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NUCLEAR SCIENCE

Performance of Participants in DOE's Inertial Confinement Fusion Program

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Resources, Community, and
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The Honorable Les Aspin
Chairman, Committee on Armed Services
House of Representatives

Dear Mr. Chairman:

On June 30, 1989, you requested through House Armed Services Committee Report 101-121, accompanying the Defense Authorization Act (P.L. 101-189), that we examine certain aspects of the Department of Energy's (DOE) Inertial Confinement Fusion (ICF) program.[1]

Specifically, the Committee report requested that we

> "review the performance of KMS Fusion, Inc., and the other five participants in the ICF program, to determine the performance of each in relation to the program objectives of the ICF program and the specific tasks and milestones that have been established for each participant in support of the overall program objectives."

We subsequently met with the Committee to discuss the request and agree on what approach to take.

The Committee report also directed us to concentrate on the performance period of January 1, 1987, through June 30, 1989, and to coordinate our activities with those of the National Academy of Sciences to avoid any duplication. The Committee requested that the Academy review the technical feasibility of the ICF concept, including the progress that the program's participants have made since the Academy's 1986 review of the ICF program.

This request was precipitated by DOE's allegation that the performance of one of the six participants in the ICF program, KMS Fusion, Inc. (KMS), "has not met program

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[1]The total ICF program budget for fiscal year 1989 was about $165 million.

expectations." KMS, a private contractor, supports the inertial nuclear fusion research experiments of the other participants, mainly by providing fusion target components for these experiments.

Other participants in the program include DOE's Lawrence Livermore, Los Alamos, and Sandia National Laboratories, the Naval Research Laboratory, and the University of Rochester. Laboratory research performed by these ICF participants involves using lasers or particle beam accelerators (referred to as "drivers") to bombard tiny fusion fuel capsules (referred to as "targets") in order to cause a momentary fusion reaction.[2] Each is involved with investigating a different conceptual approach to ICF. For example, Livermore and Rochester use glass lasers, Los Alamos uses a gas laser, the Naval Research Laboratory is transitioning from a glass to a gas laser program, and Sandia is developing a particle beam accelerator to perform ICF tests. Most of the experiments performed by these laboratories have never been done before; thus, they are on the leading edge of ICF technology.

SUMMARY OF FINDINGS

In summary, we found that KMS' performance during the period we reviewed was mixed. While KMS successfully performed some support tasks, it had difficulties with other tasks mainly because of problems transitioning to its new support role in the ICF program. These transition problems resulted in unacceptable performance by KMS on some of the tasks that are the most important for support of the ICF program. The national laboratories--Livermore, Los Alamos, and Sandia--accomplished many of their research objectives, but some objectives had to be dropped or deferred, or took longer than planned mainly because of insufficient funding and/or the complexity of the objectives. The Naval Research Laboratory and the University of Rochester met most of their objectives during our review period. More specifically, we found the following:

-- KMS' current 3-year competively awarded contract with DOE (signed on May 1, 1987) represents a transition for KMS

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[2]DOE plans to use the results of this research to support nuclear weapons effects studies because of the similarity between ICF laboratory-scale experiments and nuclear explosions.

from its previous ICF program role, which allowed KMS more involvement and flexibility in initiating and performing ICF research. Under the current contract, KMS supports the efforts of others, mainly by supplying target components for use in ICF experiments. While KMS has been able to successfully perform many of the tasks where it has sufficient staff and expertise, it has experienced difficulties in some other important task areas. For example, in 1987 and 1988, KMS laboratory customers complained that their progress had been slowed because of KMS' unacceptable performance on some target fabrication and delivery tasks--the main priority of the support contract. KMS showed some improvement in 1989 in areas that were previously rated as unacceptable, especially improving its communications with its laboratory customers. However, progress in a few target fabrication and delivery areas continues to be slow and some problems still persist. While KMS agrees with the complaints of its customers on some tasks, it cites difficulties in transitioning to its new ICF support role, including providing sufficient numbers and skill mix of staff necessary to perform the type, volume, and priority of work needed for some tasks. KMS said it is working to solve these staffing problems. DOE has tried to better direct KMS' efforts by closer monitoring, formal progress reviews, evaluations, and feedback. DOE believes that KMS has now had sufficient time (3 years) and funding to overcome any problems associated with transitioning to its current ICF support role. KMS' contract with DOE expires in 1990, at which time DOE will recompete the contract.

-- Livermore, the lead laboratory for the ICF glass laser program, accomplished many of its objectives during January 1, 1987, through June 30, 1989. However, Livermore had to defer some important target-physics experiments mainly because of insufficient funding. The two other major laboratories, Los Alamos and Sandia, also cited funding problems as reasons for not meeting some of their objectives. Los Alamos, the lead laboratory for gas lasers, also cited lack of access to other laser facilities (while developing its own) and unanticipated complexity of experiments as reasons for its program's slipping behind schedule by 1 to 2 years. Sandia, the lead laboratory for the particle beam accelerator concept, also cited technical difficulties in meeting its objectives. Sandia's program also slipped by 1 to 2 years. The two other smaller ICF laboratories, located at the University of Rochester and the Naval Research Laboratory, met most of their objectives during the period that we reviewed. A few objectives were accomplished later than originally planned mainly because of the complexity of the experiments involved.

The National Academy of Sciences reviewed the ICF program in 1986 and recommended that program funding remain at the fiscal year 1985 level in real terms to accomplish program objectives during the subsequent 5 years. Although the Congress supported ICF program funding at higher levels than requested by the administration, program funding has not kept pace with inflation. Since the Academy's 1986 recommendation on funding, there has been more than an $80 million loss in funding compared with what it would have been at the 1985 funding level.[3] In its January 1990 interim report on the ICF program, the Academy said that good progress had been made since its 1986 review of the program, but some objectives were not met because funding had fallen significantly short of the recommended level.

OBSERVATIONS

The overall progress of the ICF program during January 1, 1987, through June 30, 1989, has essentially kept pace with the "limited" funding provided the program and the difficulty of the objectives attempted. If funding continues to be limited, then the progress is likely to be affected.

Most of the six participants did not accomplish all of their planned objectives or assigned tasks for various reasons. However, we believe that comparisons of performance among the six participants would not be valid because of the different functional role each performs in the program (from major lead laboratory to support contractor), different degree of difficulty of objectives (from conceptual research on the leading edge of the ICF technology to mainly performing assigned support tasks), and different stages of development of participant programs (from the more well-developed glass laser program to the more conceptual particle beam accelerator approach to ICF).

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[3]The cumulative funding deficit due to inflation includes the period of fiscal years 1986 through 1989.

With regard to the target development and fabrication support now provided by KMS, DOE plans to recompete this contract in the near future. In designing this new contract, DOE should consider ways to maintain acceptable contractor performance (such as award fees for outstanding performance and withholding award fees for consistently unacceptable work on certain tasks).

Sections 1 through 7 contain a more detailed discussion of the results of our work.

SCOPE AND METHODOLOGY

To respond to your request, we interviewed ICF program officials at DOE headquarters, DOE's San Francisco Operations Office, and its Albuquerque Operations Office; visited and held discussions with all of the ICF participants; and reviewed pertinent internal documents concerning program objectives and performance. We also attended all National Academy of Sciences ICF conferences held at the participants and coordinated our report results with the Academy's ICF study panel.

In subsequent discussions with the Committee, it was agreed that we would not develop our own independent criteria to evaluate participant performance, but would review and discuss DOE's assessments of the participants with DOE and the participants and attempt to explain and reconcile differences.

As requested by the Committee, we did not obtain official agency comments on a draft of this report. We did, however, discuss pertinent sections of our draft report with cognizant DOE officials and ICF program participants and have incorporated their comments as appropriate. Our work was performed between August 1989 and February 1990 in accordance with generally accepted government auditing standards.

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We are sending copies of this report to appropriate congressional committees; the Secretary of Energy; the Director, Office of Management and Budget; the National Academy of Sciences; and other interested parties, including the six participants in DOE's ICF program.

If you have any questions, please contact me at (202) 275-1441. Major contributors to this briefing report are listed in appendix I.

Sincerely yours,

Victor S. Rezendes
Director, Energy Issues

CONTENTS

ABBREVIATIONS

AL	DOE Albuquerque Operations Office
CO_2	carbon dioxide
DOE	Department of Energy
FY	fiscal year
GAO	General Accounting Office
ICF	Inertial Confinement Fusion
KrF	Krypton Fluoride
KMS	KMS Fusion, Inc.
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LMF	Laboratory Microfusion Facility
NAS	National Academy of Sciences
NRL	Naval Research Laboratory
PBFA I	Particle Beam Fusion Accelerator I
PBFA II	Particle Beam Fusion Accelerator II
R&D	research and development
SAN	DOE San Francisco Operations Office
SNL	Sandia National Laboratory
UR/LLE	University of Rochester Laboratory for Laser Energetics

SECTION 1

PROGRAM BACKGROUND

INERTIAL CONFINEMENT FUSION

In nuclear fusion, nuclei of isotopes such as hydrogen collide with each other at high speed, uniting and releasing large amounts of energy. Nuclear fusion has weapons physics applications and also holds promise as a potentially abundant source of electricity.

Inertial Confinement Fusion (ICF) uses the energy from a laser or particle beam accelerator to heat and compress a tiny fuel capsule (a "target") containing a mixture of hydrogen isotopes (e.g., deuterium and tritium) to a very high density, initiating a fusion reaction throughout the fuel. The fusion reaction may yield an energy output many times greater than the original energy input, a condition known as "high gain."

Several different kinds of lasers and particle beam accelerators (known as "drivers" because they "drive" the fusion reaction) are used by ICF researchers. The DOE ICF participant laboratories use solid state glass lasers, krypton fluoride (KrF) gas lasers, or particle beam accelerators. If the driver directly bombards the target with energy, the process is known as "direct drive." If the energy is first converted to X-rays which then heat and compress the target, the process is called "indirect drive." The DOE ICF program uses both approaches.

DOE's ICF Program

The goal of the DOE ICF program is to achieve a small thermonuclear explosion in the laboratory for the purposes of weapons physics studies, for studies of weapons effects on systems, and as a possible energy source in the long term. Six participants are involved in this effort.

Lawrence Livermore National Laboratory (LLNL) has the largest and most comprehensive ICF research program and functions as lead laboratory for glass lasers. Los Alamos (LANL) and Sandia National Laboratories (SNL) have been designated as lead laboratories for the KrF gas laser and particle beam accelerator approaches, respectively. LLNL and LANL are operated by the University of California under contract to DOE as national weapons laboratories. SNL is operated by Sandia Corporation, a subsidiary of AT&T Technologies. The University of Rochester's Laboratory for Laser Energetics (UR/LLE) is a university research facility and is the only participant with a completely unclassified program. The Naval Research Laboratory (NRL) has the smallest ICF research program, and KMS is a private corporation mainly providing support to the other five participants.

Table 1.1 outlines each participant's role and the contractual agreement it has with DOE for ICF work. Five of the ICF participants (LLNL, LANL, SNL, UR/LLE, and NRL) perform experiments that are on the leading edge of the ICF technology; most of the experiments they perform have not been done before. Thus, it is difficult to estimate the amount of time and cost for some of the experiments. KMS is the only participant that operates under a contract awarded through competitive bidding. KMS' role as a support contractor is unique because it must perform specific tasks requested by other participants in a timely manner with quality work so that research schedules can be met. The tasks include target design, development, fabrication, and delivery services, as well as other support for ICF target experiments. DOE and the laboratories that KMS supports review KMS' progress twice a year. This includes a formal performance evaluation session at the end of each year for the current 3-year contract, which expires in April 1990. DOE told us that it treats its contractor, KMS, as fairly as the other participants, but unlike the other participants, it more formally and specifically evaluates KMS' performance on the tasks it has been assigned. DOE does this because KMS' role (mainly to support others' efforts) in the program is different and its contractual relationship is different. By assigning specific tasks to KMS and then having the laboratories formally evaluate KMS' performance on these tasks, DOE can better focus the efforts of KMS to meet the needs of the national program.

Table 1.1: Participants in ICF Program

Laboratory	Program	Contract type with DOE
DOE ICF Lead Laboratories		
Lawrence Livermore National Laboratory	Solid state glass laser--Indirect Drive	Management and Operations
Los Alamos National Laboratory	Developing KrF gas laser--Indirect Drive	Management and Operations
Sandia National Laboratory	Light Ion Particle Beam Accelerator	Management and Operations
Non-DOE Laboratories		
University of Rochester	Solid state glass laser--Direct Drive	Cooperative Agreement for research
Naval Research Laboratory	Starting KrF gas laser--Direct Drive	Interagency Agreement
Program Support Contractor		
KMS Fusion, Inc.	Support contractor for other participants	3-year cost-plus-fixed-fee with two possible 1-year extensions; awarded competitively

Source: DOE.

DOE's Office of Inertial Fusion (DOE/IF) manages the program. In general, DOE monitors the progress of individual participants through periodic milestone, peer, and topical reviews (e.g., target physics, driver development, etc.). All participants attend quarterly program managers meetings (attended as well by representatives from DOE/IF and the DOE Operations Offices), and maintain regular and frequent contact with DOE. All provide DOE with progress reports and/or program briefings.

DOE/IF is assisted by the DOE San Francisco (SAN) and Albuquerque (AL) Operations Offices. DOE/IF provides the laboratories with technical guidance, while SAN and AL provide administrative oversight. SAN oversees LLNL, and in 1988 SAN assumed responsibility from the DOE Nevada Operations Office for oversight of UR/LLE, NRL, and KMS. AL provides oversight for LANL and SNL. SAN and AL work with the participants in reviewing and approving proposed work plans, help with contract administration and funding matters, and review program efforts. Representatives from SAN and AL review progress reports, attend program meetings and reviews, and maintain contact with participants through telephone calls and occasional visits.

Features of the ICF Program

Program decentralization and laboratory autonomy are major characteristics of the ICF program. For example, LLNL, LANL, and SNL are granted great discretion in defining research and advanced development programs, allocating resources, and communicating directly with other government agencies. NRL, UR/LLE, and KMS possess a lesser degree of autonomy.

The program also features a mix of cooperation and competition. The six participants form a discrete, close-knit community of scientists who collaborate closely and are extremely well-informed about each participant's strengths and weaknesses. Many have spent their whole careers in the program; some have worked at more than one participant laboratory. They help each other with technical problems, share technology for commonly needed tasks, and loan each other useful equipment when needed. On the other hand, they are in obvious competition to maximize their share of program funding, and to determine whose ICF driver concept is more likely to lead to high gain.

ICF Program Funding

ICF program funding has not kept pace with the constant fiscal year 1985 level of effort recommended by the National Academy of Sciences (NAS) in its 1985/1986 review of the ICF program. Funding was cut significantly in fiscal year 1986. Using LLNL inflation indexes, we found that cumulative program funding for operating costs over the 4-year period was about $88 million less than if the fiscal year 1985 funding level had been maintained in real terms.[1]

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[1]DOE, using slightly lower inflation indexes from a more general "national defense" category, calculated a cumulative funding loss of $65 million during this period.

Table 1.2: ICF Program Actual Funding vs. Constant FY 1985 Level of Effort--Operating Costs
(Current-Year Dollars in Millions)

Fiscal year	Constant FY 85 level of effort	Cumulative LLNL escalation index	Constant FY 85 level	Actual operating funds	Difference between constant and actual
1985	154.8	1.00	154.8	154.8	0.0
1986	154.8	1.03	159.4	137.9	21.5
1987	154.8	1.05	162.5	142.7	19.8
1988	154.8	1.11	171.8	151.0	20.8
1989	154.8	1.17	181.1	155.5	25.6
Total		1.17	829.6	741.9	87.7[a]

[a]If converted to FY 1989 dollars, the total of this column is $112.5 million.

Note: Does not include capital equipment funding.

Source: DOE and Lawrence Livermore National Laboratory.

During the period fiscal year 1985-89, UR/LLE's, NRL's, and KMS' share of total ICF program funding rose from approximately 16 percent to approximately 22 percent, while that of the three DOE laboratories has declined proportionately. Since fiscal year 1986, LLNL and LANL budgets have remained fairly constant, but have not kept pace with inflation. SNL budgets have risen modestly overall but have been cut back recently. (See table 1.3.)

Total fiscal year 1985-89 funding for the laboratories was as follows:

Table 1.3: Total ICF Laboratory Program Funding
(Current-Year Dollars in Millions)

Fiscal year	Laboratory LLNL	LANL	SNL	NRL	UR/LLE[a]	KMS	Total[b]
1985	73.2	43.9	21.8	3.9	8.6	13.2	164.6
1986	66.6	32.1	23.4	2.8	9.0	13.5	147.4
1987	67.6	30.5	24.0	3.8	9.6	14.0	149.5
1988	68.8	30.7	29.5	3.8	10.9	14.4	158.1
1989	67.7	31.5	27.6	4.8	13.6	17.5	162.7

[a]A small proportion of UR/LLE's ICF funding is non-DOE funding.

[b]Figures include operating and capital equipment funds. Total does not include $1-2 million each year, which is held at DOE headquarters level.

Note: Rows may not total because of rounding.

Source: Individual laboratories.

The fiscal year 1990 President's Budget request was $168.9 million for the DOE ICF Program. Congressional committees directed that funding be $173.9 million. However, according to DOE, the final appropriation may be slightly lower due to a mandated Gramm-Rudman-Hollings deficit reduction cut and other possible adjustments under consideration.

In the past few years, congressional committees have directed that UR/LLE, NRL, and KMS receive additional funding from DOE in amounts specifically designated for them. The DOE national laboratories claim that the other three, especially KMS, are adept at winning additional funding recommendations from the Congress at the expense of the DOE laboratories. However, since 1983, most ICF participants have benefitted from funds added by the Congress to the President's initial budget request. In fiscal year 1989 congressional committees, however, added no funds to the budget but directed what amounted to a shift of funds from the DOE national laboratories to the other participants. Since fiscal year 1988, total ICF program funding has remained fairly constant. When total program funding does not increase, congressionally directed funding increases at one or more laboratories mean a shift in funds from other laboratories. The Director of DOE's ICF program told us that program funding shifts among participants are detrimental to the program if they cause the participants experiencing cuts to delay achieving their objectives. On the other hand, it can be argued that without specifically designated funding, the non-DOE laboratories (UR/LLE and NRL) may not receive a "fair" share of funding in direct competition with the larger DOE national laboratories. In the case of KMS, DOE believes that KMS' funding, as a support contractor for the program, should be determined on the basis of the specific needs of program participants for support services.

In fiscal year 1989, two laboratories underwent funding cuts from the fiscal year 1988 budget levels: LLNL ($1.1 million), and SNL ($1.9 million). LANL's budget increased by $800,000. The non-DOE laboratories and KMS received more substantial increases in funding: NRL ($1 million), UR/LLE ($2.7 million), and KMS ($3.1 million). This has led to complaints from the DOE national laboratories that some of their experiments had to be delayed and objectives postponed.

In addition, DOE and some participants told us that while reasonable competition is healthy, the current intense competition for funding is perhaps becoming counterproductive.

Future ICF program plans include a Laboratory Microfusion Facility (LMF) where participants would perform ICF target experiments designed to achieve a high-gain fusion reaction. DOE would select one of the various laser or particle beam approaches as the driver to be used in the LMF. DOE may make its LMF driver selection in the mid- to late 1990s. The DOE ICF laboratories are currently developing their respective LMF driver approaches, hoping that DOE will select their concept.

NAS reviewed the DOE ICF program in 1985/1986 and recommended future directions and priorities for the ICF program.[2] The Congress requested that NAS review the program again in 1989/1990. The NAS interim report in January 1990 again has recommendations for future ICF program directions. NAS' major recommendations in its interim report include more concentration on target-physics experiments and the termination of the Centurion-Halite program. NAS plans to issue a final report on the ICF program later in the fall of 1990.

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[2] Review of the Department of Energy's Inertial Confinement Fusion Program, National Academy of Sciences, Mar. 1986.

SECTION 2

KMS FUSION, INC.

KMS is the only private contractor in the ICF program. KMS was a pioneer during the early years of fusion research and holds many patents in this area. DOE has contracted with KMS to support the national ICF program. DOE's contract with KMS, signed on May 1, 1987, is a cost-plus-fixed-fee contract awarded through competitive bidding. According to DOE, KMS mainly supports the research and development efforts of the other participants in the ICF program. Four of the participants--LLNL, LANL, SNL, and UR/LLE--currently use KMS' support services.[1] KMS provides these participants with target component development, fabrication, delivery services, and other research support services. KMS' current contract with DOE represents somewhat of a transition for KMS from its previous ICF program role, which allowed KMS more involvement and flexibility in initiating and performing ICF research and development (R&D).

Under this latest contract, which reflects the changing needs of the program, the support contractor (in this case KMS) is required to mainly support the research efforts of others, for example, supplying target components for others to use in their ICF experiments. Although KMS has successfully performed some tasks under this contract, the necessary transition to this current contract has caused KMS some difficulties in providing the numbers of staff and skill mix necessary to perform the type, volume, and priority of work needed for other tasks. The loss of some key technical personnel has further aggravated the situation. In addition, the current contract has necessitated a role change on the part of KMS from being more of an initiator and performer of fusion research to now fulfilling a supportive, albeit important, role in the program.

These transition problems have been reflected in laboratory complaints about KMS' performance on some tasks during the period that we reviewed. Specifically, laboratory ratings of KMS' performance during May 1, 1987, through June 30, 1989,[2] ranged from "poor" to "outstanding," with unacceptable performance on several tasks considered by the laboratories as important or critical to the progress of their respective programs. In those cases where

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[1]The laboratories (LLNL, LANL, SNL, and UR/LLE) are referred to as KMS' laboratory "customers" by DOE and the respective laboratories.

[2]During January 1, 1987, through May 1, 1987, KMS was transitioning from its old contract and preparing for the new contract which started on May 1, 1987. We are not aware of any official rating of KMS' performance during the January 1 to May 1 period.

KMS agrees with negative task performance evaluations, it cites mainly the transition problems noted above as reasons.

The DOE contract with KMS is a 3-year cost-plus-fixed-fee contract with the possibility of 2 additional option years. This $44.4 million contract is due to expire in April 1990.[3] It is a level-of-effort contract in which KMS provides the ICF program with an agreed-upon number of hours of effort which are applied to authorized tasks specified by the ICF laboratories and KMS itself. KMS' congressionally recommended operating budget for fiscal year 1989 is $16.8 million ($2.4 million higher than requested by DOE). According to KMS, it provided its DOE customers with approximately 1,267 person months (192,221 hours) of support service in fiscal year 1989. KMS officials said that the DOE contract represents approximately 75 percent of KMS' business.

In the rest of this section, we discuss the types of ICF tasks assigned to KMS and the accomplishment of these tasks.

TASKS ASSIGNED UNDER THE ICF SUPPORT CONTRACT

KMS performs the following categories of tasks, as they are requested (through the DOE contracting officer) by the ICF laboratories:

-- Category "A" Tasks: Target technology development and fabrication activities, including development, evaluation, characterization, and delivery of ICF targets.

-- Category "B" Tasks: R&D support for target experiments to be performed at other ICF laboratories.

-- Category "C" Tasks: Operate and maintain government-furnished equipment, including a laser and related equipment for testing ICF targets.[4]

-- Category "D" Tasks: Theoretical plasma/target interaction and implosion physics modeling in support of target development for experiments at other laboratories.

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[3]The DOE contracting officer told us that the contract is expected to be fully costed out (the $44.4 million will have been spent) by February 1990.

[4]According to DOE, KMS' laser work will be phased out in 1990 because the ICF program has no need for this KMS work. NAS has also recommended that KMS' ICF laser work be terminated.

-- <u>Category "E" Tasks</u>: Technical and management support for category A through D tasks.

Most of the requests for KMS work are category "A" tasks followed by "B" tasks. Among the tasks, category "A" followed by "B" has the highest priority. Specifically, according to DOE, the highest priority task area under the support contract is target component fabrication and delivery for the principal target users in the program (i.e., LLNL, UR/LLE, LANL, and SNL).[5] If these components are not delivered on schedule or are of inferior quality, the laboratories are not able to meet their objectives and thus, overall program objectives may be delayed.

The procedure that has been followed to develop an annual work plan of tasks to be performed by KMS includes the laboratories' annually submitting their needs, priority, schedules, and resources estimates for tasks to the lead laboratory representative located at LLNL. The lead laboratory representative works with the other laboratories and KMS to order the priorities among the requested tasks and drafts a work plan (a list of authorized tasks to be performed).[6] The ICF Project Manager and the contracting officer at the DOE San Francisco Operations Office then get involved, and a copy of the draft work plan is sent to all, including KMS, for suggested changes and comments. After several iterations and negotiations, the annual work plan for KMS is finalized. The work plan is then approved by the DOE contracting officer as work that KMS is ordered to and authorized to perform. The approved annual work plan and any subsequent changes to this plan are incorporated into the contract. The work plan process may take several months to complete.

The San Francisco Operations Office's ICF Project Manager, with input from KMS, KMS' laboratory customers, the lead laboratory representative, and DOE headquarters ICF program officials, monitors KMS' progress toward meeting its objectives. According to DOE, a 1- to 2-day meeting involving all of the ICF laboratories (that use KMS services), DOE, and KMS is held at mid-year to review and redirect, if necessary, KMS efforts. The latest mid-year progress review was held on September 7-8, 1989.[7] According to

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[5]NRL makes its own target components.

[6]During this process, KMS and the laboratories may also directly discuss specifications and difficulties of tasks to help reach agreement on the timing and priority of tasks.

[7]We reviewed all of the year-end evaluation reports on KMS' performance and all mid-year progress reports for the performance period of May 1, 1987, through June 30, 1989, including all laboratory inputs to all of these reports. We also discussed KMS' performance with all of the laboratories and with KMS.

DOE, at the end of each contract year, it asks the laboratories to evaluate KMS' performance on each task performed for them during the year. Then, this performance is discussed among all involved at a 1- to 2-day meeting held at the end of each year. DOE then writes a formal evaluation of KMS' annual performance based on the input from the laboratories and the discussions at the mid-year progress review and the annual evaluation meeting. Two formal evaluations had been held during the period we reviewed--one for tasks performed in 1987 (a partial-year contract started in May 1987) and one for tasks performed in 1988.

KMS' PERFORMANCE

While KMS has successfully conducted many tasks assigned to it during the course of the current contract, its performance in several crucial ICF program support areas has been below that required to adequately support the needs of the ICF laboratories.

Performance in 1987

During the first partial year (May-Dec. 1987) of the support contract, laboratories assigned 23 tasks with various priorities to KMS. KMS successfully conducted many of these tasks, which were a mix of mainly target fabrication (Category A) tasks followed by R&D support-type tasks (Category B). KMS' laboratory customers rated KMS' overall performance in 1987 as adequate to good, with performance on three tasks rated as "unacceptable" or "marginal." Specific ratings ranged from "unacceptable" to "outstanding."

Table 2.1: Low KMS Performance on a Few Tasks in 1987

Priority category	Task	Laboratory rating of KMS
A	Target deliveries to LANL	Unacceptable
A	Large fuel capsule development for SNL	Unacceptable
B	Cryogenic target technology for UR/LLE	Marginal adequate

Note: According to DOE records, there were 13 category A tasks, 9 B, and 1 C assigned to KMS in 1987. KMS' performance on other tasks was rated as "acceptable" to "good" or "very good" with one "outstanding."

Source: DOE.

LANL, SNL, and UR/LLE officials said that the tasks shown in table 2.1 (as well as other Category A and B tasks successfully performed by KMS) were important to their programs, and KMS' marginal or unacceptable performance on these tasks affected the progress of their research programs. KMS said that the LANL target delivery task was critical to LANL's program and believed it had partially met the objectives. KMS said the task for SNL was important, but it did not have as high a priority as some other tasks for other laboratories. KMS told us that the UR/LLE task should not be considered in our review because it is really a 1986 task. UR/LLE told us that it was started in 1986, but that KMS' marginal performance contributed to UR/LLE's delaying some critical cryogenic experiments. UR/LLE completed these experiments in fiscal year 1988.

Performance in 1988

In 1988 KMS encountered the first full year of the rigors and difficulties of having to support the agreed-upon schedule and priorities of the other laboratories. According to DOE records, the laboratories requested that KMS perform 27 tasks during 1988. Eight of these tasks were cancelled or otherwise not undertaken/performed for various reasons. The remaining 19 tasks were: 11 Category A tasks (e.g., target fabrication for others), 7 Category B tasks (R&D support for others' experiments), and 1 Category C task for LLNL. Although KMS successfully performed many of these tasks, KMS' performance was unacceptable on some of the tasks that are the most important to the support of the ICF program. (See table 2.2.)

Table 2.2: Unacceptable KMS Performance on Several Tasks in 1988

Priority category	Task	Laboratory rating of KMS[a]	KMS' self rating
A	Polymer capsule development for LLNL, LANL, UR/LLE	Unacceptable	Below average
A	Cryo target technology (experimental portion only)	Unacceptable	Slow
A	Target deliveries to LANL	Unacceptable	Poor to average
A	Capsule characterization technology development for LANL	Unacceptable	Unacceptable
B	Calibration services for SNL	Unacceptable	Unacceptable

[a]A few A and B tasks were cancelled at mid-year because of a lack of progress.

Source: DOE, ICF laboratory, and KMS documents, including a KMS document commenting on pertinent sections of our draft report.

One of these tasks--target component deliveries to LANL--had also been rated as unacceptable in 1987. KMS told us it gave glass target component deliveries to LLNL priority over LANL's requests in 1987 and 1988 because it considered LLNL's program more important since it was further along at this point in time. KMS said it did not have enough personnel to give equal priority to LLNL and LANL. LANL said that these target deliveries were very important to the progress of its program (without them experiments could not be done), and said that KMS received enough funding to give equal consideration to all of its laboratory customers. KMS agreed that the deliveries were important to the progress of LANL's program. LLNL complimented KMS on its glass target component deliveries, but complained that KMS still could not provide the ICF program with good polymer target components, even though LLNL had transferred this technology to KMS. Polymer target components are becoming increasingly more important to the ICF program than glass target components. KMS agreed that the target delivery tasks and polymer development tasks were very important to the laboratories and the progress of the ICF program. However, KMS told us that the capsule characterization task was only a medium priority task.

KMS management officials stated that they did not agree with parts of the 1988 evaluation process, especially not being informed before the evaluation meeting as to what the laboratories' specific ratings were on each task, and the "long time" it took after the meeting to get detailed written feedback. KMS officials said in 1987 that they were provided copies of these ratings before the meeting. Otherwise, according to DOE, the 1988 process was very similar to that of 1987. DOE told us that KMS should be aware of how it is performing on each task through maintaining good communications with its laboratory customer. KMS had been criticized in the past for poor communication on some tasks. A need for KMS to improve communications with its customers was also noted in July 1988 by KMS' Vice President for Fusion Programs.

Despite KMS' disagreement with parts of the 1988 process, internal documents provided by KMS and a KMS critique of parts of a draft section of our report indicate that some KMS personnel familiar with these tasks and KMS management agree with many of the laboratories' positive and negative ratings. (See table 2.2.) In addition, KMS documents show continuous difficulties in staffing some tasks with the adequate number of people possessing the correct skills. These and other KMS documents also identify the loss of key technical personnel as a reason for diminished performance on some tasks. In addition, KMS' Vice President for Administration told us that KMS is understaffed in most of those areas where it received negative ratings from the laboratories.

Performance in 1989

The mid-year review in 1989 showed that KMS' performance had somewhat improved, including its communication with its laboratory customers. Some improvements were accomplished, in part, by putting some tasks on hold for several months while concentrating resources on long-unaccomplished tasks. For example, KMS satisfactorily met LANL's request for target components after being rated as unacceptable on this task in 1987 and 1988. KMS was able to do this, in part, by putting off target deliveries to LLNL, and as a result, LLNL missed some opportunities to conduct some experiments in April. KMS said it gave LANL priority for target deliveries during the first half of 1989 and would give LLNL priority during the second half. LLNL officials said they understood that KMS needed to give LANL priority during this period and KMS was able to deliver glass target components to LLNL later in the year.

DOE said that KMS was more responsive in 1989,[8] but a few tasks still remain unaccomplished, although progress is now being made. KMS can now do the SNL calibration task. (See table 2.2.) However, SNL waited over 7 months, became frustrated with KMS, and decided to contract outside the program for this calibration service. KMS still was unable to deliver acceptable polymer target shells to LLNL and UR/LLE. LLNL complained that KMS is over 1 year late in polymer shell deliveries. UR/LLE became frustrated with KMS' slow progress and modified existing Japanese technology to make its own polymer shells. In addition, complaints still persist concerning the quality of some of KMS' cryogenic target technology work.

Thus, KMS must continue to make progress in order to meet some of the demands of this contract. The sometimes competing demands of the laboratories force KMS to neglect some tasks to serve others while it transitions itself to the right number and mix of people to service the contract. KMS told us that it is progressing in this transition, but believes it may not be fast enough to meet the expressed needs of the laboratories. DOE told us that it believes KMS has had sufficient time (now about 3 years) and funding to solve its transition problems.[9]

Further frustrating KMS' adjustment to its new role in the ICF program is its belief that the current DOE contract, which emphasizes support for the experimental work of others, may erode KMS' ability and resources to initiate and do some of the in-house ICF experimental work that it has done in the past. However,

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[8]The meeting to formally evaluate KMS' performance in 1989 took place in mid-February 1990.

[9]KMS was alerted to this needed transition during contract negotiations in November 1986 and told DOE in March 1987 that it was redirecting its efforts toward target technology tasks and away from experiments and theory as part of this needed transition. KMS has received more funds each year through congressional recommendations then requested in the President's budget.

according to DOE and the ICF laboratories, a need no longer exists for this type of work from DOE's support contractor. DOE says it is necessary to keep the efforts of its support contractor (whether KMS or someone else) directly focused on the priorities of the ICF laboratories through assigned tasks in order to get full dollar value from the work that the contractor does.

A recent example shows KMS' frustration with its new role. According to DOE, KMS performed unauthorized work between May and September 1989 at a cost of about $195,000. DOE had directed KMS, in the 1989 work plan, to discontinue certain cryogenic experimental work. During the mid-year progress review in September of 1989, DOE discovered that KMS had continued the work without authorization. After considering the matter, however, DOE decided not to disallow payment for this work. Instead, DOE prepared a revised task assignment to designate the task as a KMS discretionary task, and accepted the work. DOE told us that the work was redesignated under a provision of the contract which allows 5 percent of the contract time to be allocated to authorized tasks that KMS wishes to perform.

The DOE San Francisco Operations Office's ICF Project Manager responsible for monitoring KMS' activities told us that he and the contracting officer decided not to disallow payment for this work because they perceived some overall interest in the work as well as a desire to see what KMS had accomplished. Also, since KMS was well into the experiments, they decided to allow KMS to finish. In addition, the manager and the contracting officer thought that the issue was not worth pursuing and would further exacerbate strained relations with KMS.

KMS' ICF Program Director told us that KMS chose to do this work without the authorization of the DOE contracting officer because KMS believed that this work is important to the long-term goal of the ICF program, and crucial to the survival of KMS as a private company and as a continuing participant in the ICF program. He said he was aware that DOE could disallow payment for the work. KMS management later denied that they believed they were not authorized to do this work.

Under the terms of the contract with KMS, we believe that DOE could have rejected and disallowed payment for the unauthorized work, but was not required to do so.[10] In choosing to accept the work, DOE became obligated to pay for it and cannot now equitably seek to recover the payment made. We believe, however, that DOE's decision to designate the task as a discretionary task and accept the work is counterproductive to DOE's desire to focus and control

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[10]The contract that KMS operates under provides no awards for exceptional performance or penalties for unacceptable performance.

the activities of KMS for the benefit of the other participants and the national program.

DOE's Director of Inertial Fusion told us that DOE has decided to recompete the ICF support contract that KMS now holds. He said that DOE has been dissatisfied with aspects of KMS' performance. However, according to the director, DOE's decision to recompete the contract was made mainly because the term of the contract will be completed in 1990, it is a competitively awarded contract, and the scope of work has changed.[11]

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[11]For example, according to DOE, the contractor will not need to perform laser-assisted experiments under the new ICF contract.

SECTION 3

LAWRENCE LIVERMORE NATIONAL LABORATORY

The University of California manages and operates the Lawrence Livermore National Laboratory for DOE. LLNL has the largest and most comprehensive ICF research program in the United States and is the site for Nova, the world's largest glass laser. During part of the period that we reviewed (Jan. 1, 1987, through June 30, 1989), LLNL used its annual budget of about $65 million and 340 personnel to maintain a balanced three-pronged approach to meet ICF program objectives.

This approach consisted of driver-target physics tests on the Nova laser, classified underground ICF target tests (called the "Halite" program),[1] and driver research and development. However, according to LLNL officials, limited program funding led them to adopt a strategy of shifting emphasis among the three elements of their program. This caused them to delay some planned objectives for Nova experiments and driver development. Subsequently, because of a combination of rapid progress on Halite coupled with shrinking funding, they decided to stop the underground tests. In addition, these budget constraints and, to a lesser extent, LLNL's choice of where to put limited funding within its program, affected the LLNL Nova program's ability to meet some important goals recommended by the National Academy of Sciences in its 1986 report on the ICF program.[2]

LLNL, however, was able to accomplish most of the revised objectives it set for itself with the limited funding. For example, the combination of results from LLNL underground experiments in 1987 and Nova experiments between 1987 and 1989 has enabled the ICF program to progress at a faster rate than anticipated. However, even within its "scoped-back" plan, LLNL still had to defer a few important experiments and activities because of a continuing decrease in funding relative to the increasing complexities and costs of experiments, the difficulty of some objectives, LLNL's management decisions concerning where to put limited funding, and other intervening events.

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[1]LANL has a companion underground ICF target test program called "Centurion."

[2]NAS made these recommendations in concert with a recommendation that ICF program funding be sustained at the fiscal year 1985 level. This has not happened, mainly because program funding has not kept up with inflation.

GOALS/OBJECTIVES

LLNL determines its goals and objectives for its ICF program on the basis of technical priority, schedule, and ICF budget. LLNL officials told us that programmatic goals typically take 3 to 5 years to complete and specific deliverables as part of the goals are to be accomplished within a fiscal year. LLNL officials emphasized that it is very difficult to meet planned goals without consistent dependable funding--LLNL's ICF funding has been steadily decreasing since 1985 mainly because it has not kept pace with inflation. (See table 3.1, last two columns.) Using inflation indexes of LLNL officials, we found that their program has lost a cumulative total of $32.5 million in operating funds compared with its fiscal year 1985 funding level in real terms.[3] LLNL officials also stated that the cost of conducting research increased by 17.5 percent from 1985 to 1989.

LLNL's main goals for its program have been to (1) study and apply the science and technology necessary to achieve high-gain ICF and (2) develop ICF military and civilian applications. These are pursued through a mix (depending on funding) of the following: ICF target-physics experiments on Nova, underground experiments designed to study characteristics of ICF targets, driver research and development, and to a much more limited extent, studies to determine the feasibility of using ICF for military and for civilian applications (e.g., a fusion-powered reactor). LLNL officials make the decision as to the amount of funding and priority that each of these areas receive within their program. (See table 3.1.)

Table 3.1: LLNL ICF Funding--Operating Costs
(Current-Year Dollars in Millions)

Fiscal year	Driver technology	Nova experiments	Target design	Halite	ICF special studies	Total actual funds	Constant FY 85 level
1985	10.2	30.4	9.1	16.3	1.3	67.2	67.2
1986	7.6	36.8	8.8	9.0	1.1	63.4	69.2
1987	7.7	27.0	9.0	22.2	0.8	66.6	70.6
1988	14.3	35.3	9.3	4.4	2.8	66.2	74.6
1989	14.7	36.0	9.5	0.8	3.3	64.3	78.6

Note: Rows may not total because of rounding.

Source: LLNL.

[3]If converted to FY 1989 dollars, the cumulative loss is approximately $42.5 million.

Nova Goals

LLNL breaks its Nova goals into three categories: (1) laser operations, maintenance, and improvements (e.g., replacing contaminated glass)[4]; (2) experiments; and (3) diagnostics. During the period we reviewed, LLNL scientists accomplished many important tasks including Nova preparation and important target-physics experiments. However, according to LLNL officials, they had to defer some important experiments (including, for example, cryogenic target experiments, Nova laser beam smoothing and some laser/target diagnostic developments, and some demonstrations of capability at certain wavelengths) because of continued decreasing funding and increasing costs of experiments. Nova was the highest funded category for LLNL's program from 1985 through 1989.

KMS makes the glass shells for fusion targets to be used in Nova experiments. LLNL transferred this technology to KMS and no longer makes glass shells. LLNL makes polymer shells, which are becoming more important than glass in ICF research experiments. About 2 years ago, LLNL transferred the polymer technology to KMS. However, KMS has been unable to make polymer shells to meet LLNL's needs and is over a year behind its promised delivery date. Thus, LLNL must continue to make its own and has also made shells for UR/LLE, which has similar needs. LLNL said the transfer was straight forward, but KMS tried to add too many improvements to the technology (in an effort to build a corporate expertise in this area) rather than meet the immediate needs of its laboratory customer. LLNL has given KMS high marks on glass shell delivery but has rated KMS as poor on polymer shell development.

Halite Tests

According to LLNL officials, they emphasized Halite underground tests in fiscal years 1985, 1986, and 1987. However, this was done at the expense of giving Nova experiments and driver development lower priority because of limited funds. Each underground Halite test cost LLNL about $30 million. LLNL chose to end its direct participation in the underground testing ahead of schedule in late 1987. LLNL officials told us this was done because they believed that little more could be learned from Halite for the amount of funding needed and the technical risk involved. LLNL officials shifted the funding previously allocated for the Halite program to Nova experiments and driver technology. (See table 3.1.)

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[4]Nova lenses were found to be contaminated with microscopic platinum chips. LLNL had to replace this glass before Nova could be operated at full power. Replacement of the glass and preparation of Nova took about 2 years, but LLNL was able to use the reduced-powered Nova to do experiments during this period.

Driver Goals

With the advent of the Laboratory Microfusion Facility's becoming an important near-term goal in the ICF program and LLNL management's desire to maintain a sound driver technology program, LLNL shifted some of its funds in 1988 and 1989 from terminated underground tests to the development of a possible driver for the LMF. Funding for driver development was increased by about 70 percent over the 1987 level.[5] (Funding for Nova experiments increased by 30 percent over the 1987 level.) LLNL's driver development effort has included not only tests for high gain for military/weapons purposes, but looking ahead into the future, LLNL is also now doing studies of which driver may be best to eventually power a nuclear fusion plant for commercial power. Most of the driver technology subtasks that LLNL had set for itself were met. However, a few important ones were deferred because of a decrease in ICF program funding and the difficulty of some objectives, i.e., they will take longer than expected.

LLNL and the NAS Recommendations

Recommendations made by the NAS panel in its 1985/1986 review have determined the thrust of the national ICF program. Even though LLNL has accomplished much in all three elements of its program during the past few years, program budget constraints and, to a lesser extent, LLNL's choice of where to put limited funds have hindered the Nova program's ability to meet specific NAS recommendations, including important experiments to analyze the hydrodynamic instabilities of fusion targets.

At the time of the 1986 NAS report, LLNL had a three-pronged program consisting of Nova experiments, Halite underground tests, and driver development. NAS recommended that LLNL give Halite and Nova experiments top priority with only "a modest exploratory effort in . . . advanced glass laser development . . . ." NAS recommended that ICF funding stay at the 1985 level ($67 million in operating funds in 1985 dollars for LLNL) to accomplish this. Funding, however, has slowly eroded to where LLNL's 1989 operating funding is about $55 million in 1985 dollars. Because of this lack of funding, LLNL scoped back its program in 1987. In addition, LLNL officials told us that two other events in 1987 caused them to further alter their ICF program plan, i.e.,

-- a continued erosion in LLNL funding due largely to "congressional redirection of funds from LLNL to KMS, UR, NRL, and SNLA," and

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[5]LLNL officials said that some of its driver technology also includes activities directed at supporting the existing Nova facility.

-- LLNL's decision that it had learned what it needed from Halite experiments (given the benefit/cost and technical risk), and given that resources were limited, LLNL officials decided it would be more beneficial to discontinue Halite and put this money into Nova and driver development.

Thus, in 1988 and 1989, LLNL officials made a program management decision to shift funds that had previously been allocated for Halite to Nova operations and experiments, driver development, and special ICF studies including the LMF and military and civilian applications of ICF. However, much of the shifted funding went into these latter two efforts (see driver development and special studies, table 3.1), which the 1986 NAS panel considered a low priority, and in the case of the special studies (a total of about $6 million dollars in 1988-89), no priority.

Thus, some important Nova experiments still remain unaccomplished, mainly because of decreasing program funding; but also to some extent because of LLNL's management decision concerning where to put available funding. According to LLNL officials, their funding decisions were made to create a balanced program between the Nova laboratory experiments program and LMF development so that the target physics and LMF design milestones could be completed on a mutually consistent schedule. However, due to the reduced funding, LLNL now plans to complete these Nova milestones later and in a somewhat different fashion from the plan recommended by NAS.

In its interim report issued in January 1990, NAS recommended dropping the Halite/Centurion program (because of past program successes and lack of funds for additional experiments) and concentrating limited resources on laser-target physics experiments, mainly on Nova. NAS also commented that LLNL's decision to concentrate some of its limited resources on developing a driver for an LMF has helped distract LLNL from accomplishing some important Nova experiments. DOE officials told us that the national laboratories, including LLNL, are allowed much autonomy in deciding the allocation of funds within their programs and that the development of an LMF is an important goal to the ICF program.

SECTION 4

LOS ALAMOS NATIONAL LABORATORY

Los Alamos National Laboratory in Los Alamos, New Mexico, is the designated ICF lead laboratory for ICF gas laser concepts and is currently developing a KrF gas laser called "Aurora," to be used primarily for indirect-drive target experiments. During the early 1970s, LANL developed a driver program based on a carbon dioxide (CO_2) laser, but abandoned it in the mid-1980s when it became clear that the long wavelengths associated with CO_2 laser light were unworkable for ICF experiments. During the early to mid-1980s, LANL made the transition to its current Aurora approach.[1]

The University of California has a cost-plus-management-allowance contract with DOE for operations and management of LANL. LANL's total annual ICF program budget (capital and operations) has remained relatively constant at slightly over $30 million since fiscal year 1987. In fiscal year 1989, LANL had approximately 135 staff supporting the ICF program.

GOALS/OBJECTIVES

LANL's ICF objectives include three areas: capsule performance (including underground target experiments with the classified Centurion Program), laser-driver development, and laser-target interaction physics. In fiscal year 1989, 70 percent of the LANL ICF budget supported KrF laser development. The remaining 30 percent went to the Centurion Program or to other ICF experiments. LANL achieved only some of its fiscal year 1987-89 objectives within the original time frames, owing to a lack of access to laser facilities (while completing Aurora); delays in target diagnostics, design, and fabrication; insufficient funding; and unanticipated complexity of experiments. Also, KMS' failure to provide LANL with target components during 1987 and 1988 contributed to LANL's inability to perform some experiments, and thus helped slow LANL's program.

Capsule Performance

The capsule performance area includes target experiments under the classified Centurion Program for underground nuclear tests involving ICF targets, as well as some experiments performed on LLNL's Nova laser. LANL accomplished about one-half of its fiscal year 1987-89 objectives in the capsule performance area

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[1]The Naval Research Laboratory is currently transitioning from a small glass laser to a small KrF laser called "NIKE," to be used for direct-drive target experiments.

within projected time frames. However, some objectives were delayed owing to a lack of access to laser facilities. LANL was to use LLNL's Nova laser, pending completion of Aurora, but an 18-month cutback of Nova operations while contaminated laser glass was replaced, and a delay in getting Aurora ready to operate caused a slippage in LANL's scheduled work. A number of experiments begun in fiscal years 1987 and 1988 were unfinished as of fiscal year 1989, because of ongoing difficulty in obtaining access to Nova or because their complexity exceeded earlier expectations.

Laser-Driver Development

This area includes experiments necessary to bring the Aurora KrF laser on-line and pursue LMF driver development. LANL officials told us that key technology areas for KrF lasers have been identified and detailed programs are being developed for those areas. According to LANL officials, all objectives in this category were accomplished 1 year late because of insufficient funding during fiscal years 1987 and 1988.

Laser-Target Interaction

This area involves experiments in driver-target interaction such as plasma physics. All objectives in this area are either unfinished or were delayed. All fiscal year 1987 experiments were still unfinished as of fiscal year 1989 because of insufficient funding or loss of access to Nova when it was shut down. Some fiscal year 1988 experiments are unfinished for the same reasons. One fiscal year 1988 experiment was completed in fiscal year 1989. One fiscal year 1988 and one fiscal year 1989 experiment have been delayed until fiscal year 1990 so they can be performed on the Aurora KrF laser.

NAS Views

In 1986 NAS recommended the joint LLNL-LANL underground testing program (Halite/Centurion) as the number-one priority for the DOE ICF program. It also noted that upon completion, Aurora would have to successfully demonstrate pulse shaping. Although not anticipating that this would provide immediate target implosion capability, NAS encouraged LANL to continue KrF laser development as an important ICF contribution. In its 1990 interim report, NAS recommended dropping the Halite/Centurion effort, believing enough had been accomplished, given the high cost of the program. NAS also recommended that LANL finish Aurora and start doing ICF target implosion experiments using Aurora.

SECTION 5

SANDIA NATIONAL LABORATORY

Sandia National Laboratory in Albuquerque, New Mexico, is the designated lead laboratory for development of the particle beam accelerator approach for the DOE ICF program. SNL has constructed the Particle Beam Fusion Accelerators (PBFA) I and II to determine the feasibility of using light ion beams as a driver to ignite ICF targets. Thus far, the program is still in the developmental state and presently is attempting to focus beams and shape beam pulses. As of fiscal year 1990, SNL has not yet attempted target implosion experiments.

Sandia Corporation, a subsidiary of AT&T Technologies, operates SNL under a 5-year renewable no-profit, no-fee contract with DOE. Sandia's ICF program currently has 93 staff, with contractors providing another 60 personnel. Ninety-five percent of the fiscal year 1989 SNL ICF budget was spent on PBFA II, while the remaining 5 percent went toward developing a Laboratory Microfusion Facility driver concept. SNL is adapting Hermes III, a nuclear weapons effects simulator at SNL, to become a light ion driver concept for the LMF. Total ICF program funding (capital and operations cost) has increased in current dollars from $23.4 million in fiscal year 1986 to $27.6 million in fiscal year 1989. In response to congressional directive, DOE has cut back SNL ICF funding twice. Capital funds have remained fairly constant since fiscal year 1987, but operating funds have increased except for a fiscal year 1989 cut.

GOALS/OBJECTIVES

SNL ICF objectives are divided into eight program elements, including such areas as PBFA II base operations; ion beam focusing and source development, diagnostics R&D, and LMF driver development. Most of these are considered to be in exploratory development, which examines the future feasibility of concepts. However, LMF driver development efforts are considered to be in advanced development, which attempts to prove the utility of a concept through an actual tested system.

SNL achieved many of its fiscal year 1987-89 program objectives within the originally projected time frames. Of those not met within the original time frames, most were due to three factors: (1) greater than anticipated complexity of the experiments, (2) insufficient funding, and (3) phasing out experiments because of changed program priorities. Some of those under (1) and (2) were completed in later fiscal years, while others are still in progress. The details are as follows:

Complexity of Objectives

Technical difficulties in developing a source to produce positive Lithium ions used in the light ion accelerator concept have hampered SNL in meeting some objectives within projected time frames. SNL plans to develop an ion source in 1990. SNL has also had difficulty in focusing the particle beam accelerator on an ICF target with sufficient power density to perform ICF target experiments.

Insufficient Funding

In mid-year 1987, congressional committees reduced the size of the original fiscal year 1987 SNL ICF funding. The final fiscal year 1987 funding remained slightly higher than in fiscal year 1986, but was substantially lower than the original figure SNL had budgeted for. In fiscal year 1989, the SNL ICF budget was approximately $1.9 million lower than in fiscal year 1988.

According to the SNL ICF Program Director, the fiscal year 1987 funding loss was a result of a shift in ICF program funds from other laboratories (including SNL) to KMS. In fiscal year 1989, funds were shifted from SNL and LLNL to KMS, UR/LLE, and NRL to implement higher congressionally designated funding for those three laboratories. The ICF Program Director at SNL estimated that the SNL ICF program was slowed 1 to 2 years (e.g., due to delays and restructuring program priorities) by having to adjust to the funding shifts.

Changed Priorities

SNL decided recently to switch its LMF driver development efforts from PBFA II to the Hermes III concept. Therefore, SNL discontinued pulse-shaping experiments by a beam-bunching method on PBFA II. Three fiscal year 1986 and 1987 objectives involving PBFA II pulse shaping by beam-bunching experiments were dropped. SNL then began pulse-shaping experiments inside the target.

SNL officials stated that although KMS' failure to provide SNL with requested technical support was not a large factor in SNL not meeting some program objectives on time, it did help slow SNL's program during this period. For example, SNL's ICF director stated in July 1988 that KMS work seems to cost SNL more in lost productivity (tasks were many months late) than KMS is budgeted for. He said the program is paying dearly for lack of KMS performance. SNL had to contract outside for service KMS was to provide. The director said he did this because tasks were not done, so he had to compensate for KMS' lack of performance.

NAS Views

In 1986 NAS commended light ion research as having potential to become the least costly ICF driver, and recommended that it continue to have high ICF program priority. However, during the past 3 years, SNL has encountered technical problems in attempting to prove the feasibility of the light ion particle accelerator for ICF experiments. In its January 1990 interim report, NAS reserved judgment on the technical feasibility of the light ion approach, saying it would address those issues in its fall 1990 final report using data through the summer of 1990.

SECTION 6

UNIVERSITY OF ROCHESTER

The University of Rochester has operated the University of Rochester Laboratory for Laser Energetics since 1970. Of the six ICF participants, UR/LLE is the only university research facility and the only completely unclassified facility in the DOE ICF program. As such, it provides research opportunities for graduate students and other researchers. UR/LLE uses its Omega glass laser for direct drive spherical target experiments. UR/LLE has estimated it would need approximately $48 million in additional funds over the next few years to increase the power of the Omega laser by a factor of 7.5. Except for a preliminary design study, the Congress has not appropriated funds for the upgrade.

UR/LLE operates under a multi-year research Cooperative Agreement with DOE. UR/LLE is currently in the third year of the current 5-year Cooperative Agreement entered into in fiscal year 1988. The Cooperative Agreement contains an annual work plan with the goals/objectives that UR/LLE plans to achieve in the coming year. Most of UR/LLE's ICF program funding comes from DOE, but a small amount (since fiscal year 1988 less than 10 percent) comes from non-DOE sponsors, including New York State energy research authorities and utilities. UR/LLE researchers also receive some non-ICF funds directly from such organizations as DOD and NAS, who pay for some work done for them by the LLE researchers. Total ICF funding (DOE and non-DOE sources) has risen from $9 million in fiscal year 1986 to $13.6 million in fiscal year 1989. DOE ICF funding has risen from $7.7 million to $12.9 million in the same time period.

In fiscal year 1989, UR/LLE's Cooperative Agreement supported 90 staff (scientists, engineers, and technicians and research associates). UR/LLE also has approximately 26 other staff. It employs approximately 50 undergraduate students on a part-time basis, and provides full or partial assistance to about 30 graduate students.

GOALS/OBJECTIVES

UR/LLE's annual work plans contained seven major objectives during the period fiscal year 1987-89. These seven objectives included such areas as beam focusing and smoothing, development of diagnostic techniques, and creating a cryogenic target capability. UR/LLE officials told us that they achieved all but one of these objectives during the originally projected time frames. UR/LLE officials said they underestimated the difficulties in developing the cryogenic target capability, which was scheduled to be completed in fiscal year 1987. According to UR/LLE officials, they also overestimated KMS' ability to provide UR/LLE with cryogenic technical support for target development. Therefore, this objective was not achieved until 8 to 9 months later during fiscal year 1988. Officials stated that they have now achieved all seven objectives.

Polymer Target Fabrication

Program officials told us that one major goal not included among the seven objectives remains unfulfilled: obtaining a reliable supply of plastic polymer target shells essential for further direct-drive Omega laser experiments. KMS is responsible for developing these plastic shells to UR/LLE's stringent specifications. However, because of technical difficulties, KMS has not been able to meet UR/LLE's needs. UR/LLE officials said they have experienced difficulty in obtaining quality polymer targets from KMS, forcing UR/LLE officials to rely on LLNL to provide them a limited number of polymer targets manufactured when LLNL has time to do this.

However, in November 1989, UR/LLE made its own "breakthrough" in polymer shell manufacturing. Using adapted Japanese technology, it produced its own plastic polymer shells that met its stringent specifications. UR/LLE officials told us it required only 1 staff month of their time to adapt this technology. KMS had not seemed as interested in pursuing the adaption of the Japanese technology as UR/LLE, but UR/LLE said it will offer to transfer the polymer technology to KMS. However, UR/LLE said it will rely on LLNL to provide the finished plastic coating for these shells. KMS is also able to do this, but, according to UR/LLE officials, LLNL's technique is better.

NAS Views

In its 1986 report NAS commended UR/LLE for its work. The NAS 1990 interim report again praised UR/LLE for its fiscal year 1987-89 accomplishments and recommended that UR/LLE proceed with upgrading the Omega laser.

SECTION 7

THE NAVAL RESEARCH LABORATORY

The U.S. Naval Research Laboratory has been part of the ICF research program since 1972. NRL has an interagency agreement with DOE for this work and concentrates its efforts mainly on solutions to questions involving the use of laser beams to directly illuminate a fusion fuel target with enough energy for implosion of the target. NRL has the smallest operating budget in the ICF program--$4.5 million in fiscal year 1989 and 17 full or part-time personnel.

GOALS/OBJECTIVES

NRL determines, within the constraints of program resources, the specific experiments, tasks, and subtasks that it must complete to eventually accomplish its main goal of resolving basic questions involving laser-target interactions occurring in ICF experiments. NRL also determines the schedule and length of time its tasks will take. This is difficult because many of the goals are research goals which have not been previously attempted. NRL gives DOE an annual work plan for its activities. DOE reviews and approves this plan and then uses various means to monitor NRL's progress, including quarterly ICF program managers meetings, progress reports, technical reviews, and peer review.

During the period of January 1987 through June 1989, NRL had an ICF glass laser experiment program and was transitioning to a KrF gas laser program.[1] Most goals that NRL set for itself during this period were met, although a few were met later than initially estimated because of the difficulty of some experiments and, in some cases, because of insufficient funding.

Glass Laser Experiments

NRL's glass laser program emphasized two topics: experiments to measure: (1) the hydrodynamic instabilities caused in the fusion target when hit by a laser beam and (2) the effect that improving the quality of the laser beam has on laser-plasma instabilities. Most of NRL's experiments were completed in the time initially estimated by NRL. However, a few took longer than expected because of the difficulty of the experiments.

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[1]Some of NRL's $4.5 million operating budget for FY 1989 is being used for necessary building modification and equipment involved with NRL's transition to a small KrF program.

NRL's KrF Gas Laser Program

NRL's other main endeavor has been the design of its KrF laser, to be called "NIKE," and, to a lesser extent, the support of LANL's Aurora KrF laser program. To support its KrF program, NRL designed and procured laser components and initiated construction of an enclosure for the new NIKE laser. In addition, NRL was tasked with the responsibility of designing, building, and installing an oscillator at LANL to support the Aurora KrF program. NRL was late in completing this task because of technical difficulties and insufficient funds. The Director of LANL's ICF program told us this did not cause a problem for his program. DOE, in giving approval for NRL's KrF program, ordered NRL to work closely with LANL, the lead laboratory for gas lasers.

NRL's ICF director told us the Congress recommended that NRL receive $4.5 million in fiscal year 1989 for its KrF program, an increase of $1 million over that requested by DOE. Funding was shifted from the three DOE laboratories to accommodate this increase.

NAS Views

According to NAS, NRL's studies of the physics of direct drive, including studies of target hydrodynamic instabilities, and its development of techniques for improving laser beam quality have added much valuable knowledge to the ICF program. NAS has endorsed the development of a small KrF laser program at NRL.

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