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JAPANESE CONTRIBUTIONS TO IAEA INTOR WORKSHOP, PHASE TWO A, PART 2

CHAPTER VII : TECHNICAL BENEFIT

July 1985

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Japanese Contributions
to IAEA INTOR Workshop, Phase Two A, Part 2
Chapter VII : Technical Benefit

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This report corresponds to Chapter VII of Japanese contribution report to IAEA INTOR Workshop, Phase Two A, Part 2. The purpose of technical benefit study is to examine the implications of having different manufacturers fabricate components of a major system of INTOR. A systematic examinations of advantages and disadvantages of designing and fabricating major INTOR components in the frame of one international joint projects is performed.

Keywords: INTOR, Technical Benefit, Tokamak, Design, Fabrication

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IAEA　INTOR　ワークショップ　フェーズⅡA，パート2　報告書

第Ⅶ章：　技術的利得

日本原子力研究所那珂研究所臨界プラズマ研究部
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（1985年5月31日受理）

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Contents

目　　次

1. Purpose and Scope

The purpose of this critical issue is to examine the implication of having four participants fabricate components of a major system of INTOR. There are potential advantages and disadvantages from such an approach, and so a systematic examination of them will be perfarmed.

Informations of an identification of differences between fabrication by a single manufacturer and fabrication by multiple manufacturers, would be most helpful in progressing the international joint project of the four INTOR participants.

2. Technical Benefit

A study is in progress on the technical feasibility of partitioning in design/fabrication/comstruction on INTOR in the frame of on international joint project of the four INTOR participants. International partitioning in such INTOR project implies some advantages and some disadvantages. Provided the disadvantages can be kept within a tolerable range and the advantages can have the sufficient meanings in technology and in cost for four participants, such the advantages in technology would be implied to be the technical benefit in present studies. That is, in INTOR project involved in many kinds of advanced technologies, the technical benefit is defined as follows;

(1) Technical transfer of advanced technologies developed in INTOR project among four participants.

(2) Development of industrial capability and experience for future fusion reactor technology. However, such technical benefit is based on the ideal assumption that each partichpant will have sufficiently developed his own advanced technology basis at the start of INTOR construction.

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3. Approaches and basic assumptions

3.1 Basic assumptions

(1) Reference organization scheme

A reference organization scheme is characteriged as shown in Fig. 3.1 and its responsibilities are given also.

(2) Three scenarios for realizing INTOR

Three scenarios are shown in Table 3-1.

Scenario A is the reference for comparison between international partitioning approaches, scenario B and scenario C, and a purely national approach, scenario A. A mixed scenario between B and C are likely considered also.

(3) Reference cost

International average figures as of phase II A Part 1 (Case 8)

(4) Reference schedule

Phase II A Part 1.

(5) Classification of systems/comp. in scenario B and C.

Table 3.2

(6) Approximately equal shares per participant.

3.2 Evaluation methods

(1) Cost evaluation

(a) First step

Relative "direct" and "indirect" capital costs are estimated in the following way; direct and indirect capital cost in average values of cost estimations of four participants, and indirect capital costs of each systems/comp. are set-up by considering both distributions of direct capital costs for systems/comp. and correction factors assumed from degree of their importance.

(b) Second step

Weight factors for estimating costs in three scenarios are estimated by using incremental costs in the systems/components questionnaires. (Table 3.3)

(c) Third step

Direct and indirect capital costs for Major INTOR components and systems in three scenarios are calculated by the above steps based on the following.

i) Scenario A

$$\text{total cost/participant} = \frac{1}{N}\sum_{i=1}^{7}\left\{W_{i,1}^{A} \times C_{i1}^{direct} + \sum_{j=2}^{5} W_{i,j}^{A} \times C_{i,j}^{ind}\right\}$$

ii) Scenario B

$$\text{total cost/participant} = \frac{1}{N}\sum_{i=1}^{7}\left\{W_{i,1}^{B} \times C_{i,1}^{direct} + \sum_{j=2}^{5} W_{i,j}^{C} \times C_{i,j}^{ind}\right\}$$

iii) Scenario C

$$\text{total cost/participant} = \frac{1}{N}\sum_{i=1}^{7}\left\{W_{i,1}^{C} \times C_{i,1}^{direct} + \sum_{j=2}^{5} W_{i,j}^{C} \times C_{i,j}^{ind}\right\}$$

where,

N : number of participant W : weight factor C^{direct} : direct capital cost

C^{ind} : indirect capital cost A,B,C : scenario,

i : comp./system (7) j : evaluation items

(2) Schedule and manpower evaluation

Based on the systems/components questionnaires (Table 3.3-1 ~ -21) and the impacts on construction process (Table 3.4 & 3.5).

(3) Evaluation of benefit from partitioning

A benefit from partitioning is evaluated by using the examination of impacts on construction process (Table 4.4 & 4.5). That is, relative evaluation values of scenario B & C V S. scenario A for three systems of reactor system, supporting system and facilities, are estimated in the impact tables. Total relative evaluations of benefit from partioning are performed by above relative values weighted with capital costs.

Fig. 3.1 Reference organization scheme

	Responsibilities
International INTOR team (+ industry studies)	- set up basic specifications - design the total system - set up management scheme - coordination, standards - control, data exchange - plan facilities, assembly, test program - operate the machine
4 National INTOR coord. teams	- control detailed national design and R and D - select national manufacturer - control procurement and fabrication, QA - survey acceptance tests, installation and check-out of national components - provide national management scheme
4 groups of national manufacturer and research organizations	- production design - fabrication and test - guarantees - R and D

Table 3.1 Three Scenarios for realizing INTOR

A	B (advanced technology components split, conventional technology components branch)	C (branch)
Four nations each build their own "INTOR" based on their national R and D = reference case for benefit evaluation	One international machine is built by four nations based on four national R and D programs sharing fabrication of multiple high technology components and of the different conventional components.	One international machine is built by four nations based on four national R and D programs sharing fabrication of different components.

Table 3.2 Classification of systems/comp. in scenario B and scenario C

No.	Systems/comp.	scenario B		scenario C		Remarks
		Multi.	Diff.	Multi.	Diff.	
1	Reactor systems					Multi: multiple high technology components Diff: different conventional components. * in scenario C, all divertors are fabricated by one participant.
	1 Torus					
	Divertor	○			○	
	Blanket sector	○			○	
	Blanket test module	○			○	
	Shield sector	○			○	
	First wall	○			○	
	Mechanical support		○		○	
	Pumping system	○			○	
	2 Magnet					
	TF magnet	○			○	
	PF magnet (solenoid)	○			○	
	PF magnet (ring)	○			○	
	Cryostat	(○)	○		○	
	Mechanical support	(○)	○		○	
	Refrigerators		○		○	
	3 Heating					
	ECRH	○			○	
	ICRH	○			○	
2	Supporting systems					
	1 Fueling	(○)	○		○	
	2 Electr. supply					
	TF		○		○	
	PF		○		○	
	RF		○		○	
	3 Tritium		○		○	
	4 Cooling		○		○	
	5 Diagnostics		○		○	
	6 Maintenance		○		○	
3	Facilities		○		○	

Table 3.3-1

SCENARIO	A	B	C
COMPONENT	Divertor		
No. of modules/units 1	12	12	12
No. of redundant modules 2	1 ~ 2	4	1 ~ 2
Are different designs tolerable? 3	yes, but not economic	yes, but only small differences	yes, but not economic
Give items that may differ in detailed design or material 4	. cooling tube . support structure . moving mechanics		
Necessary basis and detail of preproduction design 5	. incident heat load . incident particle evergy . sceparatrix line conditions . incident particle flux . operating scenario . neutron fluence . divertor plate material . coolant material . temperature, ~~pressure, velocity of coolant . arrangement in divertor chammber~~		
Give main interface items 6	. conductance of divertor duct . cooling tube . support structure of moduel . maintenance process . maintenance port		
Measures of quality control 7	. cooling test . thermal fatique test . moving test of divertor module . vacuum leak test		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	———	no	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	———	20 (interface) *	5
Incremental cost (manpower) for design (%) 17	———	20 *	10
Incremental time for procurement (%) 18	———	10 *	5
Incremental time for fabrication/construction (%) 19	———	-30 *	0
Incrementalcost for fabrication/construction 20	———	40 (for reduction of mass production effect) *	5
Incremental time for transportation/assembly (%) 21	———	40 *	30
Incremental cost for transportation/assembly (%) 22	———	30 *	20
Incremental cost for tests (%) 23	———	20 *	10
Other incremental time (%) 24	———	10 *	5
Other incremental cost (%) 25	———	15 *	10

* in scenario B, incremental cost and time mean a value per one participant same as for other components.

Table 3.3-2

SCENARIO	A	B	C
COMPONENT	Blanket Sectors		
No. of modules/units 1	12	12	12
No. of redundant modules 2	1 or 2	2 or 4	1 or 2
Are different designs tolerable? 3	yes, but not economic	yes, but only small differences	yes, but not economic
Give items that may differ in detailed design or material 4	design : cooling pipe structure, its arrangement, spacer structure, blanket vessel dimension.(withinccomplying with all interfaces) material: breeder, neutron multiplier		
Necessary basis and detail of preproduction design 5	breeding ratio, breeding materials, coolant material, neutron multiplie material, operating scenario, operating temperature (above materials) and pressure. design base faults, separable first wall or integrated first wall.		
Give main interface items 6	cooling pipe, purge gas pipe, setting to shields		
Measures of quality control 7	density of Li_2O inventry, pellet size, physical dimensions (pipe, vessel et.), welds, flaw purity of LiO_2 and multiplier, cold testing of blanket vessel.		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	————	no	————
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	————	————	not enough (even if detailed documents)
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	————	20 (interface)	5
Incremental cost (manpower) for design (%) 17	————	20	10
Incremental time for procurement (%) 18	————	10	5
Incremental time for fabrication/construction (%) 19	————	-30	0
Incrementalcost for fabrication/construction 20	————	40 (for reduction of mass production effect)	0
Incremental time for transportation/assembly (%) 21	————	40	30
Incremental cost for transportation/assembly (%) 22	————	30	20
Incremental cost for tests (%) 23	————	20	10
Other incremental time (%) 24	————	10	5
Other incremental cost (%) 25	————	15	10

Table 3.3-3

SCENARIO	A	B	C
COMPONENT	Blanket test module		
No. of modules/units 1	1	4	1
No. of redundant modules 2	1	0	1
Are different designs tolerable? 3	yes	yes	yes
Give items that may differ in detailed design or material 4	see also blanket sectors		
Necessary basis and detail of preproduction design 5	see also blanket sectors		
Give main interface items 6	see also blanket sectors		
Measures of quality control 7	see also blanket sectors		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	———	no	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough (know how could not enough understood only with detailed reviews)
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	10	5
Incremental time for fabrication/construction (%) 19	———	0	0
Incremental cost for fabrication/construction 20	———	5	0
Incremental time for transportation/assembly (%) 21	———	40	40
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-4

SCENARIO	A	B	C
COMPONENT	Shield Sectors		
No. of modules/units 1	12	12	12
No. of redundant modules 2	1 or 2	2 or 4	1 or 2
Are different designs tolerable? 3	yes, but not economical	yes, but only small differences	yes, but not economic
Give items that may differ in detailed design or material 4	design o cooling channel structure o cooling channel arrangement o cooling conditions		
Necessary basis and detail of preproduction design 5	nuclear heating density distrubution, structure material, dose rate limit outside belljar cryostat, shielding conditions for TF & PF coil, 1 turn resistivity structure		
Give main interface items 6	divertor/limiter, RF port, blanket, NBI port, torus sector, mechanical support, cooling pipe		
Measures of quality control 7	physical dimensions, welds 1 turn resistivity testing, vacuum characteristics		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	———	no	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	yes	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	10	5
Incremental time for fabrication/construction (%) 19	———	-30	0
Incremental cost for fabrication/construction 20	———	30 (for reduction of mass production effect)	0
Incremental time for transportation/assembly (%) 21	———	40	30
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-5

SCENARIO	A	B	C
COMPONENT	First wall		
No. of modules/units 1	12	12	12
No. of redundant modules 2	1 or 2	2 or 4	1 or 2
Are different designs tolerable? 3	yes, but not economical	yes, but only small difference	yes, but not economical
Give items that may differ in detailed design or material 4	design : cooling tube, first wall surface condition cooling condition material : coating		
Necessary basis and detail of preproduction design 5	. heatload (incident particle & nuclear heat) . cooling conditions . incident particle flux. & energy . neutron wall load . sputteringyield . operation scenario . electromagnetic forces . shell effect . structure materials		
Give main interface items 6	blanket module, tritium breeding ratio		
Measures of quality control 7	physical dimensions inspection water tighteness for cooling vacuum testing		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	——	no	——
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	——	——	not enough
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	——	20 (interface)	5
Incremental cost (manpower) for design (%) 17	——	20	10
Incremental time for procurement (%) 18	——	10	5
Incremental time for fabrication/construction (%) 19	——	-30	0
Incrementalcost for fabrication/construction 20	——	40 (for reduction of mass production effect)	0
Incremental time for transportation/assembly (%) 21	——	40	30
Incremental cost for transportation/assembly (%) 22	——	30	20
Incremental cost for tests (%) 23	——	20	10
Other incremental time (%) 24	——	10	5
Other incremental cost (%) 25	——	15	10

Table 3.3-6

SCENARIO	A	B	C
COMPONENT	Mechanical support (torus)		
No. of modules/units 1	12	12	12
No. of redundant modules 2	1	1 or 2	1
Are different designs tolerable? 3	yes, but not economical	yes	yes, but not economical
Give items that may differ in detailed design or material 4	design: mechanical structure (within interface condition)		
Necessary basis and detail of preproduction design 5	electomagnetic conditions, seismic condition thermal expansion		
Give main interface items 6	plasma vacuum vessel (or shields)		
Measures of quality control 7	weld inspection, dimensioniinspection., electrical inslation testing, one-turn resistivity testing		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	————	yes	————
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	————	————	not enough
Benefit, if one component concept fails 15	no	yes	no
Incremental time for design (%) 16	————	20 (interface)	5
Incremental cost (manpower) for design (%) 17	————	20	10
Incremental time for procurement (%) 18	————	10	5
Incremental time for fabrication/construction (%) 19	————	-30	0
Incremental cost for fabrication/construction 20	————	20	5
Incremental time for transportation/assembly (%) 21	————	40	30
Incremental cost for transportation/assembly (%) 22	————	30	20
Incremental cost for tests (%) 23	————	20	10
Other incremental time (%) 24	————	10	5
Other incremental cost (%) 25	————	15	10

Table 3.3-7

SCENARIO	A	B	C
COMPONENT	Pumping system (cryopump)		
No. of modules/units 1	12	12	12
No. of redundant modules 2	2	4	2
Are different designs tolerable? 3	yes, but not economical	yes	yes, but not economical
Give items that may differ in detailed design or material 4	he absorption material refrigerating pannel structure		
Necessary basis and detail of preproduction design 5	he absorption materials liquid he refrigerating loads nuclear heating		
Give main interface items 6	conductance of divertor exhaust duct,refrigerators, TMP		
Measures of quality control 7	vacuum leak testing pumping speed testing (He . T .D)		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	———	yes	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough (even if detailed document)
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	10	5
Incremental time for fabrication/construction (%) 19	———	-30	0
Incrementalcost for fabrication/construction 20	———	20 (for reduction of mass production effect)	5
Incremental time for transportation/assembly (%) 21	———	40	30
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-8

SCENARIO	A	B	C
COMPONENT	TF magnet		
No. of modules/units 1	12	12	12
No. of redundant modules 2	1 or 2	2 or 4	1 or 2
Are different designs tolerable? 3	yes, but not economic	yes, but only small differences	yes, but not economic
Give items that may differ in detailed design or material 4	design: conductor design, coil design, coil case design et. (within interface conditions) material: super conductor material, stabilizer material, insulator material (within interface conditions)		
Necessary basis and detail of preproduction design 5	coil geometry, field only plasma chamber axis, maximum field. cooling method, super conductor material, grading, operation scenario, AC loss nuclear heating		
Give main interface items 6	buking region, out-of-plane structure, electrical supply conditions, cooling conditions.		
Measures of quality control 7	material, welds, conductor testing single coil testing physical dimensions		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	———	no	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	yes
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	15	5
Incremental time for fabrication/construction (%) 19	———	-20	0
Incremental cost for fabrication/construction 20	———	50 (for reduction of mass production effects)	0
Incremental time for transportation/assembly (%) 21	———	40	30
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-9

SCENARIO	A	B	C
COMPONENT	PF magnets (central solenoid, ring coils)		
No. of modules/units 1	central solenoid : 1 (3 sections) ring coil : 8	central solenoid : 1 (3 sections) ring coil : 8	central solenoid : 1 (3 sections) ring coil : 8
No. of redundant modules 2	0	0	0
Are different designs tolerable? 3	yes, but not economic	yes, but only small differences	yes, but not economic
Give items that may differ in detailed design or material 4	design: conductor design, coil design, coil case design etc. (within interface conditions) material: super conductor material, stabilizer material, insulator material		
Necessary basis and detail of preproduction design 5	coil position, coil size, coil current & voltage, stability margine, material et., interfaces, electrical insulation operation scenario		
Give main interface items 6	PFC support structure in brucking post & in TF magnet, electrical supply conditions cooling conditions		
Measures of quality control 7	materials, welds, conductor testing; single coil testing, physical dimensions		
Transportation problems 8	national (transport problem by truck for larger ring coil)	75% overseas	75% overseas
Is on-site fabrication necessary? 9	yes (in order to resolve transport problem for larger ring coils)	yes (for larger ring coils)	yes (for larger ring coils)
Is acceptance test on-site necessary? 10	no	yes	yes
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	——	no	——
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	——	——	not enough
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	——	20 (interface)	5
Incremental cost (manpower) for design (%) 17	——	20	10
Incremental time for procurement (%) 18	——	15	5
Incremental time for fabrication/construction (%) 19	——	-20	0
Incrementalcost for fabrication/construction 20	——	50 (for reduction of mass production effect)	0
Incremental time for transportation/assembly (%) 21	——	40	30
Incremental cost for transportation/assembly (%) 22	——	30	20
Incremental cost for tests (%) 23	——	20	10
Other incremental time (%) 24	——	10	5
Other incremental cost (%) 25	——	15	10

Table 3.3-10

SCENARIO	A	B	C
COMPONENT	Cryostat		
No. of modules/units 1	1	————	1
No. of redundant modules 2	0	————	0
Are different designs tolerable? 3	yes, but not economic	————	yes, but not economic
Give items that may differ in detailed design or material 4	design bell-jar structure (within all interface conditions)		
Necessary basis and detail of preproduction design 5	vacuum condition, 1 turn resistivity, seismic condition, cooling condition (LN_2)		
Give main interface items 6	floor structure, TF & PF magnets, vacuum pump		
Measures of quality control 7	materials, welds, 1 turn-resistance testing, vacuum testing		
Transportation problems 8	national	————	national or overseas (?%)
Is on-site fabrication necessary? 9	no	————	no
Is acceptance test on-site necessary? 10	no	————	no
Specific assembly problems 11	no	————	no
Is more than one national production line economic/necess.? 12	yes	————	yes
For conventional components: Is scenario B feasible? 13	————	no	————
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	————	————	not enough
Benefit, if one component concept fails 15	no	yes	no
Incremental time for design (%) 16	————	————	5
Incremental cost (manpower) for design (%) 17	————	————	10
Incremental time for procurement (%) 18	————	————	5
Incremental time for fabrication/construction (%) 19	————	————	0
Incrementalcost for fabrication/construction 20	————	————	0
Incremental time for transportation/assembly (%) 21	————	————	30 } overseas
Incremental cost for transportation/assembly (%) 22	————	————	20 } overseas
Incremental cost for tests (%) 23	————	————	10
Other incremental time (%) 24	————	————	5
Other incremental cost (%) 25	————	————	10

Table 3.3-11

SCENARIO	A	B	C
COMPONENT	Mechanical support (magnet)		
No. of modules/units 1	12	12	12
No. of redundant modules 2	2	4	2
Are different designs tolerable? 3	yes, but not economical	yes	yes, but not economical
Give items that may differ in detailed design or material 4	design : share-panel structures (TFC) TFC support structure (adiavatic support legs) material: FRP (TFC support)		
Necessary basis and detail of preproduction design 5	electromagnetic force distribution (TFC, PFC), low temperature characteristics of structure materials (SUS, FRP etc.) 1 turn-resistivity, seismic condition		
Give main interface items 6	TF coil, PF coil temperature defference between TFC and flower base		
Measures of quality control 7	weld inspection, dimension inspection electrical insulation testing one-turn resistivity testing		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	———	yes	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	yes	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	10	5
Incremental time for fabrication/construction (%) 19	———	-30	0
Incremental cost for fabrication/construction 20	———	20	5
Incremental time for transportation/assembly (%) 21	———	40	30
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-12

SCENARIO	A	B	C
COMPONENT	Refrigerators		
No. of modules/units 1	1	———	1
No. of redundant modules 2	0	———	0
Are different designs tolerable? 3	yes, but not economical	———	yes, but not economical
Give items that may differ in detailed design or material 4	slightly changes are possible in parts and equipments of refrigerator system (within all interface conditions)		
Necessary basis and detail of preproduction design 5	reactor operation scenatio liquid He & N_2 refrigerating load of TFC, PFC etc.		
Give main interface items 6			
Measures of quality control 7	performance tests for each equipment of refrigerators performance tests for total refrigerator		
Transportation problems 8	national	———	national and overseas
Is on-site fabrication necessary? 9	no	———	no
Is acceptance test on-site necessary? 10	no	———	no
Specific assembly problems 11	no	———	no
Is more than one national production line economic/necess.? 12	yes, but slightly	———	yes, but slightly
For conventional components: Is scenario B feasible? 13	———	yes	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	———	no
Incremental time for design (%) 16	———	———	5
Incremental cost (manpower) for design (%) 17	———	———	10
Incremental time for procurement (%) 18	———	———	5
Incremental time for fabrication/construction (%) 19	———	———	0
Incremental cost for fabrication/construction 20	———	———	0
Incremental time for transportation/assembly (%) 21	———	———	30
Incremental cost for transportation/assembly (%) 22	———	———	20
Incremental cost for tests (%) 23	———	———	0
Other incremental time (%) 24	———	———	0
Other incremental cost (%) 25	———	———	0

Table 3.3-13

SCENARIO / COMPONENT	A	B	C
	ECRH		
No. of modules/units 1	4 (25gyrotroms/module)	4	4
No. of redundant modules 2	2	2	2
Are different designs tolerable? 3	yes, but not loconomical	no	yes, but not loconomical
Give items that may differ in detailed design or material 4	mirror direction, window, line-antenna interface.		
Necessary basis and detail of preproduction design 5	geometry, voltage level, line impedance, cooling parameters, antenna diagnostic, neutron and heatload, common basic design.		
Give main interface items 6	interface antenna-line, matching ranges, antenna diagnostics, cooling characteristics, materials, geometry.		
Measures of quality control 7	vacuum tightness, RF voltage strength, quality of ceramics, geometry, radiation hardness.		
Transportation problems 8	national	75% overseas	75% overseas
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	yes, but slightly	yes
For conventional components: Is scenario B feasible? 13	———	no	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	yes	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	15	5
Incremental time for fabrication/construction (%) 19	———	-20	0
Incremental cost for fabrication/construction 20	———	50 (for reduction of mass production effect)	0
Incremental time for transportation/assembly (%) 21	———	40	30
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-14

SCENARIO	A	B	C
COMPONENT	ICRH		
No. of modules/units 1	16	16	16
No. of redundant modules 2	2	4	2
Are different designs tolerable? 3	yes, but not lconomical	no	yes, but not loconomical
Give items that may differ in detailed design or material 4	central conductor, faraday screen, vacuum feedthrough, line-antenna interface.		
Necessary basis and detail of preproduction design 5	geometry, voltage level, line impedance, cooling parameters, antenna diagnostic, neutron and heatload, common basic design plasma loading impedance.		
Give main interface items 6	interface antenna-line, matching ranges, antenna diagnostics, cooling characteristics, materials,geometry.		
Measures of quality control 7	vacuum tightness, RF voltage strength, water tightess for cooling, quality of ceramics, geometry, radiation hardness.		
Transportation problems 8	national	75% international	75% international
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes	no	yes
For conventional components: Is scenario B feasible? 13	———	———	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	no
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	15	5
Incremental time for fabrication/construction (%) 19	———	-20	0
Incrementalcost for fabrication/construction 20	———	50 (for reduction of mass production effect)	0
Incremental time for transportation/assembly (%) 21	———	40	30
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-15

SCENARIO	A	B	C
COMPONENT	fueling {gas puffing system / pellet injection system}		
No. of modules/units 1	gas : 12 } 14 pellet : 2	14	14
No. of redundant modules 2	2	2 4	2
Are different designs tolerable? 3	yes, but not lconomical	yes	yes, but not lconomical
Give items that may differ in detailed design or material 4	number of gas puffing port, gas pressure.		
Necessary basis and detail of preproduction design 5	gravity feed/forced flow pellet injection rate injection velocity		
Give main interface items 6	blanket, shield, RF and NBI system.		
Measures of quality control 7	gas flow rate, pellet injection speed, gas pressure injection rate.		
Transportation problems 8	national	75% international	75% international
Is on-site fabrication necessary? 9	no	no	no
Is acceptance test on-site necessary? 10	no	no	no
Specific assembly problems 11	no	no	no
Is more than one national production line economic/necess.? 12	yes, slightly	no	yes, slightly
For conventional components: Is scenario B feasible? 13	———	———	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	———	20 (interface)	5
Incremental cost (manpower) for design (%) 17	———	20	10
Incremental time for procurement (%) 18	———	10	5
Incremental time for fabrication/construction (%) 19	———	-30	0
Incrementalcost for fabrication/construction 20	———	40 (for reduction of mass production effect)	0
Incremental time for transportation/assembly (%) 21	———	40	30
Incremental cost for transportation/assembly (%) 22	———	30	20
Incremental cost for tests (%) 23	———	20	10
Other incremental time (%) 24	———	10	5
Other incremental cost (%) 25	———	15	10

Table 3.3-16

SCENARIO	A	B	C
COMPONENT	Electrical supply : PF		
No. of modules/units 1	1	——	supply system divides to motor generator sets, transformers, thyristor sets, power feeder cable
No. of redundant modules 2	0	——	0
Are different designs tolerable? 3	yes, but not economic	——	yes, but not economic
Give items that may differ in detailed design or material 4	equipment specifications in system (within all interface conditions)		
Necessary basis and detail of preproduction design 5	PFC operation scenario(voltage, current, power, energy) back structure and control of thyristor set energy strage system (fly-wheel MG or SC coil)		
Give main interface items 6	voltage and current conditions between interfaces, such as main substation, PF power supply and PFCs.		
Measures of quality control 7	performance tests for each equipment (ex. MG, thyristor sets) performance tests for total PF power supply		
Transportation problems 8	national	——	75% overseas
Is on-site fabrication necessary? 9	no	——	no
Is acceptance test on-site necessary? 10	no	——	no
Specific assembly problems 11	no	——	no
Is more than one national production line economic/necess.? 12	yes	——	yes
For conventional components: Is scenario B feasible? 13	——	no	——
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	——	——	not enough
Benefit, if one component concept fails 15	no	large	no
Incremental time for design (%) 16	——	——	5
Incremental cost (manpower) for design (%) 17	——	——	10
Incremental time for procurement (%) 18	——	——	5
Incremental time for fabrication/construction (%) 19	——	——	0
Incremental cost for fabrication/construction 20	——	——	0
Incremental time for transportation/assembly (%) 21	——	——	30
Incremental cost for transportation/assembly (%) 22	——	——	20
Incremental cost for tests (%) 23	——	——	0
Other incremental time (%) 24	——	——	0
Other incremental cost (%) 25	——	——	0

Table 3.3-17

SCENARIO	A	B	C
COMPONENT	Electr. supply (TF, RF)		
No. of modules/units 1	1	————	1
No. of redundant modules 2	0	————	0
Are different designs tolerable? 3	yes, but not economical	————	yes, but not economical
Give items that may differ in detailed design or material 4	changes of parts and equipments specifications in power supply (within all interface conditions)		
Necessary basis and detail of preproduction design 5	TFC operation scenario (voltage, current, power, energy), TF coil characteristics parameters energy strage system		
Give main interface items 6	electric characteristics of TF coils energy strage system AC power supply		
Measures of quality control 7	performance test for each equipment (transformer, thyristor sets) performance test TF power supply		
Transportation problems 8	national	————	national or overseas
Is on-site fabrication necessary? 9	no	————	no
Is acceptance test on-site necessary? 10	no	————	no
Specific assembly problems 11	no	————	no
Is more than one national production line economic/necess.? 12	yes	————	yes
For conventional components: Is scenario B feasible? 13	————	yes	————
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	————	————	not enough
Benefit, if one component concept fails 15	no	yes	no
Incremental time for design (%) 16	————	————	5
Incremental cost (manpower) for design (%) 17	————	————	10
Incremental time for procurement (%) 18	————	————	5
Incremental time for fabrication/construction (%) 19	————	————	0
Incrementalcost for fabrication/construction 20	————	————	0
Incremental time for transportation/assembly (%) 21	————	————	30
Incremental cost for transportation/assembly (%) 22	————	————	20
Incremental cost for tests (%) 23	————	————	0
Other incremental time (%) 24	————	————	0
Other incremental cost (%) 25	————	————	0

Table 3.3-18

SCENARIO	A	B	C
COMPONENT	Tritium		
No. of modules/units 1	1	———	1
No. of redundant modules 2	0	———	0
Are different designs tolerable? 3	yes, but not economical	———	yes, but not economical
Give items that may differ in detailed design or material 4	changes of parts and equipments specification in toritium system (within all interface conditions)		
Necessary basis and detail of preproduction design 5	operation scenario: plasma, pumping system, flow rate of tritium released in accident situations, system design of subsystem: plasma exhaust reprocessing system, breeding tritium processing system, waste processing system estimations of tritium inventry		
Give main interface items 6	characteristics of T_2, D_2, HT, HD, TD, T_2O, THO, DTO, DHO etc. compositions and flow rates of gas including T, D, H, He etc. as follows. o exhaust gas from pumping system o circurating gas from blanket o atmosphere in reactor room		
Measures of quality control 7	inspections of tritium performance test for each equipments performance test for each processing system		
Transportation problems 8	national	———	national (?%) and overseas (?%)
Is on-site fabrication necessary? 9	no	———	no
Is acceptance test on-site necessary? 10	no	———	no
Specific assembly problems 11	no	———	no
Is more than one national production line economic/necess.? 12	yes, but slightly	———	yes, but slightly
For conventional components: Is scenario B feasible? 13	———	yes	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	———	no
Incremental time for design (%) 16	———	———	5
Incremental cost (manpower) for design (%) 17	———	———	10
Incremental time for procurement (%) 18	———	———	5
Incremental time for fabrication/construction (%) 19	———	———	0
Incrementalcost for fabrication/construction 20	———	———	0
Incremental time for transportation/assembly (%) 21	———	———	30
Incremental cost for transportation/assembly (%) 22	———	———	20
Incremental cost for tests (%) 23	———	———	0
Other incremental time (%) 24	———	———	0
Other incremental cost (%) 25	———	———	0

Table 3.3-19

SCENARIO	A	B	C
COMPONENT	Cooling		
No. of modules/units 1	1	———	1
No. of redundant modules 2	0	———	0
Are different designs tolerable? 3	yes, but not economical	———	yes, but not economical
Give items that may differ in detailed design or material 4	changes of parts and equipments specifications in cooling system (within interface conditions)		
Necessary basis and detail of preproduction design 5	temperature, pressure, velocity, etc. of coolant in an inlet and outlet of each equipment operation scenario.		
Give main interface items 6	temperature, pressure, velocity etc. of coolant in an inlet and outlet of first wall, blanket, divertor, shields.		
Measures of quality control 7	performance test for equipments in cooling system performance test for total cooling system		
Transportation problems 8	national	———	national or overseas
Is on-site fabrication necessary? 9	no	———	no
Is acceptance test on-site necessary? 10	no	———	no
Specific assembly problems 11	no	———	no
Is more than one national production line economic/necess.? 12	yes	———	yes
For conventional components: Is scenario B feasible? 13	———	yes	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough
Benefit, if one component concept fails 15	no	yes	no
Incremental time for design (%) 16	———	———	5
Incremental cost (manpower) for design (%) 17	———	———	10
Incremental time for procurement (%) 18	———	———	5
Incremental time for fabrication/construction (%) 19	———	———	0
Incremental cost for fabrication/construction 20	———	———	5
Incremental time for transportation/assembly (%) 21	———	———	30 } overseas
Incremental cost for transportation/assembly (%) 22	———	———	20 } overseas
Incremental cost for tests (%) 23	———	———	0
Other incremental time (%) 24	———	———	0
Other incremental cost (%) 25	———	———	0

Table 3.3-20

SCENARIO	A	B	C
COMPONENT	Diagnostics		
No. of modules/units 1	?	———	?
No. of redundant modules 2	?	———	?
Are different designs tolerable? 3	yes, but not economical	———	yes, but not economical
Give items that may differ in detailed design or material 4	slightly changes are possible in parts and equipments of diagnostics (within interface conditions)		
Necessary basis and detail of preproduction design 5	to be investigated in recent future		
Give main interface items 6	12 port structures, shields, blanket, divertor maintenance ports		
Measures of quality control 7	vacuum leak testing, weld inspections, dimension inspections., performance tests.		
Transportation problems 8	national	———	national (?%) and overseas (?%)
Is on-site fabrication necessary? 9	no	———	no
Is acceptance test on-site necessary? 10	no	———	no
Specific assembly problems 11	no	———	no
Is more than one national production line economic/necess.? 12	yes, but slightly	———	yes, but slightly
For conventional components: Is scenario B feasible? 13	———	no	———
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	———	———	not enough (even if detailed document)
Benefit, if one component concept fails 15	no	———	no
Incremental time for design (%) 16	———	———	5
Incremental cost (manpower) for design (%) 17	———	———	10
Incremental time for procurement (%) 18	———	———	5
Incremental time for fabrication/construction (%) 19	———	———	0
Incremental cost for fabrication/construction 20	———	———	0
Incremental time for transportation/assembly (%) 21	———	———	30
Incremental cost for transportation/assembly (%) 22	———	———	20
Incremental cost for tests (%) 23	———	———	0
Other incremental time (%) 24	———	———	0
Other incremental cost (%) 25	———	———	0

Table 3.3-21

SCENARIO	A	B	C
COMPONENT	Maintenance		
No. of modules/units 1	?	————	?
No. of redundant modules 2	?	————	?
Are different designs tolerable? 3	yes, but not economical	————	yes, but not economical
Give items that may differ in detailed design or material 4	slightly changes are possible in parts and equipments which consist of maintenance machines		
Necessary basis and detail of preproduction design 5	to be adjusted in recent future		
Give main interface items 6	reactor module weight		
Measures of quality control 7			
Transportation problems 8	national	————	national (?%) and overseas (?%)
Is on-site fabrication necessary? 9	no	————	no
Is acceptance test on-site necessary? 10	no	————	no
Specific assembly problems 11	no	————	no
Is more than one national production line economic/necess.? 12	yes, but slightly	————	yes, but slightly
For conventional components: Is scenario B feasible? 13	————	yes	————
For high-technology components Is know-how exchange in scenario C sufficiently beneficial? 14	————	————	not easy
Benefit, if one component concept fails 15	no	————	no
Incremental time for design (%) 16	————	————	5
Incremental cost (manpower) for design (%) 17	————	————	10
Incremental time for procurement (%) 18	————	————	5
Incremental time for fabrication/construction (%) 19	————	————	0
Incrementalcost for fabrication/construction 20	————	————	0
Incremental time for transportation/assembly (%) 21	————	————	30
Incremental cost for transportation/assembly (%) 22	————	————	20
Incremental cost for tests (%) 23	————	————	0
Other incremental time (%) 24	————	————	0
Other incremental cost (%) 25	————	————	0

Table 3.4

Task 3. Examine impact of one vs. several fabricators on construction process (general points)

(Important comments common to systems/components set up in Task 1 are listed up)

Sinario	Design Control	Equipment Specification	Nature of procurement	Tooling Requirement	Management coordination	Staffing Requirement	R & D
A	(1) Control easily and clear a limit of responsibility since the object is one fabricator only.	(1) Set up basic specifications.	(1) Nature of procurement is the simplest, ex, the organized committee can choose fabricators with considering technical balance between them.	(1) Tooling requirement can be minimum corresponding with needs.	(1) Easy.	(1) There is an advantage to minimize project staff. (2) An exclusive fabricator must keep high standard staff to design, fabricate, assemble and test.	(1) Effective and economical if the exclusive fabricator carries out R & D. (2) Desired to designate techniqually advanced fabricator. (3) There are some risk if one fabricator carries R & D.
B	(1) Must design a total system and takes responsibility to offer necessary design conditions for units of components. (ex. some TF coils) Also necessary to examine assemble procedures. (2) Each fabricator is enough to design units of components.	(1) Set up basic specifications for units of components based on total system disign. (2) Set up clear interface conditions between units of components made by 4 fabricators.	(1) Nature of procurement is simple. It is easy to reach agreements between coordinative fabricators. But, necessary to negociate and contract with 4 fabricators for units of components.	(1) Each fabricator is required to have coordinative tooling.	(1) Necessary to put in order between fabricators. (2) Necessary to govern fabricators to constract from unit of components to a total system.	(1) Project team must keep a large number of high-standard staff. (2) Each fabricator can expect to make his staff level up equally.	(1) Each fabricator carries out R & D or share R & D of technical element and exchange the result. There are some merits if a technically advanced fabricator offers his technology to disadvantaged fabricators. (2) It may be possible to develop many kinds of technology.

Table 3.4

Sinario	Design Control	Equipment Specification	Nature of procurement	Tooling Requirement	Management coordination	Staffing Requirement	R & D
C	(1) Necessary to take responsibility for system design of components (ex. TF coil system) and coordinate between fabricators.	(1) Set up basic specifications for components based on total system design. (TF coil system)	(1) Same as for A,(1) but makes negociations and contractions for each component. (2) Be able to purchase order to multicators. (3) Takes the responsibility assembling a total system.	(1) Same as for A.	(1) Same as for B,(1) (2) Necessary to govern fabricators to contract from one component to a total system.	(1) The high-standard staff of project team is required, but less than scenario B. (2) Same as for B,(2)	(1) Same as for A
Remarks							

Table 3.5

Task 4. Examin impact one vs. several fabricators on construction process (specific points)

(Important comments common to systems/components set up in Task 1 and listed up)

Sinario	Component testing	Quality assurance	Spare parts	Facility Requirement	One/more Production line	Transportation Requirement	On site fabrication
A	(1) Set up easily testing methods with only one fabricator. (2) The exclusive fabricator takes responsibility of testing.	(1) Makes clear a responsibility of quality control for the total system.	(1) Multiple component and different components (1 or 2).	(1) It is not necessary to build an on-the-spot factory if there are no limitations for transportation of products. (However there are some possibility to be built small on-the-spot factory to assemble components at the site.)	(1) Appropriate number of production line (more lines) may reduce to lower cost and shorter schedule.	(1) There is no limitation on the transportation if factories and the site locate near a seaside; If either location (or both) is not near a seaside, some counter-measures are required. (ex. decomposition a unit or mitigation of limitation on a road, et al.)	(1) It is necessary to build a site-factory for conductor windings of large PF ring coils. It is not necessary, if there is possibility of reliable connection between conductors.
B	(1) Set up testing method for units of the components. (some TF coils). (2) Should put in order and carry out testing methods of a total system also. Necessary to modulate between fabricators.	(1) Necessary to guarantee a quality as a total system. (2) Each fabricator takes responsibility to quality control of units of the components.	(1) Multiple component and different component (because of 4 fabricators, spare parts increase). (2 or 4).	(1) Same as for A(1). (2) Each fabricator needs coordinative product lines. Therefore, the investment of equipment overlaps.	(1) More production lines leads to larger increment of fabrication cost because of a few unit of component to be fabricated.	(1) Same as for A	(1) Same as for A.

Table 3.5

Sinario	Component testing	Quality assurance	Spare parts	Facility Requirement	One/more Production line	Transportation Requirement	On site fabrication
C	(1) Set up testing methods for components (ex. TF coil system). (2) Same as for B,(2)	(1) Same as for B,(1) (2) Each fabricator takes respon-sibility to quality cont-rol of com-ponents (TF coil system).	(1) } (2) } Same as for A	(1) Same as for A	(1) Same as for A	(1) Same as for A	(1) Same as for A
Remarks							

4. Information input

Table 4.1 Estimations of relative "direct and indirect" capital cost

No.	Systems/Comp.	direct capital cost (%)	Indirect Captal Cost (%)			
		Fabrication/ Construction	Design/ Engineering	R&D	Transport/ Assembly	Contingency
1	Torus	10	5	3	3	7.5
	Magnet	30	14	8	7	21
	Heating	10	4	2.5	3	7.5
2	Electr. supply	15	2	1	1	3
	Tritium & Fueling	7	1	1	1	1.5
	Other supporting system	15	2	1.5	1	3.5
3	Facilities	13	2	-	-	3
	Total	100	30	17	16	47

1) Relative capital cost is based on case 8 in INTOR Phase IIA part 1.

Table 4.2 Weight factors for estimating costs in three scenarios

No.	Comp./System	sce.	Fabrication /construction	Design /Engineering	R & D	Transportation /Assembly	Contingency
1	Torus	A	4×1.0	4×1.0	4×1.0	4×1.0	4×1.0
	Magnets	B	4×1.3 ×0.25	4×1.2	4×1.0	1×1.3	1×1.2
	Heating	C	1×1.1	1×1.1	1×1.0	1×1.2	1×1.1
2	Power Supply Tritium/ Fueling Supporting System	A	4×1.0	4×1.0	4×1.0	4×1.0	4×1.0
		B	-	-	-	-	-
		C	1×1.0	1×1.1	4×1.0	1×1.2	1×1.0
3	Facilities	A	4×1.0	4×1.0	-	4×1.0	4×1.0
		B	-	-	-	-	-
		C	1×1.0	1×1.0	-	1×1.0	1×1.0

Table 4.3 Evaluations of direct and indirect capital costs for Major Intor component and systems

No.	omp./ system	sce.	Cirect cost (%) Fabrication/ Construction	Indirect cost (%) Design/ Engineering	R&D	Transportation /assembly	Contingency /others
1	Torus (Blanket, Shield, First wall, Pumping sys., Divertor)	A	40	20	12	12	30
		B	13	24	12	4	9
		C	11	6	12	4	8
2	Magnets (TFC, PFC, cryostat, Re-frigerator)	A	120	56	32	28	84
		B	39	67	32	9	25
		C	33	15	32	8	23
3	Heating (ECRH & ICRH)	A	40	16	10	12	30
		B	13	19	10	4	9
		C	11	5	10	4	8
4	Power supply (TFC, PFC ECRH, ICRH)	A	60	8	4	4	12
		B	-	-	-	-	-
		C	15	2	4	1	3
5	Tritium & Fueling	A	28	4	4	4	6
		B	-	-	-	-	-
		C	7	1	4	1	1.5
6	Supporting system (cooling, Diagonostic, Maintenance)	A	60	8	6	4	14
		B	-	-	-	-	-
		C	15	2	6	1	3.5
7	Facilities	A	52	8	-	-	12
		B	-	-	-	-	-
		C	13	2			
	Total	A	400(100)	120(30)	68(17)	64(16)	188(47)
		B	115 (29)	115 (29)	68(17)	20 (5)	51(13)
		C	105 (26)	33 (8)	68 (17)	19 (5)	47(12)

(1) value of ( ) means % cost per partner

(2) Summing of scenario B
No. 1 ~ No. 3 : scenario B
No. 4 ~ No. 7 : scenario C

Table 4.4 Relative Evaluations (I) (general points)

Impact of scenario B & C Vs. scenario A on construction process.

Systems / Evaluation Item \ Scenario	Reactor Systems			Supporting Systems			Facilities		
	Torus, Magnet, Heating			Fueling, Electr. Supply Tritium, etc.			Facilities		
	A	B	C	A	B	C	A	B	C
Design Control Process	1.0	0.6*	0.8*	1.0	-	1.0	1.0	-	1.0
Equipment Specification	1.0	0.6	0.8	1.0	-	1.0	1.0	-	1.0
Nature of Procurement	1.0	0.8	0.9	1.0	-	1.0	1.0	-	1.0
Tooling Requirements	1.0	0.6	1.0	1.0	-	1.0	1.0	-	1.0
Assembly	1.0	0.6	0.8	1.0	-	1.0	1.0	-	1.0
Management Requirements	1.0	0.6	0.8	1.0	-	1.0	1.0	-	1.0
Staffing Requirements	1.0	0.6	0.8	1.0	-	1.0	1.0	-	1.0
Related R and D	1.0	0.8	1.0	1.0	-	1.0	1.0	-	1.0
Total	8.0 (1.0)	5.2 (0.65)	6.9 (0.86)	8.0 (1.0)	-	8.0 (1.0)	8.0 (1.0)	-	8.0 (1.0)
	S^A	S^B	S^C	S^A	S^B	S^C	S^A	S^B	S^C

* Relative evaluation values of scenario B & C Vs. scenario A (evaluation value = 1.0)

Table 4.5 Relative Evaluations (II) (specific points)

Impact of scenario B & C Vs. scenario A on construction process.

Evaluation Item \ Scenario / Systems	Reactor Systems: Torus, Magnet, Heating			Supporting Systems: Fueling, Electr. Supply Tritium, etc.			Facilities: Facilities		
	A	B	C	A	B	C	A	B	C
Component testing verification	1.0	0.6*	0.8*	1.0	-	1.0	1.0	-	1.0
Quality assurance	1.0	0.6	0.8	1.0	-	1.0	1.0	-	1.0
Spare parts	1.0	0.8	1.0	1.0	-	1.0	1.0	-	1.0
Facility requirements	1.0	0.8	1.0	1.0	-	1.0	1.0	-	1.0
One/more production lines	1.0	0.8	1.0	1.0	-	1.0	1.0	-	1.0
Transportation requirements	1.0	0.9	0.9	1.0	-	1.0	1.0	-	1.0
On-site fabrication	1.0	1.0	1.0	1.0	-	1.0	1.0	-	1.0
Total	7.0 (1.0)	5.5 (0.79)	6.5 (0.93)	7.0 (1.0)	-	7.0 (1.0)	7.0 (1.0)	-	7.0 (1.0)
	T^A	T^B	T^C	T^A	T^B	T^C	T^A	T^B	T^C

* Relative evaluation values of scenario B & C Vs. scenario A (evaluation value = 1.0)

Table 4.6 Total Relative Evaluation

Impact of scenario B & C Vs. scenario A on construction process.

INTOR sys./comp.	Capital cost (Wi)	Scenario A		Scenario B		Scenario C	
		(S^A+T^A)	$(S^A+T^A)Wi$	(S^B+T^B)	$(S^B+T^B)Wi$	(S^C+T^C)	$(S^C+T^C)W$
Reactor System	1.355	2.0	2.71	1.44	1.95	1.79	2.43
Supporting System	0.565	2.0	1.13	2.0 *	1.13	2.0	1.13
Facilities	0.18	2.0	0.36	2.0 *	0.36	2.0	0.36
Total	2.1	-	4.2 (1)	-	3.44 (0.82)	-	3.92 (0.93)

* Scenario C is applied.

5. Evaluation results

5.1 Cost, additional manpower evaluation

From Table 4.3, the relative evaluation between three scenarios for total cost per participant is shown in Table 5.1-1. On the otherhand, the total increase (%) of staffing manpower in scenario B and C may be roughly estimated from the weight factors of Fabrication/construction and Design/Engineering in Table 3.3.

Table 5.1

Item	Scenario		
	A	B	C
Relative cost per participant	1.0	0.43	0.32
Total manpower increase (%)	0	25%	10%

5.2 Schedule evaluation

The results of an evaluation in case of scenario B & C are shown in Table 5.2. These estimations are based on the evaluations of incremental time in the questionnaires and on the consideration of preserving the relation among preceding and succeeding items in the schedule.

From INTOR design and construction schedules of scenario B & C, the net increase of total schedule is about 1.8 years in scenario B and about 1.0 years in scenario C.

Table 5.2 Schedule evaluation

	Factor		Increase (Yrs)	
	Sce. B	Sce. C	Sce. B	Sce. C
Production design	1.3	1.1	0.9	0.3
Procurement	1.5	1.2	1.75	0.7
Fabrication/construction	1.2	1.2	0.9	0.9
Transport/Assembly	1.7	1.5	1.75	1.25
Engineering tests	1.2	1.1	0.3	0.2

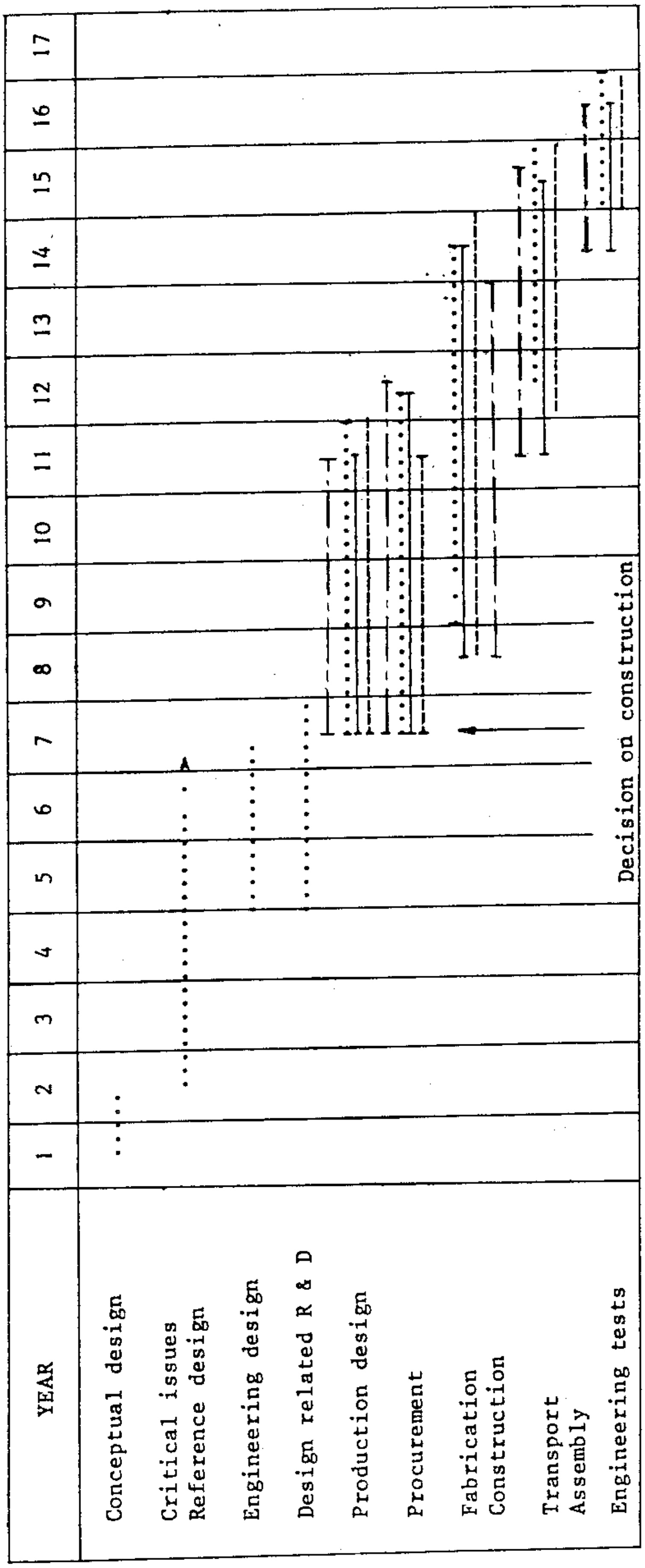


Fig. 5.1 INTOR design and construction schedule B

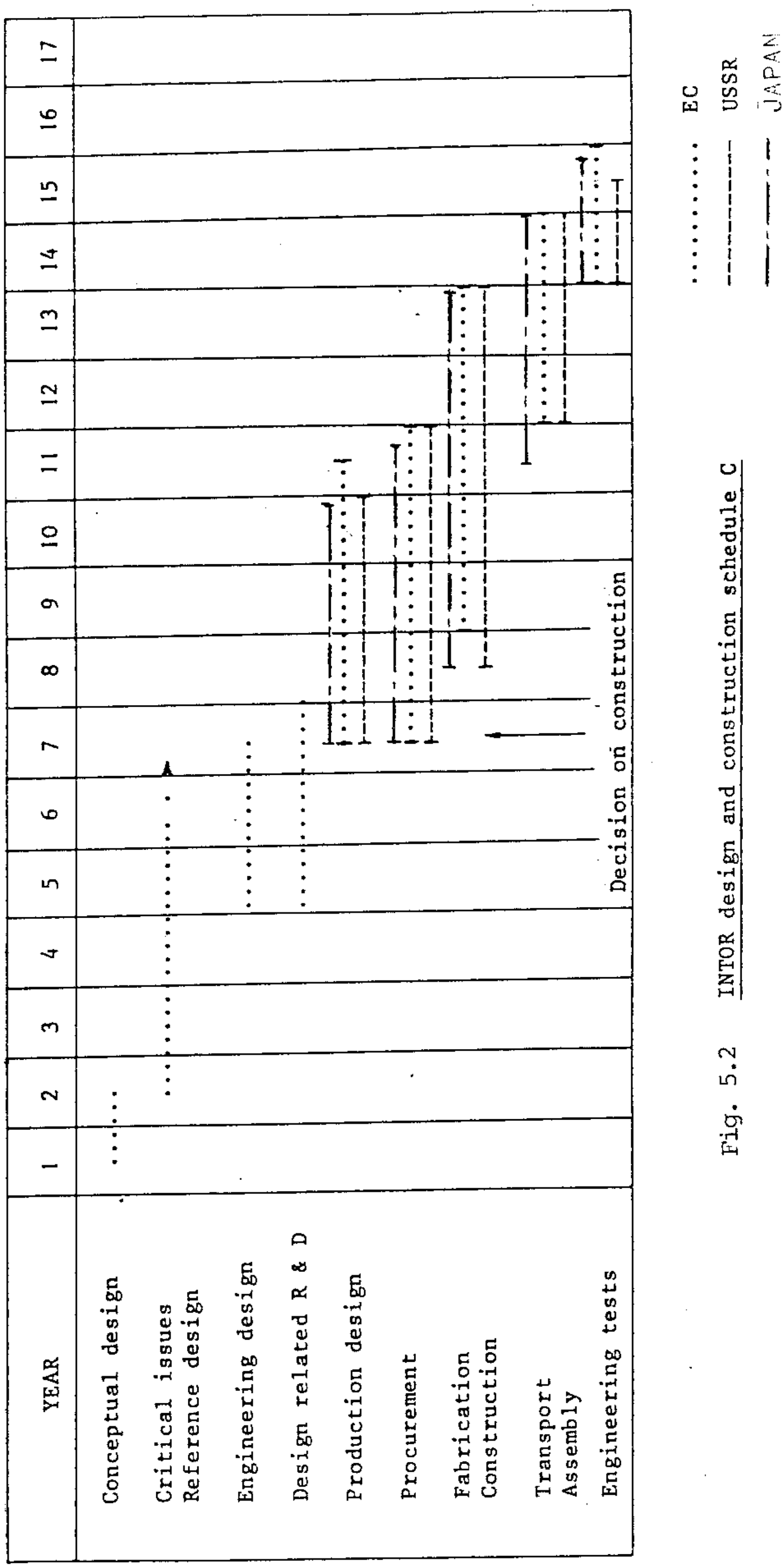


Fig. 5.2 INTOR design and construction schedule C

5.3 Evaluation of partioning impact on construction process, risk and information exchange

Evaluation of partioning on construction process is performed for impact of scenario B & C and the result shows that scenario C is superior to scenario B, as shown in Table 4.6. This coresponds to results of cost evaluation in 5.1, that is the partioning of scenario B needs a lot of manpower and leads to cost-up of INTOR construction.

From the answer of No. 15 in the questionnaires (Table 3.3-1 ~ -21), scenario C is estimated to be risky. The risk needs to be emphasized that, in case of scenario C, there would be a great damage for INTOR project execution if a participant should fail in the fabrication of one component.

Information exchanges for technical transfer are indespensable for scenario C, which only one participant is engaged in the fabrication of one component in advanced technology areas, but a effort have to be made for fruitfull information exchanges. On the otherhand, in case of scenario B, information exchanges will be made successfully on the same technology base, because four participants execute the same R & D and fabricate the same system.

6. Other large projects' experience in LCT and JT-60

a) An ideal approach is that each participant takes equally splitted portion of the work just like LCT project. For example, each participant designs and manufactures one of equally divided sectors of the torus.

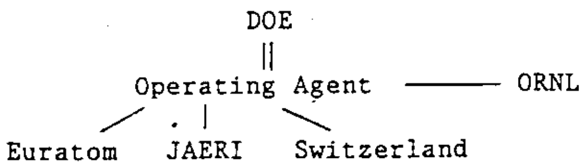
b) To perform an international collaboration such as INTOR, neutral and independent organization which supervises specifications and technical subject is needed.
Another organization is needed to check the progression of the work. Large difference in the progression between participants obstructs the execution of collaboration work. In preparation for this situation, some rules of judgement should be established.

c) Industry should be involved even in R and D work which will not necessarily be followed by a construction of a prototype reactor. Otherwise industry cannot improve its technology to the degree needed to construct a prototype reactor.

d) Examples in LCT project

1. Level of detail needed in design
   Since LCT project includes fabrication of coils, each participant made detailed design and production of its own coil.

2. Organization scheme
   (the United States will explain)



3. Interface problems
   Interfaces are common to all coils and details are determined in the specification.

4. Communication problems
   Participants exchanged their detailed design reports and then 'on-site representatives' stay at ORNL to get better communication.

5. Standardization problems
   There is no problem in standardization, because the design was made under the condition that the inside of the coil shall have its originality.

6. Code problems
   Each participant used its own codes for design. Some codes were used in common by chance.

7. QA problems
   Participants control QA by its own method.

8. Transport problem
   Transport itself doesn't have any problem. But the problem arised in the customs of the United States, because the United States doesn't apply its duty free treatment to the articles except government property.
   Big international collaboration such as INTOR must be imposible unless more flexible treatment of the customs is applied to articles produced by participants.

9. Information exchange
   Participants made much efforts to exchange information. But it is difficult to evaluate the quality and quantity of information which satisfies each other. Therefore a standard should be determined for information exchange.

10. Equity problems
   It seems to be lacking in equity that no system was formulated on the penalty concerning the delay of work which troubles other participants.

Fig. 6.1 Classification of JT-60 System and Fabricators

System	Facility & Equipment	Fabricator
Tokamak System	o Vacuum vessel o Toroidal field coil o Poloidal " " o Base o Vacuum pumping system o Gas injection system	A
Power supply system	o Toroidal coil power supply system	B
	o Poloidal coil power supply system	C
	o Motor generator power supply — TFC	B
	PFC	C
	NBI, RF	A
	o Control substation	C

System	Facility & Equipment		Fabricator
Heating System	NBI	o Ion source	D
		o Beam line	A
		o Power supply	C
	RF		E
Total control system	o Computer system o Protection interlock system		A
Cooling system	o Primary cooling system		A
	o Secondary " "		B
Diagnostics system	o Diagnostics system		A, C, F, ...

7. Conclusions

Technical benefit evaluations in scenario B and C versus A were studied from many kinds of viewpoint.

As a result, the following conclusions were obtained that from benefit evaluations of cost, manpower and schedule, scenario C is superior to scenario B, a and to the contrary in the technical information exchange and the risk, scenario B, is most promising. From the definition of technical benefit, scenario B seems to be very favorable for technical transfer of advanced technologies develped in INTOR project. In order to adopt scenario B, technological level of each participant is necessary to be almost equivalent at the start of INTOR construction and so, each participant should make a great effort to develope his own technology basis. On the other hand, the INTOR central team should be consisted of many staffs with strong management power and strong technology power, for the purpose of successful INTOR project in scenario B.