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TECHNICAL BENEFIT OF AN INTERNATIONAL PROJECT*

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ABSTRACT

One critical issue examined in the present phase of the International Tokamak Reactor (INTOR) has been an evaluation of the technical benefit of dividing up the design and component production tasks of all major advanced technologies among all participants. Two approaches were evaluated: (a) a "splitting" approach in which each country provides 1/4 of the components of each major system (e.g., 3 of 12 TF coils), (b) a "branching" approach in which each country provides all components of selected major systems (e.g., first country provides all TF coils, second country provides all torus sectors, etc.). Quantitative cost and schedule estimates were developed for each of the two approaches and compared to the cost and schedule of the entire device if it were produced only by one country. The results of the U.S. evaluation indicated that the ratio of total estimated cost to the "national" cost was 1.66 for "splitting" and 1.20 for "branching." The cost per participant was 0.41 and 0.30, respectively. The increase in the construction schedule was estimated to be 2.6 years.

INTRODUCTION

Deciding to make INTOR an actual construction project would result in several identifiable benefits to the multinational participants; the benefits are the new fusion scientific knowledge produced at a financial cost substantially less than required for any single participating nation to do the same project alone. This benefit is readily identifiable. A less obvious, but critically important, aspect of such a large project is the overall design and fabrication of the major systems and components. It is judged that sharing both the design and the fabrication among the participants would be very desirable and of inestimable benefit to each participant. Therefore, it seems natural to want to have each participating nation derive the technical benefit associated with all developments that occur during design and manufacture of the actual hardware of the major advanced technologies.

This study was undertaken by the INTOR Workshop to determine the technical feasibility of partitioning the detailed design and component production tasks so as to benefit all participants in the development of all major technologies. Where necessary, this study is based on the INTOR design concept and test programs of Phase 2A, Part 1; the study assumes that INTOR will be built as an international joint project.

This study consisted of establishing a reference framework for performing the tasks, identifying the major systems and components to be evaluated, identifying the possible ways of achieving the technical benefit by each participant, and evaluating as quantitatively as possible the technical benefit to be derived by the participants.

TECHNICAL BENEFIT DEFINITION

In the context of the present study, the term "technical benefit" means the development of industrial capability and experience to permit moving forward with the development of future fusion technology. Therefore, the concept of partitioning the design and fabrication of all of the major advanced technology components and systems was put forward for evaluation. This study, therefore, focused on establishing as concisely as possible, the technical benefit to be derived by each participant from conducting the project on an international basis. How this is best done is not clear, and approaches needed to be evaluated. This was done. Quantitative information was developed where possible. Qualitative judgments and perceptions were obtained as well and are presented. The end goal was to determine the technical feasibility of partitioning the design and fabrication among the participants so that each participant can derive the

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"technical benefit" to the maximum extent without actually doing the entire project as a solely national endeavor.

APPROACHES AND BASIC ASSUMPTIONS

A number of agreements were reached by the international participants so as to have a common basis for performing this study and for comparing results. These agreements include the following: (1) the components and systems to be evaluated, (2) a reference organizational scheme, (3) three scenarios for comparative evaluation, and (4) a systematized questionnaire to be used to obtain input from component experts. Each of these is described in the following paragraphs.

Major Systems and Components Included in Evaluation

It was decided in the U.S. to adopt two criteria in determining the candidate major systems amenable for partitioning the design and fabrication. The two criteria are (1) the system must involve advanced technology; and (2) the system must involve multiple units so production can be partitioned.

All systems judged to be of standard technology and all systems that involve only one (or a few) units were judged not to be candidate systems for partitioning the design or fabrication. Using these two criteria, a judgment was made as to which systems satisfied both selection criteria. The major systems that satisfy both criteria are the following.

Magnets:	Toroidal field coils and poloidal field coils
Nuclear:	Torus, first wall, test modules, divertor plates
Heating:	ICRH systems
Tritium:	Atmospheric tritium recovery

Description of Reference Organization Scheme

In order to perform comparative evaluations that could lead to comparable results, it was judged practical and appropriate to adopt one reference organization scheme for the project. The reference organization scheme is outlined in Fig. 1 with responsibilities for the international INTOR team, the four national coordination teams, and the national fabricators, as indicated.

An international INTOR team would be established and would form the central core group of the project with responsibility to establish the total project system; define the management scheme; provide coordination and liaison; plan facilities, develop the test program, and manage device assembly; and define specifications.

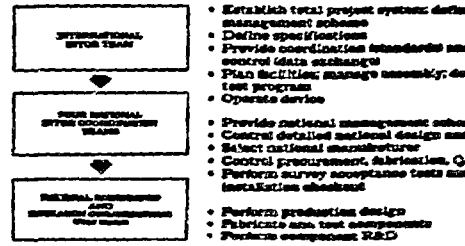

Fig. 1. Reference organization scheme for INTOR.

Each participant would establish a national INTOR coordination team. These four teams would be responsible for the control of the detailed national design effort and the national project R&D program; would select the national fabricators; would control procurement and fabrication; would perform survey acceptance tests and installation and test checkout of national components; and would provide the national management scheme.

Within each participant's country, the selected national fabricators would perform the necessary production design; fabricate and test the components; and perform the necessary project-related-component R&D in collaboration with the national research organization.

Scenarios for Comparative Evaluation

Three different scenarios were defined and adopted by the INTOR Workshop as the basis for the evaluation. Scenario A is the reference scenario for comparing international approaches to a purely national approach. It is assumed in this scenario that each national participant builds its own "INTOR" device.

Scenario B is designated "split." One international device is built and the four participants share in the fabrication of all advanced technology systems and components. For example, each participant would build three of the twelve toroidal field (TF) coils. All coils would be built to the same specification. In this scenario, it is assumed that each participant would continue to carry its own national R&D program.

Scenario C is designated "branch." One international device is built and the four participants share in the fabrication; all elements of a given major system would be done by one participant. For example, all 12 TF coils would be fabricated by one participant, all

components of the torus by a second participant, etc. Each participant would continue to carry its own national R&D program.

Systematic Input for Evaluation

An evaluation was performed for each of the advanced major systems and components selected by the INTOR Workshop. Input for the evaluation was obtained using a detailed questionnaire developed by the INTOR Workshop participants. The input was obtained by having industrial representatives complete the questionnaire. In each case, an industrial member of the Fusion Engineering Design Center (FEDC) led the effort in the U.S. The questions were designed to quantify the incremental time and cost associated with either the "splitting" or "branching" scenario. Estimates were obtained on cost increments for component/system design, procurement, fabrication, transportation, design control, cooling requirements, component verification and testing, quality assurance, spare parts, and facility requirements. In addition, the associated complexity in management coordination, project engineering, staffing requirements, and the project-related R&D were included in the incremental estimates to the overall project cost.

Input data for performing this evaluation were obtained from the estimates received on the questionnaires. The process used was to estimate from the quantitative data in the questionnaires a factor to be used to adjust the INTOR relative direct capital costs for the major tokamak systems and for the various items of the elements of the indirect costs. Similarly, factors were developed for the incremental time increases to perform each phase of the construction schedule to determine the overall impact on the schedule.

CAPITAL COST

The estimates of the increase in the total capital cost of the project are given in Table 1. The major systems comprising the direct capital cost and the major elements of the indirect cost are the same entries used in developing the INTOR cost estimate. The column labeled "National" is the relative costs from INTOR. Note that the total direct costs are normalized to 1.0. The indirect capital costs are given in units relative to the direct capital costs. The total relative indirect capital costs total to 1.08. The total relative estimate costs total to 2.08.

The costs for scenario B (splitting) and scenario C (branching) are given in the next two columns. The incremented factors increasing both the direct and indirect capital costs are given in parentheses for each item. The total increase in both direct and indirect capital costs are as indicated; the total direct capital cost increase for "splitting" is 17% and "branching" is 8%; the total indirect cost

Table 1. Cost evaluation of splitting and branching

Direct Capital Cost	National	International Splitting(B)	International Branching(C)
Torus	0.10	(1.5) 0.15	(1.3) 0.12
Magnets	0.30	(1.2) 0.36	(1.15) 0.34
Heating	0.08	(1.0) 0.08	(1.0) 0.08
Electrical (TF/PF)	0.16	(1.3) 0.21	(1.1) 0.18
Tritium	0.05	(1.2) 0.06	(1.15) 0.06
Diagnostics, I&C	0.06	(1.0) 0.06	(1.0) 0.06
Cooling	0.05	(1.0) 0.05	(1.0) 0.05
Maintenance	0.06	(1.0) 0.05	(1.0) 0.06
Facilities	0.14	(1.0) 0.14	(1.0) 0.14
Total Direct Capital Cost	1.00	1.17	1.08
Indirect Cost			
Engineering/Design	0.26	(2.4) 0.56	(1.15) 0.30
Project	0.14	(4.0) 0.56	(2.0) 0.28
Transp/Install/Assy	0.12	(1.6) 0.21	(1.25) 0.16
Contingency	0.42	(1.5) 0.63	(1.2) 0.50
R&D	0.13	(4.0) 0.52	(1.33) 0.17
Total Indirect	1.08	2.28	1.41
Total Estimated Cost	2.08	3.45	2.49
Ratio to "National"	1.00	1.66	1.20
Cost per Participant	1.00	0.41	0.30

( ) - Values in parentheses are factors of increase over "National" values.

increase is 120% for "splitting" and 33% for "branching."

The total estimated cost increase is a factor of 1.66 (from 2.08 to 3.45) for "splitting" and a factor of 1.20 (2.08 to 2.49) for "branching." This indicates the total cost increase of an international project using the "splitting" approach is 66% and using the "branching" approach is 20%. The cost to each participant for the "splitting" scenario is 41% of the total cost of building the project nationally. For the "branching" scenario, the cost to each participant is 30% of the total cost of building the project nationally.

Several possible benefits were identified for the "splitting" approach compared to the "branching" approach. The potential benefits are the following.

- Having several vendors involved in the fabrication process could be advantageous, particularly where the fabrication of a given component or system is highly developmental and truly advancing the art.
- Experience in U.S. projects suggests that selected vendors (either "splitting" or "branching") may actually reduce some time or costs relative to a national project. Having the entire international collection of vendors to choose from in the "splitting" or "branching" scenario could enable the project to obtain the "best" vendor. This

vendor might be able to complete the fabrication in reduced time and costs compared to what might occur in a purely national project.

- The relative "risk" to the project between scenario A, B, and C is not the same; therefore, strict reliance on the numerical evaluations of Table 1 could be misleading. Depending on the difficulty and complexity associated with a given advanced component/system, the risk of either "splitting" or "branching" could actually prove to be lower than that associated with a national project approach. Therefore, it would be beneficial to either "branch" or "split" the fabrication.

Based on these three considerations, the benefit from "splitting" or "branching" could counteract the estimated increase in cost and make the "splitting" or "branching" scheme very worthwhile. The requirements for project planning and implementation for the "splitting" scenario are more demanding than for the "branching" scenario.

Impact of "Splitting" on the INTOR Construction Schedule

A number of the activities associated with the engineering, design, fabrication, and erection of "split" components would require more time. The impact was evaluated by developing activity duration factors based on the questionnaire responses for the nine general activities identified in the nominal INTOR schedule. These factors were in turn used to calculate the increase in the duration of each activity affected by "splitting."

The results indicated a net increase in the total design and construction schedule of about 2.6 years. Figure 2 shows the original INTOR schedule and the revised schedule with "splitting."

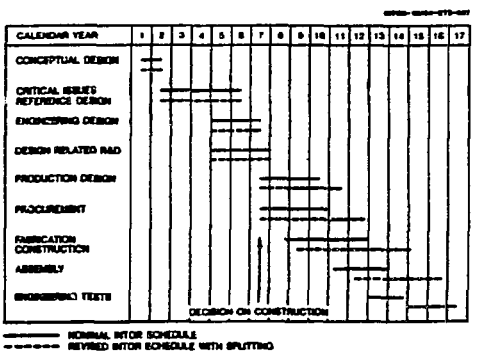

Fig. 2. Original and revised INTOR schedule.

No separate evaluation has been made of the "branching" scenario impact on the construction schedule. However, it is judged that the schedule impact would be considerably less than that due to "splitting."

CONCLUSIONS

The results of comparative evaluation and survey work indicate that either a "branching" scenario or a "splitting" scenario can be made to work successfully. Although the numerical judgments are recognized as being subjective and only provide an indication of a given impact for a given time, the quantitative data in the questionnaires were reasonably uniform. The numerical judgments suggest that if the "branching" scheme were used, the project would be more costly than a national program by ~20% and the cost per participant would be ~30%. The "splitting" scheme would be considerably more difficult to implement and if used the project would be more costly than a national program by ~66%. The cost per participant would be about 41%. There are indications that in some U.S. projects, the "splitting" scheme has been used to good advantage to minimize risk (i.e., have multiple vendors involved in case one vendor runs into difficulty, the other qualified vendors are available to assist).

The impact of "splitting" would lengthen the construction schedule by about 2.6 years from 7 to 9.6 years.

It is recognized that managing an international project would be more difficult than a similar national project. However, the results indicate a substantial cost reduction to each participant in partitioning the design and construction of such an international project. The technical benefit derived at such a reduced cost could make such a complex project very worthwhile.

ACKNOWLEDGMENT

The results of this study are those developed by the U.S. Similar results were obtained by the other INTOR participants. In addition, the overall approach and methodology were those developed in the INTOR Workshop. The author would like to acknowledge the contributions of the other INTOR members in this study: A. Knobloch, European Community; H. Iida and S. Itoh, Japan; and B. N. Kolbasov of the Soviet Union.