REPORT TO THE JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

RELEASED

Development Of The Janus Reactor Complex For Biological Research By The Argonne National Laboratory

B-165117

Atomic Energy Commission

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-165117

Dear Mr. Chairman:

At the request of the Executive Director of your Committee, the General Accounting Office made a review of the development of the Janus reactor complex by the Argonne National Laboratory for use in conducting biological research for the Atomic Energy Commission. Our principal observations are summarized in the digest appearing at the beginning of the report.

A copy of this report is being sent today to the Vice Chairman of your Committee. As agreed by the staff of your Committee, copies of the report are being made available to the Atomic Energy Commission whose comments have been incorporated in the report.

We plan to make no further distribution of this report unless copies are specifically requested, and then we shall make distribution only after your agreement has been obtained or public announcement has been made by you concerning the contents of the report.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

The Honorable Chet Holifield, Chairman
Joint Committee on Atomic Energy
Congress of the United States

Contents

ABBREVIATIONS

AEC	Atomic Energy Commission
Argonne	Argonne National Laboratory, Illinois
CH	Chicago Operations Office
DBM	Division of Biology and Medicine
DRL	Division of Reactor Licensing
GAO	General Accounting Office
RDT	Division of Reactor Development and Technology
ROD	Reactor Operations Division
RSRC	Reactor Safety Review Committee

COMPTROLLER GENERAL'S REPORT TO THE JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

DEVELOPMENT OF THE JANUS REACTOR COMPLEX FOR BIOLOGICAL RESEARCH BY THE ARGONNE NATIONAL LABORATORY
Atomic Energy Commission
B-165117

D I G E S T

WHY THE REVIEW WAS MADE

At the request of the Executive Director, Joint Committee on Atomic Energy, the General Accounting Office (GAO) has reviewed the development of the Janus reactor complex--a research complex designed and constructed by the Argonne National Laboratory (Argonne) for use in the biological and medical research program of the Atomic Energy Commission (AEC).

A number of problems were encountered during the development of this project. There were substantial delays in obtaining operation of the research reactor at full power. Ultimately, operations were discontinued so that necessary modifications could be made to the research facility.

FINDINGS AND CONCLUSIONS

The history of the Janus project is as follows:

Development of the Janus complex was approved by AEC in October 1958.

Use of operating funds was authorized because the project was developmental in nature. Argonne estimated that Janus would be completed by December 1959 and that the cost of the complex would be $330,000.

Problems were encountered during project development, and not until June 1965 was operation of the reactor at full power achieved. (See pp. 9 to 15.)

Further problems resulted in an inability to fully employ the complex for conducting biological research. Argonne found it necessary to discontinue operations in October 1968 to modify the facility. (See pp. 16 to 20.)

One of the main features of the original design of the reactor was a provision for simultaneous exposure of one group of animals to high-level, and another group to low-level, neutron radiation through the

use of two exposure rooms. The current modifications, however, will not enable the low-level room to be used for its intended purpose, and it may be necessary for Argonne to request additional funds to modify this room. (See pp. 21 to 23.)

Estimated completion date of the modifications is February 1970. GAO estimates that, upon completion, the costs of the reactor and related facilities and equipment will total about $1.3 million. (See pp. 20, 24 and 25.)

GAO believes that the following factors contributed to the delays, cost increases, and other problems associated with the development of the Janus complex:

--Because Argonne's Reactor Engineering Division, which usually designed reactors, was fully committed to higher priority projects, its Reactor Operations Division was assigned responsibility for the Janus reactor and only limited use was made of the many scientific and technical disciplines in the various engineering, physics, and other divisions.

--The project was consistently assigned a low priority by the various organizations responsible for granting safety approvals.

--After it was determined that Janus could not be fully utilized for biological research, AEC and Argonne conducted five separate studies over a 3-year period to determine whether and how to modify the complex.

AEC's Division of Biology and Medicine approved the program justification for Janus and the use of biomedical research funds for its development. GAO found no evidence that the Division of Biology and Medicine took an active role in attempting to expedite completion of the Janus reactor during the period it was under construction even though that division had the primary responsibility for directing the overall biomedical research program. In view of its responsibilities, the Division of Biology and Medicine was the AEC Headquarters organization with the most direct interest in seeing that the objectives of the project were met. GAO believes that the Division of Biology and Medicine should have given greater management attention to the project during the period the reactor was being developed.

GAO was advised that, at the time of the development of the Janus complex, Argonne did not have a formal quality assurance program to assist in ensuring that research and development projects involving the development of complex facilities were designed and developed properly. Argonne advised GAO, however, that in May 1969 a formal quality assurance program was established and that quality assurance procedures were being employed in connection with the Janus modifications. (See pp. 26 and 27.)

RECOMMENDATIONS OR SUGGESTIONS

Although GAO has not evaluated the quality assurance program at Argonne, it believes that such a program, properly conceived and implemented, should assist in preventing the recurrence of problems similar to those encountered in developing the Janus complex. As additional assurance, GAO proposed that, prior to initiating developmental projects involving the construction of costly new facilities with operating funds, Argonne develop and provide to AEC:

--A schedule for completing the major steps involved in project development, such as detailed design, construction, and preparation of safety reports.

--A description of the organization to be used in managing the project, including the scientific and technical disciplines to be involved.

--The effects anticipated, from other work, on the laboratory's ability to keep the project on schedule.

GAO also proposed improvements in (1) Argonne's method of accounting for the costs of such projects and (2) AEC's procedures for coordinating the development of reactor projects for use in programs of its research divisions. (See pp. 26 to 28.)

AGENCY ACTIONS AND UNRESOLVED ISSUES

AEC and Argonne agreed to accept GAO's proposals. (See pp. 27 and 28.)

CHAPTER 1

INTRODUCTION

At the request of the Executive Director, Joint Committee on Atomic Energy, the General Accounting Office has made a review of the development of the Janus reactor complex--a research complex designed and constructed by the Argonne National Laboratory for use in the biological and medical (biomedical) research program of the Atomic Energy Commission. Argonne is one of AEC's contractor-operated national laboratories where biomedical research is conducted.

The Janus complex consists of a nuclear reactor and an adjacent facility for conducting biological research by exposing large numbers of animals to neutron and gamma-ray irradiation. The reactor has two convex radiation faces for delivering different neutron intensities to two adjacent exposure rooms--one for low-level and the other for high-level irradiation--thus the name Janus, after the ancient Roman god with two opposite faces.

Our review was directed primarily toward the manner in which the design and construction of the Janus complex was managed by AEC and by Argonne. The scope of our review is described in detail in chapter 6.

INITIATION AND DEVELOPMENT OF THE JANUS COMPLEX

Argonne has been conducting biomedical research and investigating into the potential hazards of nuclear radiation to man, from external and internal sources, since it was established in 1946. A variety of different experimental animals have been exposed to gamma rays and fission neutrons, either alone or in various combinations, at various times by the use of either reactors or cobalt-60 exposure rooms in Argonne's biology building. However, because of the many unsolved problems in biomedical research and the need to study animal populations exposed to very low radiation levels for long periods of time, in March 1957 Argonne submitted a proposal to AEC for designing and constructing a low-level gamma radiation room that could be

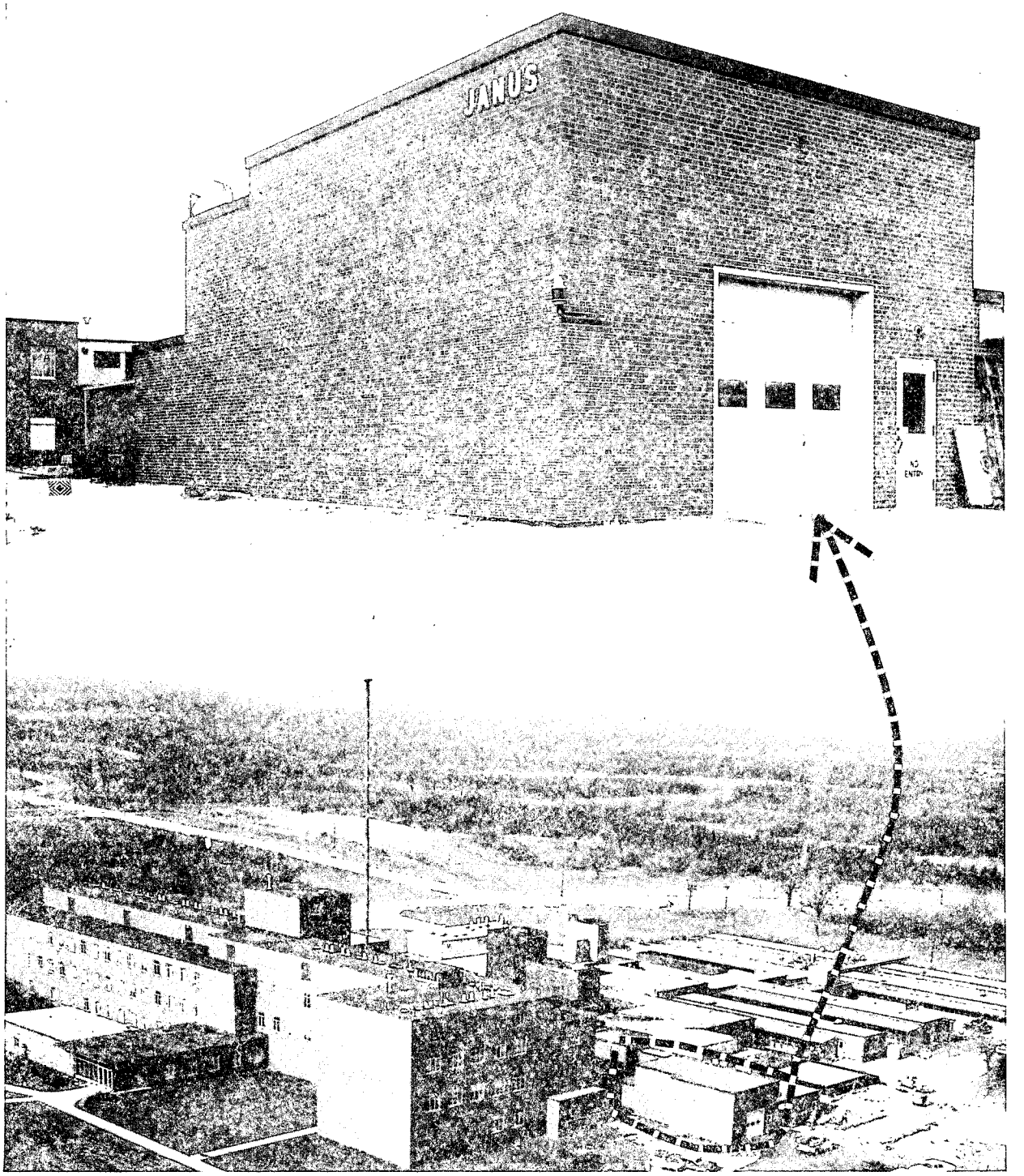
used exclusively for low-level, long-term radiation studies. In May 1957, AEC authorized Argonne to design the facility.

In April 1958, before design of the low-level gamma room was completed, Argonne submitted a revised proposal to AEC requesting authority to construct, in lieu of the low-level gamma room, a radiation complex which would accommodate irradiation of animals by both neutrons and gamma rays. The proposal stated that it was no longer possible to schedule an existing reactor at Argonne for low-level neutron radiation studies for the periods necessary--up to 1 year or more--and that an increase in the power level of the reactor had made it extremely difficult, if not impossible, to obtain the low-neutron fluxes necessary.

A prospectus prepared by Argonne in July 1958 stated that the proposed reactor and supporting research facility would be located in a separate building which would be attached to the existing biology building (see p. 6) and would have a basement and a first floor. The basement was designed to contain the reactor, a high-level exposure room, a low-level exposure room, and an area which would be used for reactor equipment and as a means of access to the two exposure rooms. The first floor was designed so that the reactor control room would be above and to one side of the reactor and exposure rooms as illustrated in the cutaway drawing on page 8.

The proposed neutron and gamma-ray complex was unique in that it provided for simultaneous neutron radiation of animals in a low-level exposure room and in a high-level exposure room, both of which were to be located adjacent to the reactor. In addition, the low-level exposure room was to be designed for radiation of animals with either neutrons or gamma rays, or mixtures thereof.

Development of the complex was approved by AEC in October 1958. Utilization of operating funds was authorized because the project was developmental in nature. Argonne estimated that the reactor would be completed by December 1959. However, because of a number of problems encountered during project development, initial low power operation of the

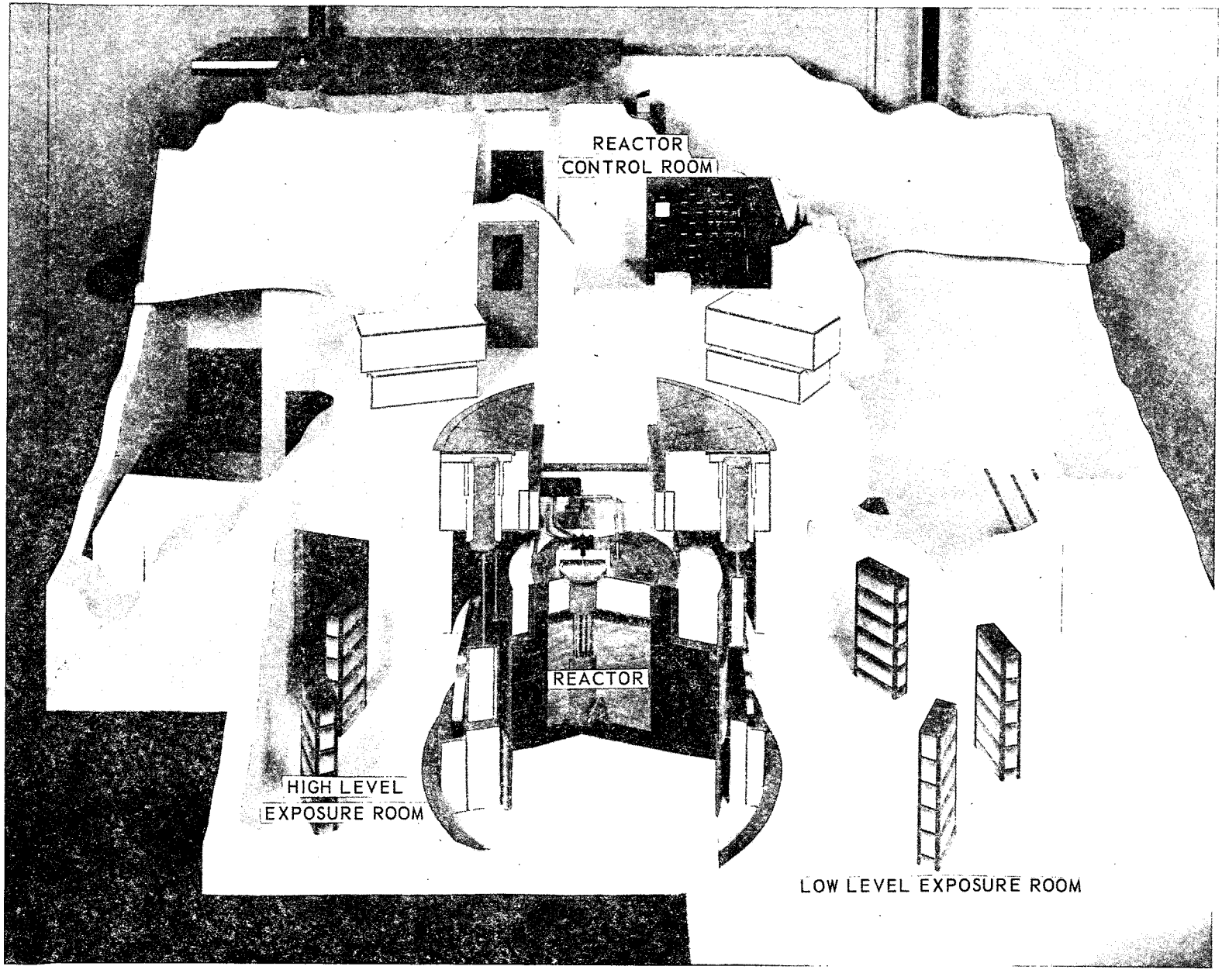

JANUS

reactor was not authorized until August 1964 and operation of the reactor at full power was not achieved until June 1965.

Certain problems affecting the utility of the research facility and the safety of research workers were noted at the time full power operations were achieved. As a result, a series of studies were initiated in August 1965 in an attempt to resolve the problems which prevented Argonne from fully utilizing the research facility. AEC and Argonne concluded by October 1968 that, on the basis of studies by five separate committees or task forces, research currently proposed could be carried out by correcting the problems affecting the utilization of the facility and the safety of research workers in the high-level exposure room. Correction of problems encountered in the low-level exposure room was deferred.

During the period 1965 to 1968, while these studies were being conducted, Argonne used the Janus complex for some biological experiments; for example, experiments involving tissue culture cells and drosophila. We were advised that the results of some of these experiments had been published.

In October 1968 reactor operations were discontinued to permit modification of the facility. Argonne advised us that the estimated completion date for the modifications was February 1970. We estimate that, upon completion of the modifications, the costs of the reactor and related facilities and equipment will total about $1.3 million, including about $318,000 for the modifications.


REACTOR
CONTROL ROOM
REACTOR
HIGH LEVEL
EXPOSURE ROOM
LOW LEVEL EXPOSURE ROOM

CHAPTER 2

LACK OF EFFECTIVE MANAGEMENT ACTION TO PROVIDE FOR SUCCESSFUL COMPLETION OF JANUS REACTOR COMPLEX

The need for a neutron and gamma-ray irradiation complex for biological research was expressed by Argonne in its proposal to AEC in April 1958. Although development of the Janus complex was authorized by AEC in October 1958, in January 1970 it was still under modification and full use of the complex for research purposes had been deferred pending completion of the modifications to the facility and evaluation of their effectiveness in resolving the problems encountered. Further, even after completion of the modifications, only part of the facility will be usable for reactor irradiation experiments.

The long delay in obtaining full utilization of the complex, and related cost increases, resulted from a series of problems, many of which, in our opinion, might have been avoided or at least minimized if the planning and execution of the project had been given greater attention by both AEC and Argonne. The problems encountered during the development of the complex are discussed in the following sections. Our conclusions are discussed in chapter 5 together with the actions agreed to by AEC and Argonne to improve management control over projects such as Janus.

PROBLEMS AND DELAYS IN COMPLETING JANUS REACTOR AND RESEARCH FACILITY

On November 11, 1958, the Argonne laboratory director's office authorized the start of reactor design and fabrication on the basis of an authorization received from AEC on October 15, 1958, to develop the reactor with operating funds. At that time, Argonne estimated that the reactor would be completed by December 1959 at a cost of $200,000.

The decision to use operating funds for the reactor rather than plant acquisition funds was made by Argonne and

approved by AEC because the project was developmental in nature and involved a reactor which would contain many novel features and would be likely to undergo substantial modifications after installation. The novel features included (1) the provision for giving low-level and high-level doses simultaneously without interference and (2) the ability to vary the ratio of fast neutrons, slow neutrons, and gamma radiation.

Because Argonne's Reactor Engineering Division, which usually designed reactors, was fully committed to higher priority reactor projects, its Reactor Operations Division (ROD) was assigned the primary responsibility for designing and developing the Janus reactor and part of the research facility. Our review showed that ROD made only limited use of the many scientific and technical disciplines in Argonne's various engineering, physics, and other divisions in designing and constructing the reactor.

Argonne's Biological and Medical Research Division was assigned the responsibility for establishing reactor building requirements, and the Plant Engineering Division was assigned the responsibility for managing the construction program. No laboratory official was formally assigned overall responsibility for the successful development of the complex.

During calendar year 1959, as design of the complex progressed, it became apparent that the cost estimate and construction period for the reactor had been considerably underestimated. In July 1959, Argonne advised AEC's Chicago Operations Office (CH) that the estimated cost of the reactor had increased to about $435,000. Factors cited as contributing to this increase included (1) the developmental nature of the project, (2) changes in scope, and (3) a lack of detailed information at the time the original estimate was made. Argonne stated that some rather large items had been overlooked in the original estimate and that the estimator had been unable to anticipate the complexity of several items.

The reasons for the cost increase, as indicated by Argonne, can be summarized as follows:

Initial estimate		$200,000
Add reactor auxiliaries erroneously classified as part of the building in the initial estimate		48,000
Revised initial estimate		248,000
Add:		
Scope changes	$ 61,000	
Lack of detail in original estimates and developmental nature of project	126,000	187,000
Total		$435,000

In February 1960 Argonne, with CH approval, revised its original project authorization to reflect the cost increase and to extend the project completion date to February 1961, an extension of about 14 months.

In March 1961 Argonne advised CH that the estimated cost for the reactor had again increased, and in June 1961 Argonne revised the project authorization for a second time to reflect a revised cost estimate for the reactor of $508,000 and a revised completion date of January 1962. Argonne correspondence indicated that the increase in the estimated cost was caused by the need for increased shielding, problems with the reactor shutters, and other revisions in estimates. The extension of the project completion date was attributed in part to a delay in the delivery of certain vendor-furnished materials.

In October 1961 Argonne advised CH of another increase in the reactor cost estimate, and in November 1961 Argonne prepared the third revised project authorization, increasing the estimate to $582,000. Argonne attributed the cost increase of about $74,000 principally to the following factors.

1. The requirement that each individual piece of graphite for the reactor be cut and fitted at the construction site was not originally foreseen.

2. Testing the reactor vessel for leaks disclosed problems related to inadequate gasket materials.

3. Technical difficulties were encountered in developing the neutron converter plates.

4. Additional instrumentation requirements resulted from a review by the Argonne Reactor Safety Review Committee (RSRC).

Fabrication of the reactor was completed in March 1963 at a final cost of about $605,000. We were advised that the delay in project completion from the previously estimated date of January 1962 was caused primarily by the need for modifications in order to obtain the approval of the RSRC.

In summary, completion of the reactor was originally planned for December 1959 but was delayed for more than 3 years because of a variety of unforeseen problems, and the final cost of the reactor was about $605,000 compared with the revised initial estimate of $248,000. Other costs associated with the development of the Janus complex also increased substantially, as discussed in detail in chapter 4.

DELAYS IN OBTAINING SAFETY APPROVALS FOR REACTOR OPERATION

Under AEC policy, review and approval by AEC of the safety aspects of a reactor are required to substantiate that reactors are designed, constructed, operated, and maintained in a manner which will insure personnel and public safety. Argonne's RSRC, CH, and the Divisions of Reactor Development and Technology and Reactor Licensing at AEC Headquarters are essentially responsible for review and approval of the safety aspects of reactors constructed by Argonne.

Under current procedures, Argonne is required to prepare a preliminary safety analysis report before construction of a reactor begins, unless a waiver is obtained from AEC. Argonne is also required to prepare a final safety analysis report before a reactor is operated.

We were informed that a preliminary safety analysis report was not prepared for the Janus reactor. Both Argonne and AEC officials informed us that, at the time this reactor was designed, it was not the practice to obtain a preliminary safety analysis report before beginning construction of small reactors.

A final safety analysis report was prepared by the Argonne ROD and submitted to Argonne's RSRC by the laboratory director on January 16, 1961. The letter of transmittal noted that, at that time, the reactor was scheduled to begin operation on or about July 1, 1961. A priority list prepared by the laboratory director in late January 1961, however, showed that the Janus safety analysis report had the lowest priority in RSRC's inventory of reactor projects.

Minutes of RSRC's meeting of April 18, 1961, show that, after reviewing the report, RSRC expressed concern regarding a lack of detail and specific analysis in the report. Also, RSRC recommended that a consultant from the laboratory staff be asked to conduct a detailed engineering safety review of the reactor control system.

Subsequently, a review of the control system was made by the Reactor Engineering Division, and additional instrumentation was added. A revised safety analysis report was prepared and submitted to RSRC on March 5, 1962. However, RSRC did not approve the report and recommended a number of design changes to increase the safety of the reactor.

Design changes were made and a revised report was submitted to RSRC on August 6, 1962. Further revisions to the report were made, and it was not finally approved by RSRC until January 1963, only 2 months before the completion of reactor fabrication. Argonne officials indicated that the 2-year period required for obtaining RSRC approval was caused primarily by (1) the unconventionality of the reactor design and (2) the lack of specific design detail to enable the RSRC to reach timely conclusions concerning reactor safety.

In January 1963 the safety analysis report was submitted to CH for approval. CH completed its review on May 3, 1963, and the revisions which it required were completed in August 1963. Following the completion of these revisions, CH in September 1963 recommended to the Division of Reactor Development at AEC Headquarters that the proposed reactor operation be approved.

CH indicated that its delay in approving the report was caused by (1) the relatively low priority given to the Janus project, (2) a staff shortage, (3) a lack of detailed design information in the report, and (4) CH's anticipation of the future requirements of the then expanding AEC Division of Licensing and Regulation. In March 1964 AEC's regulatory program was reorganized and, as a result, the Division of Licensing and Regulation and another division were abolished and certain reactor review and licensing functions were assigned to a new division--the Division of Reactor Licensing (DRL).

In September 1963 the safety analysis report was forwarded to the Division of Licensing and Regulation for review. DRL advised us, however, that the Division of Licensing and Regulation was unable to devote attention to the report until January 1964 because of higher priority

reviews. In May 1964 CH advised the Division of Reactor Development that the reactor was ready for critical loading and requested that the safety analysis report review be expedited.

After receiving the recommendations of DRL, the Division of Reactor Development approved operation of the reactor in August 1964, subject to certain restrictions.

AEC's reactor development activities were reorganized in December 1964, and most of the responsibilities and functions of the Division of Reactor Development were divided between two new divisions--the Division of Reactor Development and Technology (RDT) and the Division of Naval Reactors. RDT advised us that the delay in obtaining approval of the safety analysis report from AEC Headquarters was caused by the following factors:

1. The initial report lacked detailed design information, and it was necessary to continually request data from Argonne through CH.

2. CH could not reply and process safety data more timely because of staff shortages and a heavy workload.

3. DLR deferred its review because it knew that Janus was a relatively low-priority project.

Thus, throughout the period during which the safety aspects were under review--January 1961 through August 1964--delays were encountered because of inadequacies in both the safety report and the design of the reactor. Further, these delays appear to us to have been substantially extended because of the low priority assigned to the project and the lack of adequate attention, on the part of responsible management officials, to expediting completion of the projects. In view of the importance of the research to be conducted using the facility, as expressed at the time the project was authorized, we believe that greater efforts should have been made to accelerate completion of the project after it became apparent that development was not proceeding satisfactorily.

PROBLEMS AFFECTING REACTOR SAFETY AND UTILITY

On August 12, 1964, about 6 years after the project was initially authorized, the Janus reactor achieved initial criticality. It was found, however, that the reactor had a positive temperature coefficient--a condition in which an increase in reactor coolant temperature introduces reactivity. This condition had not been anticipated in the original design of the reactor or in the safety analysis report, and its effect on reactor safety could not be immediately determined. Therefore, the reactor could be operated only at a low power level pending further investigation of the problem.

After a great deal of study, AEC decided in May 1965 that the positive temperature coefficient did not pose a hazard and authorized the reactor to be operated at full power.

At the time full reactor power was achieved in June 1965, Argonne noted certain unanticipated problems affecting the utilization of the facility. These problems resulted in a reduction in optimum efficiency of operation of the reactor and impairment of the usefulness of the facility.

The extent to which the facility could achieve optimum efficiency was reduced because (1) radioactivity was induced in the high-level exposure room walls by neutron capture and (2) neutrons leaked into the high-level exposure room. To maintain exposure of research workers within acceptable levels, it was necessary to reduce reactor power and await partial decay of radioactivity before each entry into the exposure room.

The usefulness of the facility to conduct biological research was impaired also by (1) excessive dose contributions from gamma radiation in the low-level room and (2) too many low-energy neutrons for the purpose of biological research in the high-level exposure room. These factors adversely affected the research results because they impaired the researchers' ability to control overall

radiation dose levels applied to animals exposed in the facility.

As a result of these problems, from August 1964 to October 1968, Argonne was able to operate the reactor for only 1,772 hours--an average of about 35 hours a month. Argonne officials advised us that during this period the reactor was operated about 20 percent of the time for biological experiments and about 80 percent for testing experiments, dosimetry, and dosimetry experiments related to the design of the facility modifications.

Thus, it is apparent that the Janus reactor has been operated at a much less efficient and effective level than contemplated, which has resulted in an inability to fully utilize the complex for the performance of biological research.

MODIFICATIONS TO JANUS FACILITY

In about August 1965, a committee was established within Argonne's Biological and Medical Research Division to make a study in an attempt to devise solutions to the problems encountered in operating the reactor and the research facility. By memorandum dated April 7, 1966, the committee submitted a proposal to line the high-level exposure room with lead to reduce the activation of the walls. It was proposed that similar modifications to the low-level room be deferred because funds for this purpose were not available.

On April 25, 1966, the laboratory director appointed a task force to recommend solutions to the problems with the facility. The laboratory director stated that, although solutions to the problems had been proposed, it was not clear which solutions were best.

The task force submitted its final report on June 7, 1966, which recommended the installation of lead shielding and a number of other modifications. The report recommended that no changes be made to the low-level room until the proposed changes to the high-level room could be made and their effects evaluated.

After further technical design considerations, the laboratory director advised the Division of Biology and Medicine (DBM) at AEC Headquarters of the proposed design changes on November 9, 1966, estimating the cost at $300,000, and requested additional funds to do the work involved.

In reply, the director of DBM informed the laboratory director on November 21, 1966, that he could not endorse going ahead with the proposed $300,000 outlay to put the high-level room in order, and at some later date have another $300,000 or $400,000 outlay for the low-level room, without a thorough review of requirements for the facility for priority biological research. He requested that the review take cognizance of work done elsewhere during the past 8 years which might have resolved some of the biological problems that formed the original justification for construction of the Janus complex. He also suggested that,

meanwhile, the reactor be put in mothballs and no further operations costs be incurred.

As a result of this reply, Argonne appointed a committee to review the continued need for the Janus complex. In a report dated March 1967, the committee concluded that the research complex was still needed and recommended that the modifications to the high-level room be made.

The report stated that the improvements in the high-level room would make it feasible to expose large numbers of animals simultaneously and that the neutron dose rate could be adjusted, as required, by varying reactor power. The report stated further that, if at a later time it seemed desirable to use the low-level room, any necessary modifications would be proposed separately but that the low-level room was not essential for the program. As a result of the report, on June 5, 1967, the acting laboratory director proposed to the Division of Biology and Medicine, that the modifications be approved.

In July 1967 DBM advised Argonne that it wished to convene an ad hoc committee to consider the question of continuation of the Janus program. The committee, composed of scientists from a university and other AEC laboratories, met in September 1967 and in a report dated October 24, 1967, recommended that the proposed modifications be approved.

The committee noted, however, that the history of the Janus complex was unfortunate and had been a source of concern to both Argonne and DBM. The committee stated that the obvious failings in the past had been lack of coordination and diffuseness of responsibility and that it was essential that in the future every effort be made to avoid further delays and mistakes.

As a result of the committee review, DBM approved the modifications on January 18, 1968--about 1 year and 2 months after they had been proposed to it. Argonne, however, spent several more months considering whether or not to proceed with the modifications. In June 1968 the laboratory director requested that the director of the Argonne Reactor Physics Division further review and evaluate the

proposed modifications to provide every reasonable assurance that they would meet the desired objectives.

The report of the Reactor Physics Division, dated September 24, 1968, stated that the review provided a basic confirmation that the modifications proposed in the final report prepared by the Argonne task force in June 1966 would meet the desired objectives.

With respect to the procedures to be used in carrying out the modifications, the report recommended that:

> "The final detailed designs for the JANUS improvements should be performed with adequate review procedures by a shielding-design expert and by an experienced reactor physicist. The original Task Force for JANUS Improvements included experts in both categories. As the final detail drawings are generated, there will be a need for such guidance as well as for final review. I recommend, therefore, that the JANUS Design Group be enlarged to include these specialists, or that a well-defined alternative review procedure be established, with final review of each drawing assured by the shielding-design specialist and by the reactor physicist.
>
> "In the implementation of the final design modifications, it will be essential to set realistic specifications and then to establish and maintain supervisory and checking procedures that will assure that the design condition are met."

The modifications to the Janus facility were started in October 1968, and procedures implementing the above recommendations were established. Argonne advised us that the estimated completion date for the modifications was February 1970.

The modifications include (1) installing a material with minimal activation qualities to line the walls, ceiling, and floor, (2) installing a false ceiling, (3) modifying electrical and mechanical systems, and (4) installing more effective reactor shutters, a new neutron converter plate, and neutron absorber plates.

CHAPTER 3

REVISED OBJECTIVES OF JANUS AFTER MODIFICATION

In April 1958 Argonne justified the Janus complex on the basis of the need for studying not only the biological effects of neutron radiation but also those pertaining to gamma radiation. One of the main features of the original design was the provision for simultaneous exposure of one group of animals to high-level and another group to low-level neutron radiation through the use of two exposure rooms. The current modifications, however, will not enable the low-level room to be utilized for its intended purpose; and, depending upon the results of experiments to be conducted using the facility, it may be necessary for Argonne to request additional funds in the future to modify the low-level room.

Initially Argonne pointed out that, although progress had been made in the study of certain effects of neutron radiation, further research was needed of the effects of long-term, very low-level neutron and gamma radiation, and mixtures thereof. Argonne stated that, although some neutron studies had been made, the proposed Janus complex was needed for long-term, low-level studies because Argonne reactors which had previously been used were needed for other research at higher radiation levels.

As discussed in the previous chapter, Argonne has decided to correct only the problems in the high-level exposure room of the research facility. AEC commented on the future plans for the low-level exposure room in hearings before the Joint Committee on Atomic Energy in April 1969 as follows:

> "The present design differs from the original design principally in that the low dose rate room [low-level exposure room] will not be modified and all the radiation exposures will be made utilizing the high dose rate room [high-level exposure room]. To obtain low dose rates, the reactor will be operated at a lower power level." (Underscoring supplied.)

The decision to attempt to perform both low-dose and high-dose experiments in the high-level room was predicated, at least in part, on the results of limited research at AEC's Oak Ridge National Laboratory and at a laboratory in England.

An Argonne scientist advised us that this research indicated that the effects of relatively short daily exposures to neutron radiation may be equivalent to exposure on a continuing basis. He stated also that limited tests had indicated that scientists may be able to calculate the effects of long-term neutron radiation on the basis of short-term exposure. We were further informed by Argonne officials that these hypotheses could be verified only if experiments were conducted using the Janus complex. We were advised also that, if these hypotheses proved to be in error, Argonne officials would give serious consideration to modification of the low-level exposure room for conducting long-term, low-level studies.

Argonne advised us further that these proposed short-term exposures referred to daily exposures of 4 hours or less, compared with 8 hours or more for long-term exposures, and that its scientists did not propose to withdraw from their original intention to study the effects of neutron irradiation delivered over the lifetime of the animal since irradiation protracted over the lifetime remained as a significant experimental variable.

Thus, Argonne and AEC officials concluded that if they could corroborate the feasibility of calculating the effects of long-term radiation from short-term exposure through further experiments, the high-level room might have sufficient capacity to conduct both high-level and low-level radiation experiments by increasing or decreasing reactor power. In that event the low-level exposure room would not be essential to performing neutron radiation studies.

In May 1969 an official of AEC's Division of Biology and Medicine advised us that:

> "The facility was modified such that only the high-flux room [high-level exposure room] would

be used for the experiments. This decision was based on the judgment that most of the research planned for both rooms could be carried out in the high-flux room. By adjustment of the power level of the reactor, essentially any desired flux could be obtained in the high-flux room. The cost of modifying the low-flux room therefore did not seem warranted. Should it become necessary at any time in the future to have the low-flux room, it could be reinstated with additional cost for modification." (Underscoring supplied.)

The laboratory director informed us that, on the basis of the study of the modifications of the Janus facility conducted by the Reactor Physics Division in 1968 (see p. 20), he was convinced that upon completion the complex would be operable for neutron irradiation of animals. Other Argonne officials expressed confidence that, if the validity of calculating the effect of long-term neutron radiation from short-term exposure could be corroborated, the modification would provide the capability of performing the desired research.

If calculations of the results of Argonne's initial neutron experiments do not corroborate the validity of calculating the effects of long-term neutron radiation on the basis of short-term exposure, Argonne may find it necessary to make a separate proposal to modify the low-level room at a later date to conduct low-level, long-term neutron radiation studies.

On the basis of our review, it appears that, even if the high-level room proves to be capable of being used for both long-term and short-term studies, the capacity of the Janus complex will be substantially reduced because of the nonavailability of the low-level room. This is so because the low-level room is more than three times as large as the high-level room and can accommodate more animals. Thus, the loss of more than 75 percent of the space available for experimental purposes could curtail the number of long-term, low-level studies performed in the facility at any one time.

CHAPTER 4

COSTS OF JANUS COMPLEX

At the time AEC authorized development of the Janus complex in 1958, Argonne estimated that its design and construction would cost about $333,000--$133,000 for the building and certain related equipment and $200,000 for the reactor.

In hearings before the Joint Committee on Atomic Energy in April 1969, AEC stated that the reactor had been constructed at a cost of $760,000 and estimated that the modifications (which had been initiated in October 1968) would cost an additional $274,000. Our review showed that this statement was based on information that had previously been furnished to AEC by Argonne.

Because of the nature of the Janus project, it was financed primarily from operating appropriations, and therefore Argonne did not provide for the accumulation of the total costs of the project. In attempting to develop the cost of the project, we found that Argonne inadvertently did not include costs of about $206,000 incurred in constructing certain facilities and providing certain equipment related to the project. Argonne agreed that these costs should have been included. We estimate that the costs of the reactor and related facilities and equipment constituting the Janus complex prior to its modification totaled about $966,000.

In January 1970 Argonne advised us that the estimated cost of the modification work had increased to about $318,000, which brings our estimate of the total costs of the reactor and related facilities and equipment to about $1.3 million.

In the April 1969 hearings before the Joint Committee on Atomic Energy, AEC reported that, through 1966, operational costs for the Janus complex amounted to $530,000. When the reactor was shut down for modification in October 1968, an additional $210,000 in costs had been incurred for its operation, for a total of $740,000.

Of the $740,000, about $416,000 in costs were incurred by Argonne's Reactor Operations Division in connection with the operation of the reactor. The remaining $324,000 represented ROD costs prior to fiscal year 1965, which were incurred essentially for certain technical services provided by ROD, such as design, engineering, supervision, installation and testing of reactor components, and reactor operator training. Through December 31, 1969, Argonne also incurred costs of about $143,000 for ROD services during the modification period. Thus, the costs incurred by Argonne's ROD in connection with the development and modification of the Janus complex totaled about $467,000 through December 31, 1969.

In arriving at the actual costs incurred for the Janus complex, it was necessary for us to make numerous analyses of Argonne's accounting records because, as previously noted, Argonne did not provide for the accumulation of the total costs of the project. At our suggestion, Argonne agreed to revise its internal accounting practices to better identify the total costs of future projects of this type.

CHAPTER 5

CONCLUSIONS

We believe that the following factors contributed to the delays, cost increases, and other problems associated with the development of the Janus complex.

1. Because Argonne's Reactor Engineering Division, which usually designed reactors, was fully committed to higher priority projects, ROD was assigned responsibility for the Janus reactor. ROD made only limited use of the many scientific and technical disciplines in the various engineering, physics, and other divisions in designing and constructing the reactor.

2. The project was consistently assigned a low priority by the various organizations responsible for granting safety approvals.

3. After it was determined that the complex could not be fully utilized for biological research, AEC and Argonne conducted five separate studies over a 3-year period to determine whether and how to modify the complex.

DBM approved the programmatic justification for Janus and the use of biomedical research funds for its development. During our review, we found no evidence that DBM took an active role in attempting to expedite completion of the Janus reactor during the period it was under construction, even though DBM had the primary responsibility for directing the overall biomedical research program. In view of its responsibilities, DBM was the AEC Headquarters division with the most direct interest in seeing that the objectives of the project were met, and we believe that DBM should have given greater management attention to the project during the period the reactor was being developed.

We were advised that, at the time of the development of the Janus complex, Argonne did not have a formal quality assurance program to assist in ensuring that research and

development projects involving the development of complex facilities were properly designed and developed. Argonne advised us, however, that in May 1969 a formal quality assurance program was established and that quality assurance procedures were being employed in connection with the modification of the Janus complex.

Although we have not evaluated Argonne's quality assurance program, we believe that such a program, if properly conceived and implemented, should assist in preventing the recurrence of problems similar to those encountered in developing the Janus complex.

To provide additional assurance in this regard, however, we proposed that, prior to initiating developmental projects involving the construction of costly new facilities with operating funds, Argonne develop and provide AEC with (1) a proposed schedule for completing the major steps involved in project development, such as detailed design, construction, and preparation of safety reports, (2) a description of the organization to be used in managing the project, including the scientific and technical disciplines to be involved, and (3) the effects anticipated, from other work, on the laboratory's ability to keep the project on schedule. We proposed also that Argonne revise its internal accounting practices to better identify the total costs of future projects of this type.

AEC informed us that Argonne had agreed to accept our proposals.

Under current procedures, the Division of Reactor Development and Technology establishes project coordinators for its reactor projects who are responsible for supervising their development. In the past, such project coordinators have also been appointed by RDT for reactor projects developed for other AEC divisions under agreements reached with such divisions. We proposed that, to provide greater control over the development of all such projects by AEC officials with appropriate expertise, such a procedure as that followed by RDT be established by AEC as a formal requirement where reactors are constructed for use in programs of AEC's research divisions.

In response to our proposal, AEC informed us that procedures would be established providing that each new reactor project of AEC divisions reporting to the Assistant General Manager for Research and Development would be assigned to RDT for project execution.

CHAPTER 6

SCOPE OF REVIEW

We conducted our review at AEC Headquarters in Germantown, Maryland, and at the Chicago Operations Office and the Argonne National Laboratory, Argonne, Illinois.

Primarily, we examined into the manner in which the development, design, and construction of the Janus radiation complex were managed by AEC and by Argonne. We did not evaluate the need for or the quality of the biomedical research conducted under the program.

As a part of our examination, we reviewed pertinent legislative history and inquired into AEC's and Argonne's policies and procedures for developing research facilities. We also obtained the views of various laboratory and AEC officials knowledgeable of and responsible for the design and development of the radiation complex.

We reviewed the history and the purposes of the project to learn whether the original project objectives had been achieved, or were to be achieved upon modification of the research complex, which is expected to be completed in fiscal year 1970.

We also reviewed the initial cost estimates and the actual project costs and examined into the reasons for the cost increases and delays incurred during the development of the research complex.