypothesis*, Kennett, et al., suggest that as recently as the Late Quaternary Period (15,000 years ago) hydrates contributed to the greenhouse warming effect.[5] There is a scientific community consensus that this hypothesis, reviewed in this Committee's 2004 Report to Congress, requires substantial verification via research before it can advance to the state of being a reliable theory.

There is substantial evidence within the isotopic fossil record of massive methane release, probably from hydrates 5 million years ago, at the Last Paleocene Thermal Maximum, which caused warming of the earth by as much as 8 °C.[6] Verifying the role of methane hydrates in global climate change is critical because of the fact that methane has a greenhouse warming potential 21 times that of CO_2. A better understanding of the pivotal role that hydrates might play in the global climate could influence U.S. policy choices related to global warming mitigation decisions.

A second important aspect of the relationship between hydrates and the environment concerns seafloor stability. In the last few decades, energy companies have grown increasingly concerned about the impact of hydrates on seafloor stability, particularly as development activities have ventured further into deeper waters. Destabilization of hydrates in seafloor sediments may cause underwater landslides or sediment fluidization that can jeopardize offshore oil production facilities. A possible example of this is shown in Figure 4, which displays a seismic cross-section from the Blake-Bahama Ridge off the southeastern coast of the United States. In this example, the seismic line reflection that appears parallel to (but is deeper than) the mudline—the so-called BSR—is seen to be absent under the area exhibiting evidence of disrupted sediment. This could be interpreted as providing evidence of methane evolution from a hydrate accumulation and an associated disruption of the sediments above as methane is released into the ocean.

[4] W.S. Reeburgh, Chem. Reviews, vol 107(2), 486-513, 2007, doi:10;1021/cr050362v.
[5] Kennett, *et al.*, Methane Hydrates and Quaternary Climate Change:The Clathrate Gun Hypothesis, AGU, 2003.
[6] Dickens, *Science*, 299, 1017, 2003.

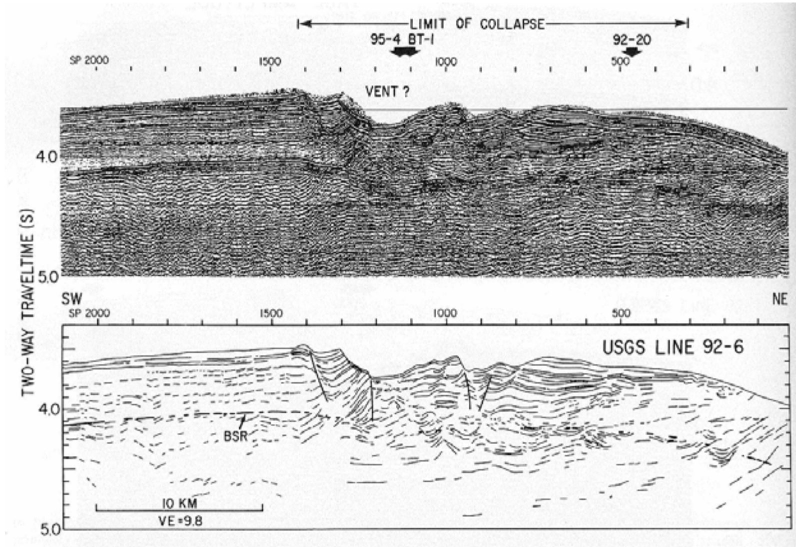


Figure 4. Hydrate disruption below the seafloor at the Blake-Bahama Ridge (Dillon, et al., *Natural Gas Hydrates: Occurrence, Distribution and Detection*, Dillon and Paull, eds., American Geophysical Union, p. 218, 2001). The bottom image is a sketch of the seismic section. Note the disruption in the middle of the diagram, between the mudline and the BSR, indicating gas evolution.

III. Assessment of the Federal Program

The National Methane Hydrate R&D Program is being undertaken by four Departments (Energy, Interior, Defense, and Commerce), as well as the National Science Foundation, with the Department of Energy responsible for leading the effort. There is oversight and advice from a Technical Coordination Team, and an Interagency Coordinating Committee composed of representatives from these groups. In addition, review of the program is conducted by a Methane Hydrate Advisory Committee (MHAC)—the authors of this report—and a 5-year external review by the National Research Council is mandated by the legislation that launched the Program. Clearly, a large number of parties are engaged to oversee and to advise this modestly funded program.

Based on its assessment, the Committee finds that the program appears to be well-managed. The interagency group has generated a long range 20-year plan (*An Interagency Roadmap for Methane Hydrate R&D*, July 2006) as well as a draft 5-year plan (*An Interagency Five-Year Plan for Methane Hydrate R&D, FY 2007-2011*, January 2007), which was reviewed by the MHAC. The revised draft 5-year plan is provided in Appendix C.

The program funded by the Methane Hydrate R&D Act is now built around two flagship projects: 1) the BP project for permafrost hydrate development at Milne Point, Alaska, and 2) the Chevron Joint Industry Project (JIP) for subsea hydrate development in the Gulf of Mexico. A third large seafloor observatory project coordinated by the University of Mississippi has received "earmarked" funding in past years.

The underlying philosophy of the program has been to fund large field projects and simultaneously to do peripheral research in support of these projects. The rationale is that if hydrates are shown to be viable in successful field experiments, other non-governmental funding will arise to support hydrates-in-nature R&D, for more-efficient energy extraction.

Table 1 summarizes key results from three recent successful hydrate field experiments involving drilling projects: 1) Milne Point on the Alaskan North Slope (ANS), 2) the Chevron Gulf of Mexico JIP, and 3) the 2006 Indian Hydrate expedition undertaken with U.S. cooperation.

However, one of the major challenges for program management under this approach is that the program is grossly under-funded. The available budget is insufficient to support two major field projects. At Milne Point, the Mt. Elbert hydrate well preparation, site evaluation, and drilling program cost was $18 million, about evenly divided between Federal funding and in-kind contributions from BP. The subsequent field program expenses were approximately $4.3 million. Because the Federal budget for hydrates was only $9 million per year after earmarked funding, it will be difficult to fund other field projects such as the Chevron Gulf of Mexico JIP, which will be considerably more expensive than the Alaskan effort.

Table 1. Significant Accomplishments of Three Major Projects

BP Milne Point Project	Chevron Gulf of Mexico JIP	2006 Indian Expedition
1. Demonstrate ability to safely drill hydrates below the permafrost	1. Showed industry that hydrates do not pose risk to drilling deeper	1. First Indian hydrate discovery and recovery in complex geology
2. Confirmed sound ANS exploration/assessment methodology	2. Provided base for future hydrate-as-a-resource project in the Gulf of Mexico	2. Discovered/sampled the richest known marine hydrate accumulation (Krishna-Godavari Basin)
3. Provided complete data sets on natural hydrates	3. Developed and tested a range of sampling technologies including analyses of pressurized cores	3. Discovered hydrate bearing volcanic ash layers as deep as 600 meters below seafloor
4. Confirmed U.S. gas hydrates production via depressurization	4. Established government-industry collaboration for drilling program	4. Established India/USA collaboration expected to continue in the future
5. Provided basis for long-term production testing of reservoirs	5. Advanced 3-D seismic data for pre-drilling marine hydrate saturations	5. World hydrate community trained 40 Indian scientists

The MHAC acknowledges the contribution of foreign efforts to gas hydrate research. The U.S. effort has and should leverage contributions made by other national energy authorities. For example, drilling and formation evaluation practices at Mt. Elbert on the Alaska North Slope have been informed by the work done at Mallik in the Canadian Arctic. Lessons and techniques learned during the highly successful Indian offshore drilling campaign will materially assist a prospective Gulf of Mexico basin-wide assessment campaign.

The Committee further recommends that U.S.-DOE efforts should focus on three areas of concern unique to the Unites States:

1. ***Assessment of the U.S. resource base.*** Present estimates of the domestic hydrate resource base, especially offshore, are highly speculative and lack a firm scientific foundation. U.S. efforts should focus on the Gulf of Mexico.

2. ***Production technology in the arctic environment.*** The Canadian hydrate effort is driven by the Japan Oil, Gas, and Methane National Corporation, whose intention is to develop techniques in the arctic only for transfer to offshore Japan. Canada, Russia, and the Scandinavian countries have no independent production research efforts.

3. ***Environmental issues.*** These include the safety of production techniques and avoidance of accidental releases of methane into the atmosphere as a result of production (especially in the arctic), and issues of subsidence and slope instability as a result of gas and water withdrawal.

IV. The Critical Need for More Funding and Its Effect on the Program

Unless the United States increases funding, as recommended by this Committee, the program managers may be forced to curtail activities. This will undermine our international leadership in science and technology. Continued low funding levels will necessitate the implementation of two strategies:

1. ***Downgrading of long-term plans, pushing realization of the major goals far into the future***. This will, at a minimum, delay marine testing and reduce the extent of necessary environmental investigations.

2. ***Greater focus on leveraging U.S. funding via international cooperation***. The two co-chief scientists of the 2006 Indian hydrate expedition were from the United States (one was from the U.S. Geological Survey, and the other was the DOE hydrate program manager). As a result, India was able to capitalize on hard-earned experience from previous decades of hydrate drilling sponsored by the U.S. National Science Foundation and by Canada. However, relying on such opportunities, where the United States essentially trades its experience for funding, will only become more difficult as other countries acquire their own experience and seek to control technology development to meet their own specific national goals.

In summary, the choice is clear: Either the United States should downgrade the expectations outlined in the Methane Hydrate R&D Act, or the program should be funded at the levels authorized in the Act to enable achievement of the stated goals. The authorized amounts stated in the Act are defined as follows:

> *"There are authorized to be appropriated to the Secretary to carry out this Act, to remain available until expended--*
>
> *(1) $15,000,000 for fiscal year 2006;*
> *(2) $20,000,000 for fiscal year 2007;*
> *(3) $30,000,000 for fiscal year 2008;*
> *(4) $40,000,000 for fiscal year 2009; and*
> *(5) $50,000,000 for fiscal year 2010."*

The elements for an accelerated FY08 hydrate program with increased appropriations (at the Act authorization level or beyond) are described in Appendix B.

V. Conclusions and Recommendations

The U.S. government currently has in place a well-managed methane hydrate R&D program, which has directly addressed previous suggestions for program improvements made by the National Research Council in *Charting the Future of Methane Hydrate Research in the United States* (National Research Council, Washington, DC, 2004). However, the program is grossly under-funded relative to the hydrate programs of other nations and the goals established for the program. The result is that the United States is in imminent danger of losing its premier place in hydrate science and technology to others. Critical advancement in both knowledge and skills for accessing and exploiting this important domestic energy resource will be lost at a time when it is most urgently needed.

The Committee unanimously supports the following findings:

1. The goals of the Methane Hydrate R&D Act are important to the Nation and should be pursued;
2. Meeting these goals will require vigorous support from the Federal government;
3. An integrated interagency methane hydrate research plan has been developed for both the near- and long-term that the Committee fully endorses the plan and believes it to be achievable, if sufficient funding is provided;
4. Program planning and management has actively addressed the assessment concerns of the National Research Council and others; and, most importantly,
5. ***Current funding levels for the program are not sufficient to achieve the stated goals.***

The Committee therefore strongly recommends that current funding levels be significantly increased, particularly in light of the great strides the program has made in recent years, and the exciting opportunities the program has for pursuing high-value R&D activities in the near future.

Our recommendation is that near-term appropriations honor the authorizations provided by the Methane Hydrate R&D Act with authorizations increasing to levels of $50 million per year by 2010.

Such funding is necessary to enable the full assessment and demonstration of gas hydrate resources and potential environmental implications, through the achievement of four major goals:

1. Establish a semi-permanent production test facility in the Alaskan Arctic,
2. Finalize research on a remote hydrate sensing mechanism for the economic assessment of marine hydrate accumulations,
3. Conduct a series of exploratory, multi-well drilling, coring, and logging programs in the Gulf of Mexico, and
4. Determine the role played by methane released from hydrates in global climate change, in particular as to its potential contribution to the greenhouse gas effect and global warming.

Appendix A: Methane Hydrate Advisory Committee Members List and Charge

Methane Hydrate Advisory Committee Listing

Peter Brewer (Monterey Bay Aquarium Research Institute)
Richard Charter (Defenders of Wildlife)
Nader Dutta (Schlumberger)
Arthur Johnson (Hydrate Energy International)
Emrys Jones (Chevron)
Kimberly Juenger (World Energy Systems)
Miriam Kastner (Scripps Institute)
Devinder Mahajan (Brookhaven National Lab)
Stephen Masutani (University of Hawaii)
Dendy Sloan (Colorado School of Mines)*
Robert Swenson (State of Alaska)
Jean Whelan (Woods Hole Oceanographic Institution)
Scott Wilson (Ryder Scott)
Robert Woolsey (University of Mississippi)

** Chairman*

Charge to the Methane Hydrate Advisory Committee

(As stated in the Methane Hydrate Research and Development Act of 2000, as amended)

<u>Section 4.(c) Methane Hydrates Advisory Panel</u>

(1) IN GENERAL – The Secretary shall establish an advisory panel (including the hiring of appropriate staff) consisting of representatives of industrial enterprises, institutions of higher education, oceanographic institutions, State agencies, and environmental organizations with knowledge and expertise in the natural gas hydrates field, to:

(A) assist in developing recommendations and broad programmatic priorities for the methane hydrate research and development program carried out under subsection (a)(1);

(B) provide scientific oversight for the methane hydrates program, including assessing progress toward program goals, evaluating program balance, and providing recommendations to enhance the quality of the program over time; and

(C) not later than 2 years after the date of the enactment of the Methane Hydrate Research and Development Reauthorization Act of 2005, and at such later dates as the panel considers advisable, submit to Congress—

(i) an assessment of the methane hydrate research program, and

(ii) an assessment of the 5-year research plan of the Department of Energy.

(2) CONFLICTS OF INTEREST – In appointing each member of the advisory panel established under paragraph (1), the Secretary shall ensure, to the maximum extent practicable, that the appointment of the member does not pose a conflict of interest with respect to the duties of the member under this Act.

(3) MEETINGS – The advisory panel shall—

(A) hold the initial meeting of the advisory panel not later than 180 days after the date of establishment of the advisory panel; and

(B) meet biennially thereafter.

(4) COORDINATION – The advisory panel shall coordinate activities of the advisory panel with program managers of the Department of Energy at appropriate national laboratories.

Appendix B: Elements of an Accelerated R&D Program

Key Elements of an Accelerated Hydrate R&D Program with Increased Appropriations at the FY08 Funding Authorization Level or Beyond

1. ***Fund the Chevron Gulf of Mexico JIP for a multi-well transect with full logging and coring programs for Spring 2008.*** The estimated cost is on the order of $15 million and will represent a program about half the scale of the 2006 India program (~6 sites and ~18 wells versus 22 sites and 39 drilling locations). A similar program, also in the Gulf of Mexico, would be planned for 2009 or 2010. Adding drillstem or other types of flow tests to the program for sites of high potential could increase the cost but would be extremely valuable in terms of proving the viability of marine hydrate production concepts.

2. ***Fund the program with BP to initiate the recently developed production test plan at either Milne Point or Prudhoe Bay.*** This program would cost $8 to $10 million.

3. ***Expand U.S. financial contributions to international activities.*** For example, support in a meaningful way the continued development of exploration tools much needed by Indian researchers, to allow improved site selection for their next field venture. This investment would also benefit the United States, because India would permit access to the wells to verify the tool performance shortly thereafter. The idea of similar collaborative programs could be broached with the Chinese and the South Koreans.

4. ***Carefully consider participation in the Japanese/Canadian program at the Mallik site.*** Meaningful support to the OOI/Orion etc., efforts might also be possible at these levels.

5. ***Increase support for methane hydrate research within select National Laboratories.***

6. ***Solicit an additional field project in Alaska.***

7. ***Examine the potential for the careful environmental monitoring activities for both the BP and JIP programs. This could be accomplished by*** 4-D seismic surveys over the production test site. Workshops and solicitations for projects for borehole and in-situ characterization and monitoring may also be considered.

Appendix C: The Interagency Five-Year Plan

Attached separately

AN INTERAGENCY FIVE-YEAR PLAN FOR METHANE HYDRATE RESEARCH AND DEVELOPMENT FY2007-FY2011

Prepared By

The Technical Coordination Team
of the National Methane Hydrate R&D Program

April 2007

An Interagency Five-Year Plan for Methane Hydrate Research and Development

Table of Contents

This document compliments an earlier *Interagency Roadmap for Methane Hydrate Research and Development (2006*). The Roadmap can be found on the Office of Fossil Energy's website at http://www.fe.doe.gov./programs/oilgas/publications/methane_hydrates/mh_interagency_plan.pdf

1.0 Executive Summary

An Interagency Five-Year Plan for Methane Hydrate Research and Development is a joint effort of representatives of seven federal agencies: the U.S. Department of Energy (DOE), the U.S. Geological Survey (USGS), the Minerals Management Service (MMS), the Bureau of Land Management (BLM), the Naval Research Laboratory (NRL), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF). This document outlines near-term research priorities and a set of performance milestones designed to enable measurement of program progress relative to the goals of the Methane Hydrate Research and Development Act of 2000 (the MHR&D Act), as amended in Section 968 of Public Law 109-58, 30 USC 1902 (The Energy Policy Act of 2005). This 5-year plan is set within the context established by *An Interagency Roadmap for Methane Hydrate Research and Development* (2006) that set long-term (through 2025) goals for the program and described the overall nature, scale and progression of R&D activities necessary to meet those goals.

The Fiscal Year 2007 through 2011 R&D activities and milestones set forth in this document are designed to ensure that U.S. gas hydrate science moves forward at a pace necessary to meet the program's key long-range goals. In accordance with the MHR&D Act, the program's goals are wide ranging, with particular focus on demonstrating the technical and economic viability of methane recovery from gas hydrate deposits. The program will achieve this goal through the integrated development of the following: geologic and geochemical models of gas hydrate occurrence, validated exploration tools, numerical simulation capability, specially-tailored drilling and completion technologies, and applied reservoir engineering to maximize the efficiency and safety of production methods. Primary near term milestones to meeting this goal include 1) the establishment of the first of a series of long-term production testing programs on the North Slope of Alaska, and 2) the initiation of multi-well exploration and assessment studies within the Gulf of Mexico to test different models of gas hydrate occurrence and the ability of remote sensing technologies to accurately identify and characterize natural accumulations. In pursuing these goals, the program will aggressively seek out opportunities to leverage, and collaborate with, all interested international R&D programs.

The program will also pursue its long-term goals to assess 1) the role of gas hydrate in global environmental systems such as carbon cycling, global climate, and sea-floor stability and 2) the potential for, and impacts of, degassing resulting from either ongoing "conventional" oil and gas exploration and production (E&P) activities or future gas hydrate production activities.   Included in these possible impacts are land or seafloor surface subsidence, disturbance of permafrost, negative impacts on sensitive deepsea environments, and release of gaseous methane that may find its way into the atmosphere. The program recognizes that defining, and designing effective mitigations for, any potential environmental impacts is a true prerequisite to large-scale commercial production. Primary near term milestones in meeting these goals includes increased support for ocean-bottom observatories, support for new field and modeling studies to better determine the flux and fate of methane from marine and permafrost environments, and the leveraging of future resource-related field programs for monitoring the impact of drilling and production perturbations on natural gas hydrate systems.

The program will continue to emphasize sound management practices, including extensive interagency communication, public outreach, and the use of external merit-based peer review of potential and ongoing projects. The program will seek out opportunities to support, collaborate with, and leverage the data-collection opportunities provided by, international gas hydrate research and development programs. Finally, the program will place a strong emphasis on providing educational and training opportunities for future generations of energy scientists.

2.0 Background

2.1 Program Philosophy

The Department of Energy (DOE) will work with collaborating agencies, public and private research partners, and interested international entities to achieve the goals of the Methane Hydrate Research and Development Act (MHR&D Act) of 2005. These goals, and the general nature of R&D activities required to reach them, have been outlined in a preceding Interagency Roadmap for Methane Hydrate Research and Development (Technical Coordination Team, 2006).

To maintain progress towards reaching these goals, the program's highest priorities in the near term will be as follows: 1) to establish the first of a series of long-term production tests on the North Slope of Alaska that will enable the program to determine the response of natural accumulations of varying nature to a range of alternative potential production methods; and 2) to conduct the first of a series of multi-well drilling and evaluation expeditions within the Gulf of Mexico to assess both the scale and nature of the gas hydrate resource and the technologies for pre-drill prospect identification and characterization through remote sensing. These two priorities are designed in order to provide answers to the two following questions as quickly as possible: 1) is production from naturally-occurring gas hydrates economically feasible in certain settings? and 2) does gas hydrate occur in the abundance and nature sufficient to provide the meaningful longer-term resource potential?

In the near term, the DOE expects these two goals to be pursued primarily within the existing cooperative agreements with BP (focused on permafrost issues) and the Chevron JIP (focused on the Gulf of Mexico). These efforts will continue to be supported by focused activities that tap unique talents and equipment within the DOE National Laboratories and in collaborating federal agencies. Funding for these supporting efforts will be directed primarily to those organizations producing the highest impact studies as determined through regular scientific peer review.

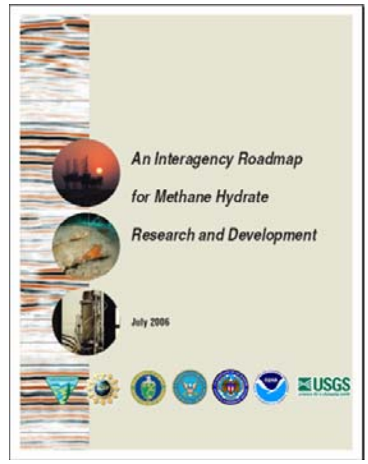
A second priority for the program in the near term will be to continue to advance our understanding of gas hydrate's role in the natural environment. In this regard, the program will refocus its efforts toward 1) supporting the most promising efforts to establish ocean-bottom observatories, 2) identifying and supporting promising new field and modeling studies to better determine the flux and fate of methane from marine and permafrost environments, and 3) leveraging opportunities within existing production-focused field efforts to monitor the impact of drilling and production perturbations on natural gas hydrate systems.

Both of these primary research priorities will be supported through ongoing studies within 11 additional existing cooperative agreements (CAs) selected during competitive solicitations offered in FY2005 and FY2006. The merits and contribution of these projects to the program's critical goals will be regularly evaluated through external merit reviews, the first of which to be held in the Fall of 2007. Regardless of available funding, the DOE will not continue projects that are deemed to be providing minimal benefits. The need for the addition of new projects will be determined through periodic public workshops designed to identify the key remaining R&D and data gaps. As was the case with all the existing CAs, all new projects will be selected through a competitive process incorporating external merit review and will contain internal decision points that can be used as opportunities to modify project scope to maximize impact, or to terminate projects that are deemed underperforming or no longer relevant.

This Five-Year Plan assumes that appropriations not significantly different from the authorizations of the MHR&D plan will be available over the near term. If future appropriations deviate significantly from these levels, this plan, as well as the program portfolio, will be re-evaluated. DOE would conduct this re-evaluation through consultation within the existing interagency working groups, and would also provide the gas hydrates research community and other interested stakeholders a full opportunity to provide input through open public meetings.

2.2 The Interagency Roadmap and the Interagency Five-Year Plan

R&D plans for the DOE-led interagency program are developed through discussion within two interagency working groups (see Appendix A) that include representatives of seven federal agencies concerned with naturally-occurring gas hydrates: the DOE, the U.S. Geological Survey (USGS), the Minerals Management Service (MMS), the Bureau of Land Management (BLM), the National Science Foundation (NSF), the Naval Research Laboratory (NRL), and the National Oceanic and Atmospheric Administration (NOAA). The Interagency Coordination Committee (ICC) consists of program managers and other high-level officials and is responsible for communication of the overall mission and focus of each agency. Coordination of events in the field and technical collaboration occurs within the Technical Coordination Team (TCT), consisting of field scientists and those responsible for program implementation.



The 2006 Interagency Roadmap (Technical Coordination Team)

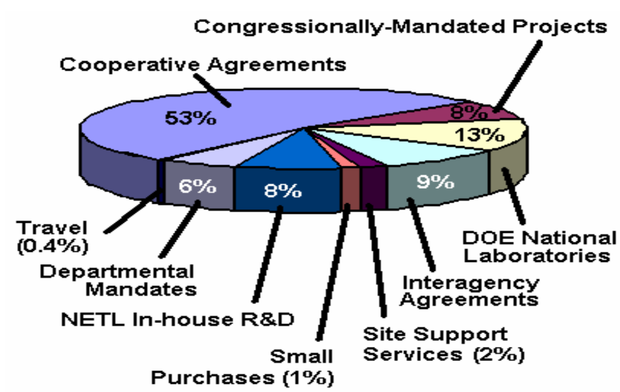
In 2006, the ICC asked the TCT to develop *An Interagency Roadmap for Methane Hydrate Research and Development* (the "Roadmap"). That document was designed to obtain and describe a general consensus within the collaborating federal agencies as to the general nature and progression of R&D activities through year 2025 that would be needed to achieve the stated goals of the Methane Hydrate Research and Development Act of 2000 (MHR&D Act; as modified and extended by the Energy Policy Act of 2005).

Like the earlier Roadmap, this "Interagency Five-year Plan" was developed by the members of the TCT at the request of the ICC. The purpose of this five-year plan is to detail the near-term R&D activities that are necessary to move the program efficiently toward the long-term goals laid out in the Roadmap. Together, these plans are designed to achieve three purposes: 1) align long-range and near term R&D activities within the collaborating agencies; 2) provide a document for communication of program goals and areas of research emphasis to the broader national and international research community; and 3) provide information to the Methane Hydrates Federal Advisory Committee (FAC, see Appendix B) in support of an evaluation that the FAC is required to submit to Congress by August 2007 on the adequacy of the program's five-year research plans.

2.3 Past Program Funding

This Interagency plan and in general, the overall "Interagency R&D effort" refers to the total federal effort related to goals of the MHR&D Act. A primary component of that effort is the R&D program accomplished using funding provided to the DOE. As directed by the MHR&D Act, the DOE actively collaborates with the other participating federal agencies to help assure that the DOE funded work takes full advantage of, and does not unnecessarily duplicate, work being accomplished within the other agencies using their own budget allocations. Over the past seven years, the level and ultimate allocation of DOE-directed funds for this program over the past seven years is shown below: the distribution of funding for 2006 is shown in the pie chart to the right.

2000:	**$2,900,000**
2001:	**$9,900,000**
2002:	**$9,800,000**
2003:	**$9,400,000**
2004:	**$9,000,000**
2005:	**$9,400,000**
2006:	**$11,880,000**
2007:	**$12,000,000**



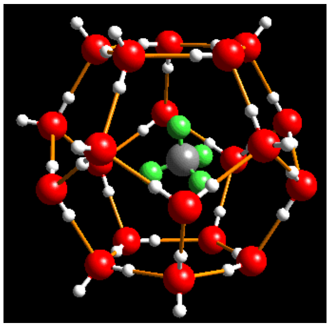
The allocation of DOE's FY2006 funding. The funding through cooperative agreements (competitively-awarded projects with industry and academia) totaled 53% of all funding. Non-competitive funding totaled 37% of all allocations, including congressional mandates (earmarks), funded Field Work Proposals with National Labs, agreements with other federal agencies (USGS, NRL, and NIST), and projects within NETL. Project support activities, such as travel, and funding for NETL (site-support) and DOE HQ (departmental mandates) support services accounted for the remaining 10% of all allocations.

2.4 Key Planning Assumptions

Using guidance from the ICC, the 2006 Interagency Roadmap was not limited by historical or anticipated funding levels. Instead, the goal was to describe what progression of R&D activities would be needed to achieve the goals of the MHR&D Act. Similarly, the interagency Five-year Plan describes activities that would be pursued assuming funding consistent with the existing authorization (totaling $150 million over the period FY2006 through FY2010). Also, this Five-year plan follows the Interagency Roadmap in preferring continued alignment of major field-based R&D activities with industry to the extent possible, but similarly realizes the necessity of considering options for direct coordination with state and federal agencies, as well as other nations, that offer opportunities to accelerate the achievement of critical milestones.

2.5 Program Drivers

Gas hydrate is an abundant natural form of clathrate, a unique chemical substance in which molecules of one material (e.g., water) form an open solid lattice that encloses, without chemical bonding, appropriately-sized molecules of another material (e.g., methane and related gases). Surveys conducted around the world's coastal oceans demonstrate that methane is the dominant gas contained in gas hydrates. Research during the past two decades has revealed that gas hydrates exist both as a void-filling material within shallow sediments (both onshore in the Arctic and within deep-water continental margins) and as massive "mounds" (often in association with unique chemosynthetic biota) on the deep sea floor. Once thought to be relatively rare in nature, gas hydrates are now widely considered to store immense volumes of organic carbon, rivaling, if not exceeding, the amount remaining in all the world's oil, natural gas, and coal deposits combined. A major driver for the U.S. program, and for a number of growing economies worldwide that currently rely on foreign energy sources, is the desire to determine, and then realize, the energy supply potential of gas hydrates.



Model of methane hydrate's cage-like structure in which methane (green/gray molecules) are enclosed - without direct chemical bonding - in voids within a solid water lattice (red/white molecules) (Heriot-Watt U.)

In addition to being a potential energy resource, gas hydrates represent a highly dynamic and poorly-understood component of the natural environment.   It is apparent now that this global methane reservoir is in constant flux, absorbing and releasing gas as it continually equilibrates to natural (and potentially man-made) perturbations in pressure, temperature and geochemical regimes. Understanding the behavior and implications of this previously unrecognized component of the natural environment on the carbon cycle, long-term climate, and seafloor stability is an additional critical component of the Interagency R&D program in methane hydrates.

2.6 The Federal Role

The federal government has a recognized role in addressing opportunities to catalyze long-range R&D with the potential to significantly promote the public good. To date, industry has clearly determined that R&D on the resource potential of gas hydrates is too high-risk or too long-term to justify investment. Instead, industry has elected to invest in gas hydrates R&D only to address issues that impact their core business – primarily safety concerns related to 1) secondary gas hydrate formation within pipelines and production equipment and 2) in strata that must be drilled through to reach deeper target horizons.   In contrast, a growing number of foreign governments, lead by Japan and India, but also including Korea, China, and Malaysia, are conducted gas hydrates R&D at scales that match or exceed the level of the U.S. investment.

The benefits of a successful federal program to study the resource potential and environmental implications of naturally-occurring gas hydrates includes; 1) increased assurance of the long-term sustainability of natural gas supply, with enormous ramifications for the nation’s economy and energy security, as well as the global balance of energy supply; 2) an improved understanding of our natural environment, providing significant benefits through more informed decision-making on a wide variety of issues including from ocean policy and global climate change; and 3) continuation of the nation’s role as a leader in fundamental scientific research and in the development of the information and technology that would support a future gas hydrates industry.

2.7 Program Long-Range Goals

As described in the Roadmap, the long-term goals of the program are to develop a comprehensive knowledge base and suite of tools/technologies that will enable 1) safe and economic methane production from hydrates while minimizing environmental impacts and 2) full integration of gas hydrate science into our understanding of global environmental and climate processes.

The program's primary goal for the next five years is to determine whether gas hydrates have significant potential as a future energy resource by:

- conducting a long-term production testing program on the North Slope of Alaska (to begin by 2008); and
- initiate (by 2010) a large-scale, multi-well exploration and assessment program in the Gulf of Mexico in collaboration with industry and interested international partners that will result in a marine production test.

As described in the Roadmap, the program's goals for year 2015 are as follows:

- conduct additional sampling, analyses, and testing to assess the economic feasibility of Arctic gas hydrate development and production;
- demonstrate viable technologies to assess and mitigate the environmental risks related to unintended gas hydrate dissociation related to ongoing "conventional" oil and gas E&P activities; and
- document the risks and demonstrate viable mitigation strategies related to safe drilling in gas hydrate-bearing areas;

The goals for year 2025 are as follows:

- conduct the necessary demonstrate the technical recoverability and assess the economic recoverability of marine gas hydrates;

- document the potential for and impact of natural gas hydrate degassing on the environment, including carbon cycling and climate change; and

- assess the potential to further extend marine gas hydrate recoverability beyond the initial producible areas.

Chapter 4 of this report outlines the specific near-term (5-year) accomplishments that the interagency Technical Coordination Team feels are necessary to keep the program on the course to accomplishing these goals.

2.8 Interagency Collaboration

In implementing this Five-year R&D plan, the DOE will continue to foster a true spirit of interagency involvement in the R&D activities conducted under the authority of the MHR&D Act. Representatives of the DOE, USGS, MMS, NOAA, BLM, NSF, and NRL will continue to meet at least twice per year, through both the ICC and the TCT, to discuss research activities and priorities. DOE will also continue to pursue a number of recent initiatives to further interagency communication and improve program effectiveness, including the incorporation of technical experts from the collaborating agencies into program planning and evaluation (merit reviews), the selection of fellowship awardees, and review of new project proposals. Active scientific collaboration will also continue, including: 1) the co-funding of projects of mutual interest, including IODP and critical international ventures; 2) the communication and incorporation of research results into our respective programs; and 3) direct funding to fellow agencies to tap into unique capabilities.

2.9 International Collaboration

The participants in the DOE-led interagency effort understand the outstanding value and contributions that collaboration with international gas hydrate R&D efforts can provide to our national R&D program. In particular, the USGS and the NRL have done exceptional work in building U.S.-International scientific collaboration in gas hydrates. The DOE-led interagency program will continue to build on this foundation through support of cooperative efforts with foreign R&D programs and researchers when meaningful opportunities arise. The agencies will also enable, to the extent possible and practical, opportunities for foreign parties to observe and participate in domestic gas hydrate programs. In the near-term, the USGS and the DOE will work to build on the great success of the recent exploration program conducted by the Indian government, and will encourage cooperative post-cruise studies that seek to integrate the findings of that expedition into the existing body of gas hydrate knowledge. In addition, international collaborations initiated by NRL and DOE with New Zealand and Chile are expected to continue, and new collaborations with additional countries will be explored. The agencies will similarly look to expand collaborative opportunities with Japan, and will continue to nurture ties built through cooperative ventures such as Mallik 2002 and an ongoing collaborative effort (with DOE, USGS, and others) to compare gas hydrate reservoir simulators. The program will also work to assure the success of the international database effort being conducted in association with CODATA.

Indian and U.S. Scientists collaborate aboard the Joides Resolution during NGHP (India) Expedition 01, summer 2006.

The program will also look to expand its interaction and collaboration with leading international working groups such as the United Nations Framework Conventional on Climate Change, the Intergovernmental Panel on Climate Change and others. DOE will continue its interaction with international organizations such as the Asia Pacific Economic Cooperation Forum (APEC), and the North American Energy Working Group (NAEWG) that have, in the past, included gas hydrates within their areas of interest. To help accomplish these linkages, the TCT will plan to establish a sub-working group of interested individuals to pursue these opportunities.

2.10 External Scientific Oversight and Review

In both 2005 and 2006, the DOE actively incorporated external scientific oversight into its program management through merit reviews of selected ongoing projects, external review of proposals for new projects under DOE solicitations, and ongoing consultation with the interagency committees and the Federal Advisory Committee (see Appendix B). This input has been extremely valuable, and the program will continue to solicit and carefully consider this input. Notably, an external merit review of the full program portfolio is expected for the fall of 2007 and will be accomplished biannually thereafter.

2.11 Ensuring Information Availability

Critical to a collaborative effort such as the national methane hydrate R&D program is the efficient dissemination of information. The DOE will continue to ensure that its researchers and research partners share research results through publication in peer-reviewed journals and regular participation in professional conferences and planning workshops. To further encourage wider data availability, the DOE signed (in 2006) an Interagency Agreement with the Department of Commerce's National Institutes for Standards and Technology (NIST) to develop a searchable, web-based gas hydrates database in association with the international CODATA gas hydrates effort. Going forward, the DOE will work with its research partners to ensure that research findings are available through this international database. An additional avenue for information exchange will be the continued quarterly publication of the DOE's electronic newsletter, *Fire in the Ice,* as well as regular maintenance of the program's web sites including latest project status and downloadable copies of all federally-funded reports and products.

2.12 Public Outreach

Essential to the ultimate achievement of the resource-related goals of this program will be the acceptance and understanding of the public. Although initial gas hydrate-derived resources may come from established oil and gas production areas (Alaska, the Gulf of

Mexico), full realization of gas hydrate's resource potential may mean tapping areas that currently lack an industry presence. Furthermore, gas hydrates have an uncertain association with past episodes of rapid climate change, raising concerns over the behavior of gas hydrate bearing sediments during potential methane extraction. Therefore, the program will actively search for ways to responsibly address these topics and to fully share the facts as they emerge on issues of rightful concern to the public.   To improve the availability of information on gas hydrates to those outside the scientific community, the DOE will work with the collaborating agencies to 1) provide through its websites (and promote the existence of) information, graphics, videos, and other materials in a format designed for use by educators (K to 12) on gas hydrate-related issues; 2) conduct a series of public lectures, symposia, and/or prepared articles for the non-technical press on the findings and implications of gas hydrate science; and 3) explore other activities that expand the awareness and understanding of gas hydrate issues and potential.

2.13 Providing Educational and Training Opportunities for New Scientists

Over the past five years, universities have played a major role in the program, both in support to the program's industry-led field projects, as well as in individual competitively-awarded R&D projects. The DOE and the collaborating agencies will continue to expand this commitment to providing educational and training opportunities to the next generation of energy scientists. Furthermore, in FY2007, the DOE established a formal, competitive, merit-based program in cooperation with the National Academy of Sciences that will recognize and provide full support to at least two "National Methane Hydrate R&D Program Fellows" per year at either the graduate or post-doctoral level.

Ms. Monica Heintz of U. California-Santa Barbara was selected as the initial NETL-NAS National Methane hydrate R&D Program Fellow

3.0 Overview of the State and Needs of Gas Hydrates R&D

Gas hydrate science is now clearly dominated by its major field expeditions, with critical and important contributions continuing to be made in the lab, in the design of new and improved exploration and laboratory analysis tools, and in numerical simulation. The following is a very brief outline of the current status of research in several critical areas.

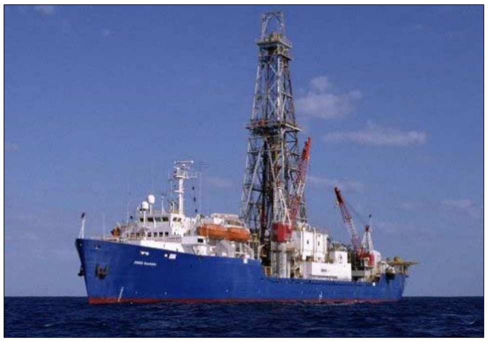
3.1 Field Production Tests

Mallik, Northwest Territories Canada, site of the Mallik 2002 Gas Hydrate Production Research Well Program

Since the Mallik production experiment in 2002, there has been a broad consensus in the gas hydrate scientific community that a long-term field production test is the most critical need in advancing gas hydrate science as it relates to resource issues. The Japanese government, in association with the government of Canada, is currently preparing for an extended production test at Mallik over the next two winter seasons (2006/2007 and 2007/2008). Ongoing discussions with Japan will clarify the ability of the U.S. program to collaborate in this effort or to access its findings. In the U.S., a long-term and continuous production test is currently planned as part of the project with BP Exploration (Alaska), Inc, and should begin, with both BP and DOE approval, by FY2008. FY2009 is anticipated as the approximate date for an initial marine production test by the Indian government; extensive U.S. involvement (USGS and DOE) in that effort, when it occurs, is expected.

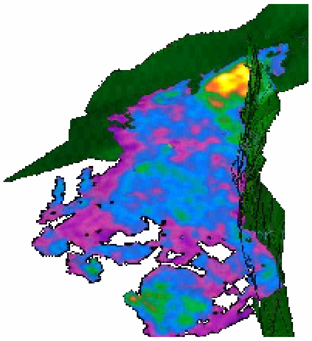
3.2 Major Field Programs

Although a number of comprehensive field studies have occurred in the past decade, the vast majority of potential global gas hydrate occurrences remain unsampled. In recent years, three seminal marine expeditions and two critical arctic field programs have occurred that will widely inform the near-term efforts of the program. The first marine effort, in 2004, was the Integrated Ocean Drilling Program's (IODP) Expedition 311 (with major U.S. funding provided by NSF with contributions from the USGS and DOE) within the accretionary wedge offshore Vancouver Island. X311 (building on the ODPs earlier Leg 204 to "Hydrate Ridge") has greatly advanced the gas hydrate community's understanding of the primary controls on gas hydrate distribution in nature; including the importance of gas source, gas solubility, and the presence of suitable host lithologies and structures. The second expedition, conducted by the Chevron JIP in the Gulf of Mexico in 2005, probed drilling safety issues related to gas hydrate-bearing fine-grained sediments and provided the first ground-truthing of pre-drill estimates of gas hydrate occurrence from remote sensing data. The third, India's summer 2006 Expedition 01 (with major support by the USGS and additional contributions by DOE), collected an unprecedented volume of data and samples from a wide range of gas hydrate-bearing geologic environments.



The drillship Joides Resolution was the platform for ODP leg 204, IODP X311, and NGHP Expedition 01 (Ocean Drilling Ltd.)

In the Arctic, the 1998 and 2002 Mallik programs, accomplished the government of Japan through a broad international consortium, have provided an enormous wealth of data on the nature and behavior of gas-hydrate bearing sandstones. The DOE-USGS effort with BP Exploration (Alaska) at Milne Point early in 2007 has built significantly on the Mallik data, providing confirmation of exploration methods and extensive new data on gas hydrate reservoir petrophysics. A primary near-term goal of the program will be to fully integrate the findings of these expeditions into the existing body of knowledge to obtain a fuller view of the overall controls on hydrate occurrence in nature.



Seismic amplitude display of the fault-bounded "Mt. Elbert" gas hydrate prospect, Milne Pt. Alaska, (BPXA; USGS)

3.3 Exploration Tools

Currently, the most promising tool for remote detection and characterization of gas hydrate deposits, either in the permafrost or in the deep ocean, is the integration of acoustic data with existing (or newly acquired) well log data. In 2005 and 2006, BP, the USGS, and others demonstrated the ability to delineate and describe discrete accumulations of hydrate-bearing reservoir sandstones within the Milne Point region of the Alaska North Slope (ANS). The ability was confirmed with the successful drilling of the Mt. Elbert prospect in early 2007. In 2005, the Chevron Gulf of Mexico Joint Industry Project (JIP) demonstrated an ability to discern general trends of gas hydrate occurrence in the marine environment through advanced velocity analysis of existing 3-D seismic data. Currently, the JIP is working to determine its ability to delineate the extent of a known (observed in a borehole with a full log suite) gas hydrate-bearing sandstone through analysis of existing seismic data. Ongoing work with Stanford University and Rock Solid Images, Inc., is advancing the fundamental rock-physics models that are needed to reliably and consistently infer gas hydrate occurrence from acoustic data. A project with the University of Texas-Austin plans to build on the success of groups in Norway and elsewhere that demonstrate the ability of four-component ocean-bottom seismic data to improve remote sensing capabilities in gas hydrate detection and quantification. In addition to seismic data, DOE has recently awarded a contract to Baylor University to apply a promising electro-magnetic (EM) resistivity technology to deep water hydrate detection, and is also supporting EM work by other groups as part of the JIP activities. NRL, supported by DOE and ONRG, will continue working on preliminary gas hydrate site evaluations with a combination of seismic surveys, geochemical analyses of piston core porewaters, and heatflow probes. Going forward, the program will work to integrate these methods of detection into a full exploration system that integrates gas hydrate indicators derived from modeling of the relevant geologic, geochemical, and hydrologic systems.

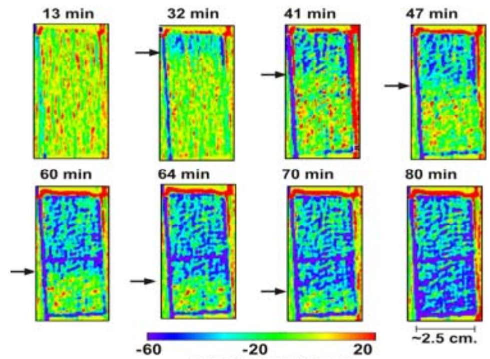
3.4 Field Analysis Tools

Currently, the analyses of subsurface gas hydrate accumulations occur primarily through well logging and collection, handling, and analysis of conventional and pressure cores. Well logging technologies are currently well advanced, and based on the successes of Logging-while drilling (LWD) deployments in IODP Expedition 311, the Gulf of Mexico JIP, and India Expedition 01, future field projects will likely to make use of up-front LWD to efficiently screen sites and collect *in-situ* property data. Although LWD deployment is costly, its advantages over the difficult and time-consuming open-hole wireline logging are considerable. Among the technological improvements needed for more efficient LWD is a reliable sonic velocity tool. Conventional coring continues to rely heavily on technologies developed nearly two decades ago (IODP's Advanced Piston Coring (APC) and Extended Core Barrel (XCB) systems). Although these technologies work sufficiently well, recovery remains poor in non-cohesive sediments, and core quality degrades rapidly as formation stiffness increases. A major development from NGHP Expedition 01 is the significant increase in the reliability of pressure coring technologies. In particular, the HYACE Rotary Corer (HRC) performed very well and will likely be viewed by IODP and others as a reliable and fully-operational technology in certain geologic settings. Through the Chevron/DOE Gulf of Mexico JIP, the program will look to further extend the operational capabilities of pressure coring to include poorly-consolidated sands systems by developing a modified version of the Pressure Temperature Coring System (PTCS) first applied by the Japanese in the Nankai Trough with apparent great success.


The IPTC is used to measure geophysical and mechanical properties of hydrate bearing cores under in situ pressures (Ga. Tech/Chevron JIP)

With regard to sample analysis, recent work is showing that critical physical property measurements become unreliable with even minor sample disturbance. Therefore, tools for making measurements on pressure cores, including further development of Georgia Tech Integrated Pressure Testing Chamber (IPTC), will continue to be a program priority. Beyond pressure core analysis, special emphasis within the JIP will be given to the development of tools that can be taken to the seafloor or downhole to measure gas hydrate-sediment characteristics *in situ*.

3.5 Laboratory Analyses



Progressive X-Ray CT Scans of hydrate dissociation in a porous media (LBNL)

Gas hydrate research in the lab has made great advances, with several groups currently able to create samples and make meaningful property measurements. An external merit review of the ongoing activities in the National Labs (January 2006) provided several key recommendations that build upon the findings of an earlier workshop hosted by the USGS (August, 2005) and were subsequently closely echoed in a recent workshop hosted by the Colorado School of Mines (September 2006). Implementation of recommendations for increased use of standards, incorporation of geomechanical issues, collection of measurements throughout samples (not simply on the surface), and focus on transient properties of gas hydrate-bearing porous media (rather than intrinsic properties of gas hydrate) will be a priority of the laboratory component of the program going forward. In addition, many laboratories continue to investigate the most appropriate gas hydrate-formation techniques. New methods will continue to be developed that more closely mimic both the process and the results obtained in specific natural settings, although it is recognized that the variety of natural processes and results is not yet fully known.

3.6 Numerical Simulation

Numerical simulation will continue to be a critical component in the Interagency R&D program. Simulation capabilities will inform the selection, design, and analysis of results for both field and laboratory efforts. At present, several unique simulators exist, and the leading codes are participating in a comparison effort designed to reveal both their unique strengths and areas for further improvement. Completion of this effort, and the ultimate creation of a community-based, publicly-available code that contains the scientific rigor and utility required for the evaluation of field gas hydrate occurrences, will be a major focus of the program.

4.0 Planned R&D Activities and Milestones by Long-Range Goal (2007-2011)

The following provides descriptions of the types of activities and areas of investigation planned for the next five years that are necessary to keep the program on track to achieve its long-term goals. In each section, proposed milestones are presented as a series of bulleted items with the initial date indicating the Fiscal Year in which the milestone is expected to be achieved. The parentheses that follow show the lead federal agencies addressing that issue.

4.1 Cross-cutting: Milestones Directly Supporting All Program Goals

Many activities within the program provide fundamental data or programmatic functions that will benefit the ultimate achievement of the program's primary R&D goals.

Key Cross-cutting Programmatic and Procedural Milestones

4.1.1 **Ongoing:** Ensure that student researchers continue to have a meaningful role in the program's major projects and that funding policies enable universities and research institutions to attract and retain the best students (DOE, other agencies).

4.1.2 **Quarterly:** Publication of the electronic newsletter, *Fire in the Ice* (DOE).

4.1.3 **Quarterly:** Post up-to-date and comprehensive descriptions and of all DOE funded activities on the NETL methane hydrates website (DOE).

4.1.4 **FY2007:** Establish clear objectives and activities for participation and collaboration with the Indian R&D program (USGS, DOE, and other agencies).

4.1.5 **FY2007:** Establish a sub-group of interested scientists within the interagency working groups to focus on opportunities for effective programmatic outreach opportunities including lecture series, educational materials, and others (DOE, other agencies).

4.1.6 **FY2007:** Award initial Methane Hydrate R&D Program fellowship via program established with the NAS. Make from 1 to 3 additional awards annually thereafter (DOE, with selection assistance from members of other agencies).

4.1.7 **FY2007:** Hold first biannual external merit review of work funded through Cooperative Agreements and Interagency Agreements (DOE).

4.1.8 **FY2008:** Develop clear objectives and activities for collaboration with Japan and other emerging Asian gas hydrate R&D programs (USGS, DOE, NRL, and other agencies).

4.1.9 **FY2008:** Hold second biannual external merit review of work funded through National Laboratory field work proposals (DOE, with assistance for collaborating agencies).

4.1.10 **FY2008:** Develop, and subsequently maintain and improve, internet-based informational content suitable for use by K-12 educators (DOE, other agencies).

4.1.11 **FY2008 and FY2010:** If available funding permits, conduct a public workshop designed to identify existing R&D and data gaps to guide solicitation of new projects (DOE).

4.1.12 **FY2008/Ongoing:** Draw representatives of 20 nations to the 6^{th} International Workshop on Methane Hydrate Research and Development in Bergen, Norway. Provide ongoing support for the regular international methane hydrates meetings (DOE, NRL, others).

Key Cross-cutting Technical Milestones

4.1.13 **Ongoing:** Maintain databases of gas hydrate relevant public data, and make those data available as feasible to collaborating agencies and other researchers (USGS, MMS, BLM).

4.1.14 **Ongoing:** Continue to pursue opportunities to partner with industry on new data collection in wells of opportunity (USGS, MMS, BLM, DOE).

4.1.15 **Ongoing:** Continue to work with DOI to access and utilize existing data in the Gulf of Mexico and elsewhere for the assessment of gas hydrate occurrence (USGS, MMS, DOE).

4.1.16 **FY2007:** Quantify the impacts of depressurization of pressure core samples on sample integrity (USGS, DOE).

4.1.17 **FY2007:** Finalize design and conduct field tests of new pressure coring tools (DOE (Chevron JIP)).

4.1.18 **FY2007:** Support further testing and development of the Georgia Tech IPTC device through testing of pressure cores obtained during Indian Expedition 01 (DOE, (Chevron JIP)).

4.1.19 **FY2007:** Document dramatic improvements in usability and run-time performance for Tough+Hydrate (DOE).

4.1.20 **FY2007:** Integrate results of laboratory investigations into the basic relationships of intrinsic permeability, relative permeability, and capillarity within hydrate-bearing sandstones (DOE).

4.1.21 **FY2007:** Create a gas hydrates mark-up language (GHML) to support development of global searchable hydrates database (DOE).

4.1.22 **FY2007:** Identify appropriate locations with the Gulf of Mexico to assess the utility of 4-D OBS seismic in the detection and characterization of hydrate occurrence (DOE).

4.1.23 **FY2007:** Establish an internet site housing the problems, solutions, and analyses of results from the international code comparison effort (DOE, USGS).

4.1.24 **FY2008:** Pursue new opportunities for *in situ* measurement of gas hydrate/sediment physical and chemical properties (DOE, TBD).

4.1.25 **FY2007:** Publish a dozen or more articles based on work conducted within Phase 1 of the Gulf of Mexico JIP within a peer reviewed journal (DOE, USGS, NRL, other agencies)

4.1.26 **FY2008:** Publish improved rock-physics models for interpretation of hydrate occurrence from sediment acoustic responses that incorporates the latest available data (DOE).

4.1.27 **FY2008:** Conduct field tests of the utility of electromagnetic (EM) resistivity surveys as a means of remote detection/quantification of hydrates deposits in deepwater marine environments (DOE).

4.1.28 **FY2008:** Complete the initial phase of the international reservoir simulation code comparison study in collaboration with scientists from Japan and Canada with publication of the results of a field-scale problem based on the data acquired on the Alaska North Slope (DOE, USGS).

4.1.29 **FY2008:** Demonstrate the ability to collect and conduct sophisticated geophysical and mechanical measurements on pressure cores in marine sandstones bearing hydrates (DOE (Chevron JIP)).

4.1.30 **FY2008:** Complete modeling studies of well-bore stability issues related to production/dissociation from unconsolidated gas hydrate-bearing sandstones (DOE).

4.1.31 **FY2008:** Create a data query portal and search engine that can be access data from a wide range of international gas hydrate databases (DOE).

4.1.32 **FY2009:** Create a comprehensive internet-based database of gas hydrates information (DOE, other agencies).

4.1.33 **FY2009:** Integrate experimental results of the impacts of geomechanical deformation of gas hydrate reservoir hydraulic properties into existing gas hydrate numerical simulation capabilities (DOE).

4.1.34 **FY2011:** Develop geologically-based mathematical models for the distribution of gas hydrate within marine gas hydrate systems based on integrated pore scale models of gas migration, sediment failure, and hydrate formation (DOE).

4.2 Safe Drilling in Gas-Hydrate-Bearing Areas

The following are critical near-term milestones that contribute to the program's effort to provide the information and technology necessary to assure safe drilling of oil and gas wells in gas-hydrate bearing areas.

4.2.1 **FY2008:** Provide updated well-bore stability model (DOE (Chevron JIP)).

4.2.2 **FY2008:** Complete experimental work to determine geomechanical properties of end-member marine gas-hydrate-bearing sediments (DOE).

4.2.3 **FY2009:** Complete predictive studies of gas hydrate bearing sediment stability under mechanical and thermal loading (DOE).

4.2.4 **FY2009/2010:** Publish Gulf of Mexico JIP final project report that integrates drilling safety findings related to both low-gas-hydrate saturation shale reservoirs and high-gas-hydrate saturation sandstone reservoirs (DOE (Chevron JIP)).

4.2.5 **FY2010:** Demonstrate effective marine gas hydrate prediction, detection and quantification technologies (DOE, USGS, MMS, NRL).

4.3 Production Potential of Gas Hydrates

The following are critical milestones specific to the program's effort to realize a comprehensive assessment of gas hydrate production potential on the Alaska North Slope, in the Gulf of Mexico, and in the remaining U.S. Outer Continental Shelf.

4.3.1 **FY2007:** Collect data from well log, core, and borehole-scale reservoir performance tests from several gas hydrate-bearing horizons at the Mt. Elbert prospect, Milne Point, Alaska to provide insight into pre-well seismic evaluation of gas hydrate occurrence and critical reservoir properties (DOE, USGS, (BPXA)).

4.3.2 **FY2007:** Complete geochemical, geological, and geophysical studies to determine the presence and potential production history of gas hydrates at the Barrow and Walakpa gas fields in partnership with the North Slope Borough in order to determine the area's suitability for further field evaluation or potential test drilling (DOE, USGS).

4.3.3 **FY2007/2008:** Conduct a drilling and logging program (and potentially a limited flow testing program as well) over several high-priority sites in the Gulf of Mexico that have evidence of high-saturation gas hydrate accumulations within sandstone reservoirs. Use data to better characterize gas hydrate reservoirs and ground-truth pre-well predictions of reservoir extent and nature (DOE, USGS, MMS (Chevron JIP)).

4.3.4 **FY2008:** Incorporate results of the DOI's initial assessment (methane in-place as well as technically-recoverable) of gas hydrate resources on the North Slope of Alaska and on the U.S. Outer Continental Shelf (U.S. Department of Interior into program planning and priorities and adjust the nature of the targets for field investigation as appropriate (USGS, MMS, BLM), DOE).

4.3.5 **FY2008:** Initiate a program of regional resource assessment and characterization in the Gulf of Mexico that incorporates extensive advanced geophysical analysis with geochemical data and geological modeling for reservoir occurrence following the model set by the ongoing MMS assessment (DOE).

4.3.6 **FY2008/FY2009:** Initiate an initial production test program on the ANS that couples investigation of production technologies with monitoring of environmental impacts such as gas release, permafrost affect, and land subsidence. The currently preferred location for the test is the confirmed hydrate accumulations in the western portion of the Prudhoe Bay unit (DOE, USGS, BLM (State of Alaska DNR and/or interested industry partners)).

4.3.7 **FY2008:** Complete integrated bench-scale studies and numerical simulation of the potential feasibility of CO_2 injection and resultant CO_2/CH_4 exchange as a means of coupling CO_2 sequestration with effective methane production while enhancing reservoir stability (DOE).

4.3.8 **FY2008/FY2009/FY2010:** Conduct incremental analyses of the potential economics of future gas hydrate production on the North Slope of Alaska that incorporates data as provided by work in Alaska and elsewhere (DOE).

4.3.9 **FY2009:** Solicit and select additional laboratory and modeling efforts to test and refine the most promising production technologies and address specific reservoir engineering and environmental issues identified in the initial field production tests (DOE).

4.3.10 **FY2009:** Initiate a second gas hydrate evaluation project on the ANS, potentially in an area outside the Eileen accumulation. Location, well design, and ultimate production test method to be influenced by progress within the Prudhoe region and will be intended to provide a second location of differing geological conditions to test emerging gas production and environmental monitoring technologies (DOE, USGS, BLM).

4.3.11 **FY2009:** Establish the ability to conduct meaningful production simulations within a laboratory setting that includes natural heterogeneities and fully distributed temperature and other pertinent data in order to provide a controlled setting to cost-effectively screen new ideas or investigate phenomena of interest (DOE).

4.3.12 **FY2009:** Complete controlled experimentation and modeling to isolate the impact of variations in reservoir lithology, pore geometry, and other factors on gas hydrate destabilization due to various drivers (heat, pressure drop, chemical inhibition) (DOE).

4.3.13 **FY2010:** Initiate/continue Gulf of Mexico exploration program and initiate project/program designed to lead to production testing and environmental monitoring activities in the Gulf of Mexico (DOE, USGS, MMS).

4.3.14 **FY2010:** Calibrate and improve existing reservoir simulation codes using long-term production test results generated in the initial production testing operations both in the Arctic, and potential in deep marine environments (DOE, USGS and linkages to international R&D programs).

4.3.15 **FY2010:** Depending upon the findings of the DOI gas hydrate resource assessment and the progress of domestic and international field programs, evaluate the appropriateness of initiating a program to assess potential hydrate accumulations with resource potential along the Atlantic and/or Pacific coasts (DOE, USGS, MMS).

4.3.16 **FY2010/2011:** Conduct initial analyses of the economic potential of marine gas hydrate production incorporating data obtained from international collaborations and the program's work in the Gulf of Mexico (DOE).

4.3.17 **FY2011:** Present final interpreted results of initial ANS long-term production tests and associated environmental monitoring activities, and plans for further testing/evaluation of ANS gas hydrate resource potential (DOE, USGS, BLM).

4.3.18 **FY2011:** Incorporate the findings of additional exploratory drilling and testing into Outer Continental Shelf resource assessments (USGS, MMS, DOE, BLM, NRL).

4.4 Assessing the Potential for, and Impacts of, Gas Hydrate Degassing

The following are critical milestones related to the program's efforts to document the role of gas hydrate in the natural environment (including carbon cycling, global climate, and large-scale instabilities of the continental margins) and to understand the potential impacts of methane release and sea-floor/permafrost instability related to gas hydrate dissociation due to either human activity or natural phenomena.

4.4.1 **Ongoing:** Continue to pursue means to integrate gas hydrate-related data into leading oceanic and global climate modeling efforts (DOE, NOAA, NRL).

4.4.2 **Ongoing:** Seek opportunities to collaborate in the development of local, regional, and global sea-floor process monitoring stations through existing projects (such as with CMRET) and potential new collaborations with OOI/ORION, Canadian (the Neptune Program) and/or European efforts (DOE, NOAA, NRL, other agencies).

4.4.3 **FY2007:** Work with NOAA to develop an advance solicitation that will access the global climate modeling community and provide additional time for proposal response and review (DOE, NOAA).

4.4.4 **FY2008:** Work with the Chevron JIP to establish clear objectives and activities that will provide relevant information on the effects and implications of drilling and other non-natural disturbances on methane hydrate stability (DOE, other agencies (Chevron JIP)).

4.4.5 **FY2008:** Complete analysis of rates of methanogenesis in deep marine environments and incorporate that data into global carbon cycling models (DOE).

4.4.6 **FY2008:** Initiate capability for 4-D geophysical monitoring at the Mississippi Canyon 118 site through acoustic, electric resistivity and other means (DOE, MMS, NOAA).

4.4.7 **FY2008:** Conduct collaborative North America west coast sub dives for research on surface methane hydrate deposits (NOAA, NRL).

4.4.8 **FY2008:** Publish a review and synthesis of recent surveys of geophysical and geochemical indicators of gas hydrate occurrence in different coastal regions, including the Cascadia Margin, Texas-Louisiana Shelf, Mid-Chilean Margin, Blake Ridge and Hikurangi Margin off Northeastern New Zealand (NRL).

4.4.9 **FY2008:** Complete studies of historical variation in carbon inputs and potential methane flux rates through analysis of sea-floor sediments in a variety of global settings (DOE).

4.4.10 **FY2008:** Initiate geochemical and biogeochemical evaluation of methane cycling related to methane hydrate deposits and global warming in the Arctic Ocean through the Pacific Energy and Climate Change Program (NRL).

4.4.11 **FY2008:** Complete geochemical studies of sediments from the Bering Sea for evidence of past rapid natural gas hydrate dissociation and any correlation to interpreted periods of global climate change (DOE).

4.4.12 **FY2009:** Complete installation of sea-floor monitoring station in Gulf of Mexico Mississippi Canyon Block 118 (MMS, NOAA, DOE).

4.4.13 **FY2009:** Expand national and international collaboration for coastal hydrate exploration and global warming prediction in the Arctic Ocean through the PECCP (NRL).

4.4.14 **FY2009:** Complete the coupling of geomechanical and pore scale fluid pressure/flow modeling to describe the dynamic interactions of gas and water subjacent to marine hydrate systems (DOE).

4.4.15 **FY2009:** Incorporate into second round of Gulf of Mexico field studies efforts to monitor the effects of drilling and testing on gas hydrate stability, sediment physical properties, and released gas and water migration (DOE other agencies).

4.4.16 **FY2010:** Complete analyses of the nature and effectiveness of the ocean column microbes in controlling the flux of methane from the seafloor to the atmosphere (DOE).

5.0 Concluding Remarks

This document presents an overview of the near-term (FY2007 through 2011) research priorities and milestones for the DOE-led interagency program in natural methane hydrates. This plan, taken together with the earlier long-range *Interagency Roadmap,* will be the subject of a report to Congress from the methane hydrate Federal Advisory Committee by August, 2007. Subsequently, this plan will be revisited annually to reflect the continuing progress of the program.

Appendix A: The Interagency Coordination Committee and Technical Coordination Team

Interagency Coordination Committee:

- Jim Slutz, Chairman, DOE/Office of Fossil Energy
- Edith Allison, DOE/Office of Fossil Energy
- Nick Douglas, DOI/Bureau of Land Management
- Bilal Haq, National Science Foundation
- Bob LaBelle, DOI/Minerals Management Service
- Brenda Pierce, DOI/United States Geological Survey
- Bakhta Rath, DOD/Naval Research Laboratory
- Richard Spinrad, DOC/National Oceanic and Atmospheric Administration

Technical Coordination Team:

- Ray Boswell, Chairman, DOE/National Energy Technology Laboratory
- Roger Amato, DOI/Minerals Management Service
- Rick Coffin, DOD/Naval Research Laboratory
- Tim Collett, DOI/U.S. Geological Survey
- George Dellagiarino, DOI/Minerals Management Service
- Bob Fisk, DOI/Bureau of Land Management
- Matt Frye, DOI/Minerals Management Service
- Joe Gettrust, DOD/Naval Research Laboratory
- Bilal Haq, National Science Foundation
- Deborah Hutchinson, DOI/U.S. Geological Survey
- Beth Maclean, DOI/Bureau of Land Management
- Tamara Neukam, DOI/Bureau of Land Management
- Kimberly Puglise, DOC/National Oceanic and Atmospheric Administration
- Kelly Rose, DOE/National Energy Technology Laboratory

Appendix B: The Federal Advisory Committee

Installed in May, 2006

- Chair: E. Dendy Sloan, Colorado School of Mines
- Peter Brewer, Monterey Bay Aquarium Research Institute
- Richard Charter, National OCS Coalition
- Nader Dutta, Schlumberger
- Art Johnson, Hydrate Energy International
- Emrys Jones, Chevron
- Miriam Kastner, Scripps Institute of Oceanography
- Devinder Mahajan, Brookhaven National Laboratory
- Steve Masutani, University of Hawaii
- Robert Swenson, Alaska Department of Natural Resources
- Jean Whelan, Woods Hole Oceanographic Institute
- Scott Wilson, Ryder Scott Petroleum Engineers
- Robert Woolsey, University of Mississippi
- Kim Juenger, World Energy Systems, Inc.

Appendix C: Current Program Portfolio

Department of Energy:

Research Projects Started FY2001

- ***BP Exploration (Alaska)*** with research partners U. Alaska-Fairbanks, U. Arizona, U.S. Geological Survey, Interpretation Services Inc., APA Petroleum Consultants, and the Ryder-Scott Company. Phases 1 and 2 utilized proprietary 3-seismic data provide by BP as well as existing well log data/interpretations provide by the USGS to conduct geologic, geophysical, and numerical/economic modeling in the Milne Pt. unit of the greater Prudhoe Bay region. The project established the existence of 14 separate mappable hydrate prospects and selected one ("Mt. Elbert") as the target of Phase 3 field activities. A well to be drilled, logged, cored, and tested in 2QFY07 will provide information relative to BP/DOE's joint decision on progression into a subsequent long-term production test phase.

- ***Chevron Gulf of Mexico Joint Industry Project*** with research partners ConocoPhillips, U.S. Geological Survey, Minerals Management Service, Total, Schlumberger, Rice U., Georgia Institute of Technology, Reliance Industries, JOGMEC, and Scripps Oceanographic Institute. Phases 1 and 2 resulted in the 2005 drilling, logging, coring of two sites in the Gulf of Mexico to investigate safety aspects of hydrates in fine-grained sediments. Phase 3 (currently in planning) will pursue improved pressure coring tools, evaluate locations for gas hydrates within coarse-grained (sand) sediments, conduct initial drilling and LWD evaluation of those sites (4Q2007) and conduct follow-on drilling and coring operations (FY2008/2009).

Jointly-funded Projects

- ***University of Mississippi/Center for Marine Research and Environmental Technology*** led a large research group in continuing to develop and install a sea-floor monitoring station in Mississippi Canyon Block 118. This is a congressionally-directed program that is jointly funded by the MMS and NOAA.

Research Projects Awarded in FY2005

- ***Stanford University*** is investigating fundamental rock-physics models for improved evaluation of the seismic response of hydrate-bearing strata.

- ***Battelle Memorial Institute and U. Alaska-Fairbanks*** are conducting reservoir simulation (using STOMP) and bench-scale experimentation to determine the feasibility of CO_2 injection as a means of enhance reservoir stability, methane production, and CO_2 sequestration.

- ***University of Texas-Austin*** is utilizing an existing four-component ocean-bottom seismic dataset in the Green Canyon area (Gulf of Mexico) to determine the value and methodologies for improved hydrate characterization from advanced seismic.

- ***Woods Hole Oceanographic Institute*** is utilizing pre-existing cores from the Bering Sea to probe the links between sediment geochemical signatures, massive episodes of past methane release, and known global climatic events.

- ***Texas A&M University, U. California-Berkeley, and Lawrence Berkeley National Lab*** are conducting integrated reservoir simulation, numerical simulation, and lab-scale experimentation to probe the nature and implications of the geomechanical response of hydrate-bearing sediments under changing conditions (both natural and induced).

Research Projects Awarded in FY2006

- ***Baylor U.*** will develop and field test equipment and procedures for conducting direct current resistivity profiling for hydrate detection in deep-water settings.

- ***The North Slope Borough*** will conduct new gas sampling and utilize existing geologic, geophysical and production data to probe the occurrence and potential production contribution of methane hydrates within the Barrow and Walakpa fields of the Alaska North Slope.

- ***Rice University*** will conduct a coordinated multi-disciplinary study of marine methane hydrate issues, including geochemical profiling, geological process modeling, geomechanical investigations, and geophysical modeling.

- ***The University of Texas-Austin*** will conduct theoretical modeling of gas-water-sediment interactions both below and within the hydrate stability zone to provide prediction of sediment stability, fracturing, and hydrate and free gas occurrence.

- ***Georgia Institute of Technology and Oak Ridge National Lab*** will conduct multi-scale experiments on hydrate-sediment interactions to gain insight into the response of various systems to a range of possible production mechanisms.

- ***Rock Solid Images*** will investigate existing seismic/well log data sets to generate new cumulative seismic attributes that are predictive of hydrate occurrence.

FY2006 Projects with the DOE National Labs

- ***Lawrence Berkeley National Lab*** pursued the further development and calibration of ToughFX/HYDRATE and conducted focus laboratory experiments on hydrates in porous media.

- ***Pacific Northwest National Lab*** continued development of IR-based technologies for field applications, participated in the NGHP Expedition 01, and worked to develop and validate resonant ultrasound spectrometry as a novel investigative tool for hydrate research in the lab.

- ***Oak Ridge National Lab*** began an effort to instrument the 72-liter sea-floor process simulator and develop/implement procedures for conducting lab simulations of well-based production from hydrate reservoirs.

- ***Idaho National Lab*** with partners Monterey Bay Aquarium Research Institute, Oregon State University, and Rice University are establishing realistic rates for marine methane production and incorporating those data into existing global carbon cycle models.

- ***The National Energy Technology Lab*** continued to direct an international comparison of existing hydrate reservoir simulators, conducted molecular modeling studies, and continued development of a practical tool for accurate and non-destructive thermal property measurement.

- ***Brookhaven National Lab*** continued development of the FISH unit for the investigation of the dynamics of methane hydrate within well-characterized fine-grained sediments.

FY2006 Interagency Agreements

- ***The U.S. Geological Survey*** provided ongoing technical expertise and recommendations for the programs major field projects (BP, Chevron JIP), and conducted experimental laboratory studies of the effects of short-term depressurization on cores (with LBNL) using elastic and thermal properties measured on gas-hydrate-sediment mixtures.

- ***The National Institute for Standards and Technology*** initiated an effort to produce a database of methane hydrate information that would be searchable through the World Wide Web.

- ***The Naval Research Lab*** conducted geophysical and geochemical surveys to provide new information on the relationships between geophysical response, hydrate occurrence, microbiology and active methane flux offshore New Zealand.

Other Initiatives

- ***Queens College*** and the Colorado School of Mines produced a Gas Hydrates Mark-up Language and associate software to produce a framework for a searchable internet-based hydrates database.

- ***NETL and the National Academy of Sciences*** established a fellowship program to support promising graduate students in furthering their academic careers.

Acronyms Used

ANS	Alaska North Slope
APC	Advanced Piston Core (IODP)
APEC	Asia-Pacific Economic Cooperation Forum
BLM	Bureau of Land Management
BPXA	British Petroleum Exploration (Alaska)
CA	Cooperative (Research and Development) Agreement
CMRET	Center for Marine Resources and Environmental Technology (U. Miss.)
CODATA	Committee for Data for Science and Technology
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DNR	Division of Natural Resources (Alaska)
EM	Electro-magnetic
E&P	Exploration and Production
EPACT	Energy Policy Act (2005)
FAC	Federal Advisory Committee
FPC	Fugro Piston Core
FY	Fiscal Year
GHML	Gas Hydrate Markup Language
GOM	Gulf of Mexico
HRC	HYACE Rotary Core

ICC	Interagency Coordination Committee
INL	Idaho National Laboratory
IODP	Integrated Ocean Drilling Program
JIP	Joint Industry Project
LBNL	Lawrence Berkeley National Laboratory
LWD	Logging-while-drilling
MBARI	Monterey Bay Aquarium Research Institute
MHR&D	Methane Hydrate Research and Development
MMS	Minerals Management Service
NAS	National Academy of Sciences
NETL	National Energy Technology Laboratory
NGHP	National Gas Hydrate Program (India)
NIST	National Institute for Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NSF	National Science Foundation
ODP	Ocean Drilling Program
ONRG	Office of Naval Research (Global)
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
TCT	Technical Coordination Team
USGS	United States Geological Survey
XCB	Extended Core Barrel (IODP)