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Draft Program Plan for TNS—The Next Step After the Tokamak Fusion Test Reactor

Part IV—Program Planning

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DRAFT PROGRAM PLAN FOR TNS — THE NEXT STEP AFTER THE TOKAMAK FUSION TEST REACTOR

PART IV — PROGRAM PLANNING

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NOTICE This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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This planning document is Part IV of a four-part report that comprises the Draft Program Plan for TNS. The other parts of the report are:

ORNL/TM-5982	Part I — Summary
ORNL/TM-5983	Part II — R&D Needs Assessment
WFPS/TME-044	Part III — Project Specific R&D Needs

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FOREWORD

The Next Step (TNS) Program, established by ERDA's* Division of Magnetic Fusion Energy (DMFE) at ORNL in early 1976, has two principal objectives:

1. to demonstrate in a timely fashion a fusion reactor core that can be extrapolated to an economically viable fusion reactor and
2. to provide a near-term means of focusing the efforts of the National Fusion Program to achieve the first objective.

This first draft of an attempt to outline a TNS program plan addresses the second objective. The draft program plan is presented in four parts:

PART I — Summary
PART II — R&D Needs Assessment
PART III — Project Specific R&D Statements
PART IV — Program Planning

This assessment was developed initially in an intense few-week period, based on the understanding and information that had been built up at ORNL and Westinghouse over the preceding years by participation in the Fusion Program in general and in the Tokamak Fusion Test Reactor (TFTR) [both the Feasibility/Burning Experiment (F/BX) and the Two Component Torus (TCT)], the Experimental Power Reactor (EPR), and prior TNS studies in particular.

In attempting to develop a program plan, two kinds of information were included in the assessment, namely, current status and extrapolation. With rapid technical progress being made in many laboratories, elements of the current technical status should be reevaluated on perhaps a semiannual or annual basis. Inasmuch as the fusion program is tied strongly to the nation's energy program in general, the extrapolation can and does change on a much more rapid time scale. In particular,

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*Effective October 1, 1977, ERDA became part of the Department of Energy (DOE).

this "snapshot" of the TNS support program taken in January-February 1977 does not take into account budget changes discussed in the same period and does not reflect the evolution of schedular planning that occurred in the March-April 1977 period. As a result, some of the plans for action based on the targeted FY-1980 line item are no longer meaningful; however, the basic arguments will apply to a line item some years later.

In particular, the organizational arrangements assumed represent one specific extrapolation of the situation in February 1977 and should be viewed only as a means of describing a planning scenario, not as a proposed future path.

This document is therefore issued principally for comment and discussion, rather than as a definitive statement.

ACKNOWLEDGMENTS

Development of the information in this Draft Program Plan is the result of the efforts of many people in the fusion community, who invested from a day to a month or more in this task. The principal contributors are members of the Oak Ridge TNS Program team, both at ORNL and Westinghouse, who have devoted their full efforts to this task for many weeks. Bringing specific technical expertise to the development for varying lengths of time have been individuals from the ORNL Fusion Program and from various institutions in the country. Preparation of Part IV has been aided by extensive discussions with E. H. Bryant, M. Roberts, and T. E. Shannon. J. O. Neff and his colleagues from DOE-DMFE have provided valuable guidance and comments; S. Waddle and G. Benedict have participated in the review process from DOE-ORO.

Throughout this exercise, J. F. Clarke has provided valuable direction and strong support.

DRAFT PROGRAM PLAN FOR TNS — THE NEXT STEP AFTER THE TOKAMAK FUSION TEST REACTOR

PART IV — PROGRAM PLANNING

W. B. Wood, TNS Project Engineer

ABSTRACT

In this fourth part of the four-part TNS Draft Program Plan, project engineering concerns are considered. The TNS Project is first broken down into the major time and functional periods of feasibility study, preconceptual design, conceptual design, and line item construction, while the elements of the project are organized into an administrative work breakdown structure. With the aid of these two classifying schemes, the project tasks are described in terms of schedule, estimated cost, type of funding, and proposed type of participant. The initial constraints of completion date, anticipated scientific inputs, and budget procedures are used to develop a two-phase project in which the facilities are authorized first and the device 2 years later. This specific mechanism is fundamental to the construction of the schedule and should be reconsidered when the completion and initiation dates are reformulated.

Because the purpose of this work is to aid the development of the eventual TNS Program Plan rather than to be the final plan itself, it is the process contained herein and not the specific numbers that should be the focus of continuing discussions. In particular, a second fundamental premise on which the schedule is based is that there exists at the outset a commitment to the fusion program in general and to TNS specifically. The schedule must therefore be rethought to include initially the decision-making process before the design and construction period, which was the principal topic of the TNS planning exercise.

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1. INTRODUCTORY SUMMARY

1.1 Introduction

Preparation for the Next Step (TNS) as an attainable line item project[1] in the National Fusion Program[2] requires concerted and comprehensive planning in addition to the technical basis underlying fusion advances. The TNS Program and Budget Proposal,[3] Form 189, for FY 1977

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specifies five critical objectives, one of which defines the basic technical work to be done and another of which defines the means of communication with the fusion community. Three of these critical objectives constitute the planning effort, namely, clarification of the role of TNS in the fusion program, development of supporting RD&D program coordination, and specific project planning. Expressions of similar concern about planning efforts have been made recently by both DOE-DMFE[4] and DOE-ORO[5] in letters specifically addressing TNS, dated December 10, 1976, and by DOE-ORO[6] in a broader context. As a result of these now commonly held concerns, the Oak Ridge TNS Team has put together a first-draft version of a comprehensive planning document (Parts I, II, III, and IV). This draft version of Part IV has been developed as a starting point, along with the companion documentation on the technical basis, for focused discussions on the planning process. The contents of the document have been prepared on the basis of our perception of the many contributing factors, specifically of management of large, complex R&D-based projects; expectations about the outputs of the underlying technical support program, budget, and schedule constraints; the evolving organizational nature of the fusion community; and the specific features of a tokamak fusion device.

Inasmuch as this draft document is being developed before conceptual design has been initiated, we expect revisions and refinements to the draft to be an inherent part of the planning process. After a Summary of Findings (Sect. 1.2) and a brief Project Overview (Sect. 2), the document continues in the chronological order of the TNS Program steps, starting with the initiating Feasibility Study and Preconceptual Design Periods (Sect. 3), continuing with the Conceptual Design Period (Sect. 4), and concluding with the Line Item Design, Construction, and Preoperational Period (Sect. 5). Relevant correspondence and fiscal documents are contained in the Appendixes.

1.2 Summary of Findings

A discussion of findings is best presented here in two parts: (1) the output product of schedules, fiscal charts and tables, and the work breakdown structure (WBS) and (2) the underlying premises and the projected sensitivity of the output to changes in the premises.

1.2.1 Output product

For discussing the project engineering aspects of TNS, a set of specific plans has been developed. These plans include an overall master schedule, which is broken down by WBS elements, and more detailed plans for each of the four periods of the project: feasibility study, preconceptual design, conceptual design, and construction line item. For each period, the projected milestones, estimated funding (costs and type), and participants are presented. Presented as an insert at the end of this document is an integrated schedule of TNS as a Proof of Principle (POP) with the prior TFTR and succeeding Power Technology Demonstration (PTD) or EPR and Commercial Power Demonstration (CPD) or DEMO. This integrated schedule represents redrawing, editing, and clarifying with the Grumman Aerospace Corporation on its initiative. Close examination of this master schedule will reveal that contractor selection and site discussions could well change the timing of the schedule.

1.2.2 Sensitivity to underlying premises

The plans discussed above are the result of applying conventional project engineering practice to the two fundamental premises of this study, namely,

- Completion date is set as October 1986.
- Governmental commitment to fusion in general and TNS in particular is made by April 1977.

The first premise is set by ERDA-DMFE and is driven by the needs of the overall program.

The second premise is made as a working assumption by the TNS team for planning purposes.

Basing the schedule on the first premise results in the necessity to phase the project in two parts, starting with the facility portion first and implementing the device portion second. This technique reduces the risks as low as possible but proceeds with facility construction to reduce overall schedule delays and defers device design as long as possible to ensure the greatest amount of current research input.

Basing the plan on the second premise results in the design/construction portion of the plan being internally consistent but the initiation of the plan not being clearly addressed.

Although a directed study of the sensitivity of the output product to the underlying premises has not been made, it seems clear that there is strong sensitivity. If, for example, completion is moved by 2 years relative to the expected outcome of the major research endeavor, the need for phasing the program is lessened considerably. The concept of a committed fusion site, now under study at ORNL, could also change the schedular makeup of the plan by providing the facilities basis in a way somewhat separate from TNS and more closely related to the fusion program, that is, common to tokamak, mirror, and exploratory concept needs.

With respect to the second premise, it is crucial that the planning exercise incorporate the reality of the decision-making process. If, as has been the case in this study, reality is not well modeled, then the acceptance or value of the outcome is less than it could be. Specifically, what remains to be effected is a means of developing a commitment to TNS, a means of developing a choice of objectives and designs for TNS, and a means of choosing the project team and site. Each of these difficult developments or choices was assumed as a starting point for the present exercise. To make the plan more real, a way must be found to bridge the gap between the current status of fusion and the initial starting point of the schedule in this report.

REFERENCES FOR SECTION 1

1. Letter from E. E. Kintner to R. J. Hart, FY 1979 Construction Project Identification, Oct. 28, 1976.

2. *Fusion Power by Magnetic Confinement — Program Memo/Executive Summary*, ERDA-76/110/0, July 1976.

3. Project Goals for FY 1977, TNS Program and Budget Proposal — Form 189 No. 00037, Mar. 1, 1977.

4. Letter from J. O. Neff to M. Roberts, Conceptual Design Plans for Proposed Construction Projects, Dec. 10, 1976.

5. Letter from J. T. Milloway to G. R. Jasny, T Phased Line Item Project, Dec. 10, 1976.

6. Letter from R. J. Hart to R. F. Hibbs, Improvements in Construction Project Scope and Definition, Dec. 7, 1976.

Note: References 1, 3, 4, 5, and 6 are contained in Appendix A.

2. PROJECT OVERVIEW

2.1 Basic Premises

The Next Step (TNS) facility is proposed as the next logical major step in the development of fusion power after the Tokamak Fusion Test Reactor (TFTR), which is to be operational in FY 1981-1982. The DOE-DMFE Logic III Plan calls for a TNS device, possibly characterized as an ignition test reactor, to be operational by FY 1986.

As a definite starting point in developing these plans, we have assumed that program management will be provided by ORNL in a manner similar to that of the Princeton Plasma Physics Laboratory (PPPL) management of TFTR. It is recognized, however, that for a major project of this magnitude, DOE may elect to organize a project-management structure similar to that for the CRBR Project. This decision should not significantly affect the main technical features of the overall scope and schedule developed in this plan.

A key premise affecting both the nature of the succeeding action steps and the postulated schedule is that there is now a fusion-program policy commitment to the TNS goal. (Note added in proof: Much of the discussion in the intervening year between initial preparation of this draft plan and the present has centered around this premise.)

A construction schedule that meets the desired FY-1986 completion date appears to be obtainable, assuming that engineering design criteria would be available as required for the Title I and Title II designs in FY 1980, 1981, and 1982. Many of the final criteria will not be available until FY 1981-1982. Considering the interactions required between the many R&D programs and the TNS design process, it is unlikely that all of the information and hence the overall project design will be available on schedule. To assess the overall impact of uncertainty in the outcome of the R&D programs on TNS, integrated systems sensitivity studies must be conducted.

We have assumed a success-oriented program for this first plan to evaluate the requirements for the targeted FY 1986 completion. Three key dates were taken for the basic skeleton of the plan, as presented in Table 1.

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Table 1. Key dates underlying the schedule development

Schedule	Date
1. Starting date for formal project (Title I), chosen to maintain an accelerated fusion program pace and to incorporate the findings of the midterm experiments in 1978 and 1979	FY 1980
2. Starting date for hardware fabrication (Title II), chosen to base the final design review on confirmation from TFTR results with H plasma	∿FY 1982
3. Starting date for operation, chosen to be the earliest possible completion date	FY 1986

We propose a phased line item project funding schedule, beginning in FY 1980 with the first phase (principally the facility). At the same time, we propose continuing conceptual design and preliminary engineering on the uncertain features of the tokamak device until the second phase (principally the device) funding begins in FY 1982. This plan, although admittedly optimistic, is the only means by which we can envision meeting the desired FY 1986 starting date.

The idea of phasing is not new for major ERDA construction projects and has been used in the past as a funding technique for large projects. The capacity-expansion project for the DOE Gaseous Diffusion Plants, for example, is phase funded.

A complete project cost estimate would need to be prepared for submission of the first phase, Conceptual Design Report (CDR), in April 1978. However, the device or second phase portion of this estimate will not be supported by a conceptual design by April 1978; consequently, the cost estimate must be revised on a yearly basis until the final second-phase CDR in April 1980. This schedule will continue to allow input from the R&D programs until the start of Title II design in October 1981.

The ERDA/DMFE planning document has estimated funding for this device at $400 million (in constant FY 1978 dollars). Preconceptual design trade-off studies by the ORNL/Westinghouse design team are currently being used to evaluate various design options with the help of a system design model that includes cost factors. The ultimate cost of TNS depends on the objectives of the experiment. For development of this plan, we assume a total project cost of $500 million to $1 billion.

2.2 Project Cost

ERDA-DMFE has instructed ORNL to plan and proceed along a logical path to the selection of a minimum-cost option for The Next Step (TNS) after TFTR which fulfills the most critical TNS objectives. This work will result in the selection of a principal reference design by May 1977. The first budgetary estimate developed in the DMFE long-range planning projections was based on a certain perspective of the steps connecting the TFTR to a commercial power plant (CPP). In this view of ever-increasing size from TFTR to CPP, TNS was targeted at $400 million. With initial design information based on the first nominal reference design of July 1976, a rough budgetary estimate of $515 million was defined (excluding engineering, contingency, and escalation). A more soundly based estimate must await completion of the conceptual design.

2.3 Project Schedule

The DMFE plan defines the following schedule for TNS [which encompasses both the options of the Prototype Experimental Power Reactor (PEPR) and the Ignition Test Reactor (ITR)].

<u>Major milestones</u>

10-1-77	Begin conceptual design
10-1-80	Begin Title I design
10-1-86	Begin operation

This schedule did not include the requirement for conducting a thorough design space exploration until mid-FY 1977. Current detailed network analysis of the construction schedule (to be discussed in detail in Sect. 5) defines a schedular critical path that continues through the main test-cell beneficial occupancy date and requires the date to occur as soon as possible. In addition, needed R&D input for the device design effort is also on a critical path that requires conceptual and Titles I and II device design to be delayed as much as possible. Because of these two opposing critical-path requirements, it is proposed that the project be phased, with the main test building and related systems and subsystems being defined as a 1980 line item project (Phase I) and the device as a 1982 line item project (Phase II) to meet the operational requirement of October 1986. A preliminary summary schedule for the TNS program, including the line item project and the clearly associated prior activities, is presented in Fig. 1.

2.4 Project Technical Base

The design criteria, technical requirements, and fundamental understanding, which form the technical basis for the total TNS Project, are in a constant state of evolution. Ongoing refinement of the reference design reflects this constant improvement in the technical basis. The timing of this improvement, as judged from the planned experimental, theoretical, and technological program, currently appears to allow a substantial refinement to the basic FY-1977 reference design in FY 1979-1980, during the device conceptual design and before Phase I design and construction, and a final refinement following TFTR testing in the FY 1981-1982 time period, before final Phase II design and construction.

To ensure the best technical base for the device systems conceptual design effort and simultaneously to start the project in FY 1980 to meet a mid-1980s operations date, the phasing concept was used. A FY 1980-1982 phased project allows facilities conceptual design to be based on the envelope characteristics of the reference design (which results in minimum schedule delay at the small cost increment in the overall plant of a more general facilities specification) and the device conceptual design to be based on the subsequent substantial refinement of that reference design (which reduces the economic and technical risk on the predominant device portion of the plant). This technique results in two more years of device conceptual design and integration of the R&D input (into the device technical base) scheduled to be available in FY 1979-1980.

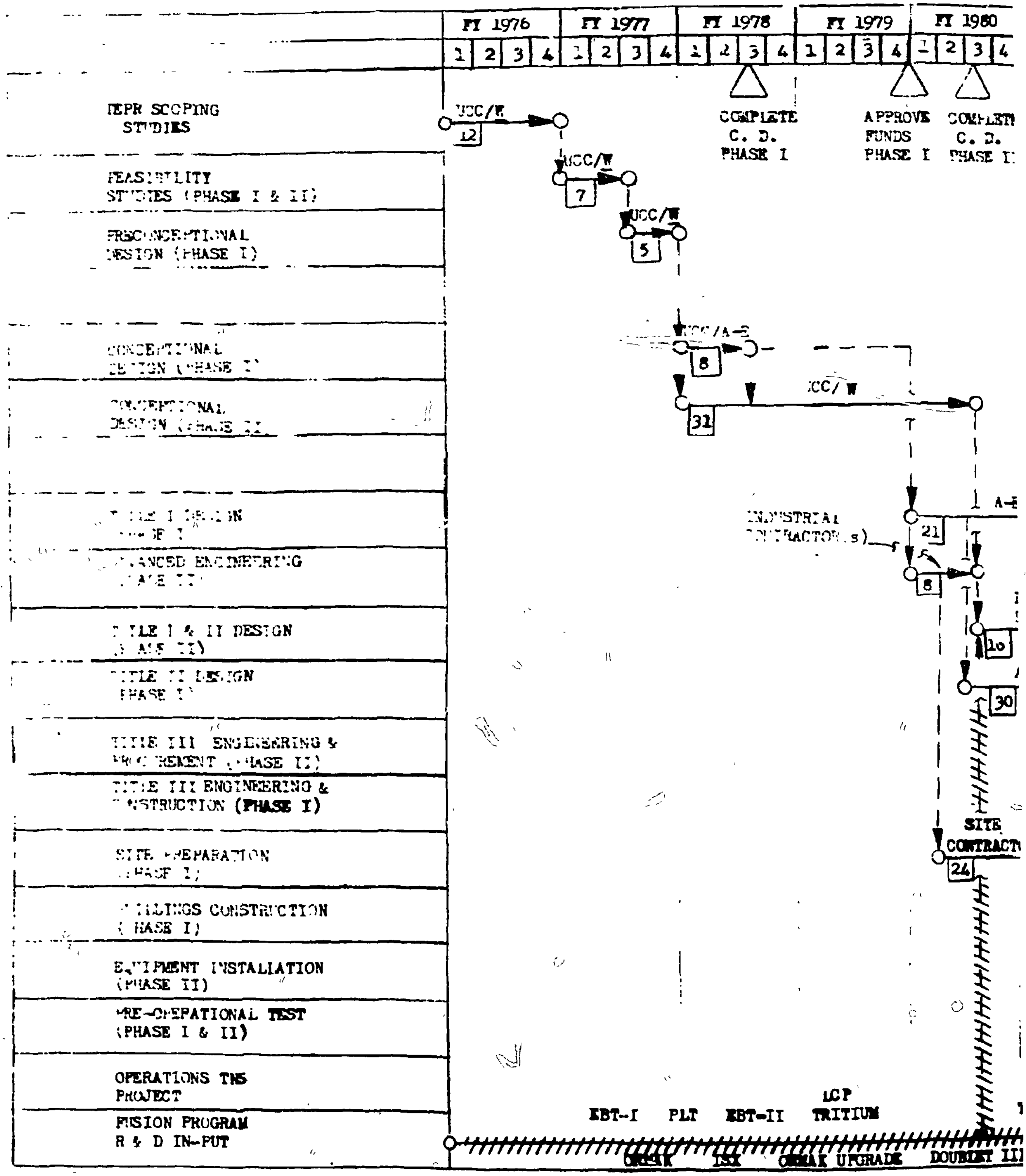

Fig. 1. TNS Program — o

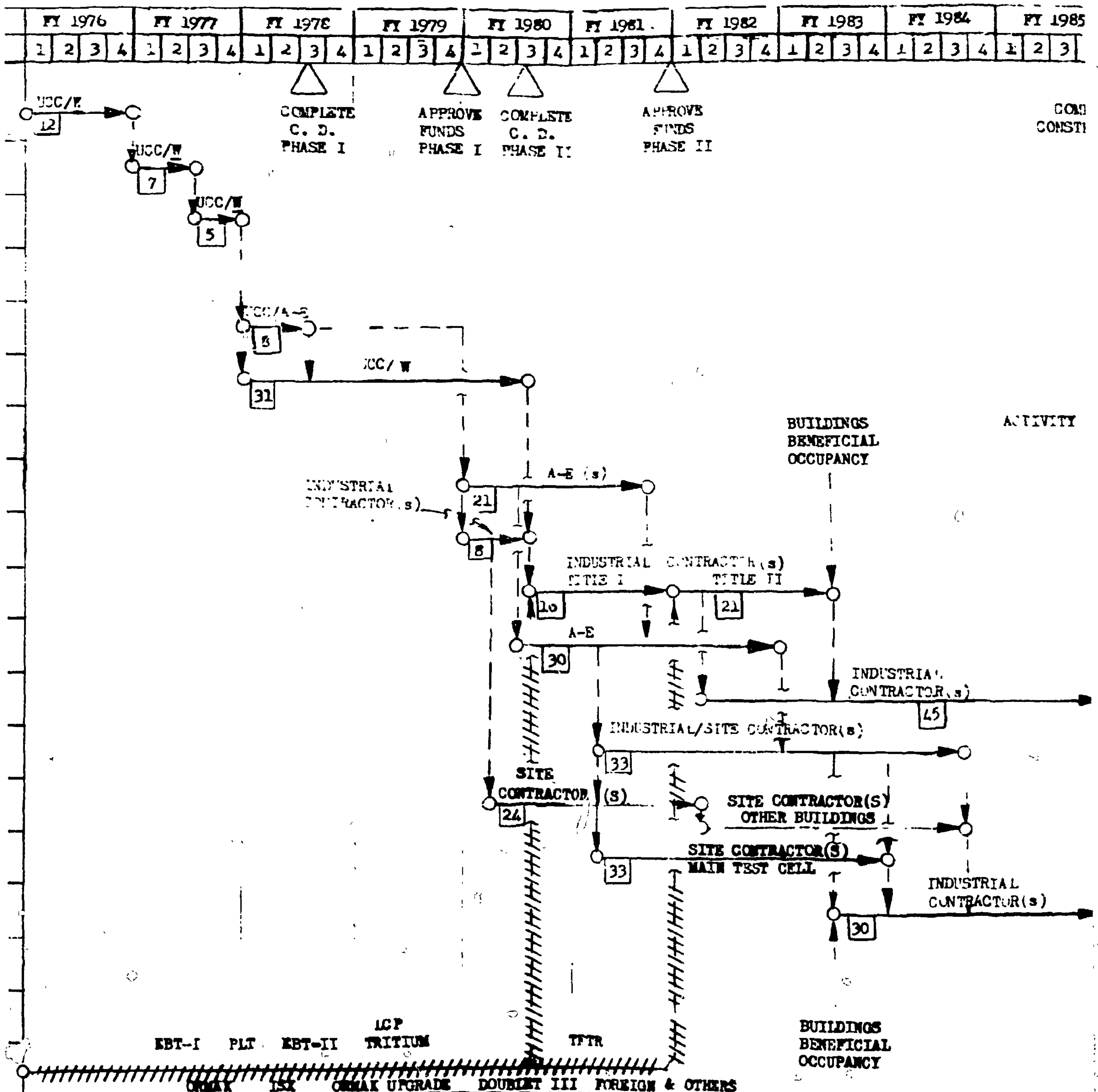

Fig. 1. TNS Program — overall summary schedule.

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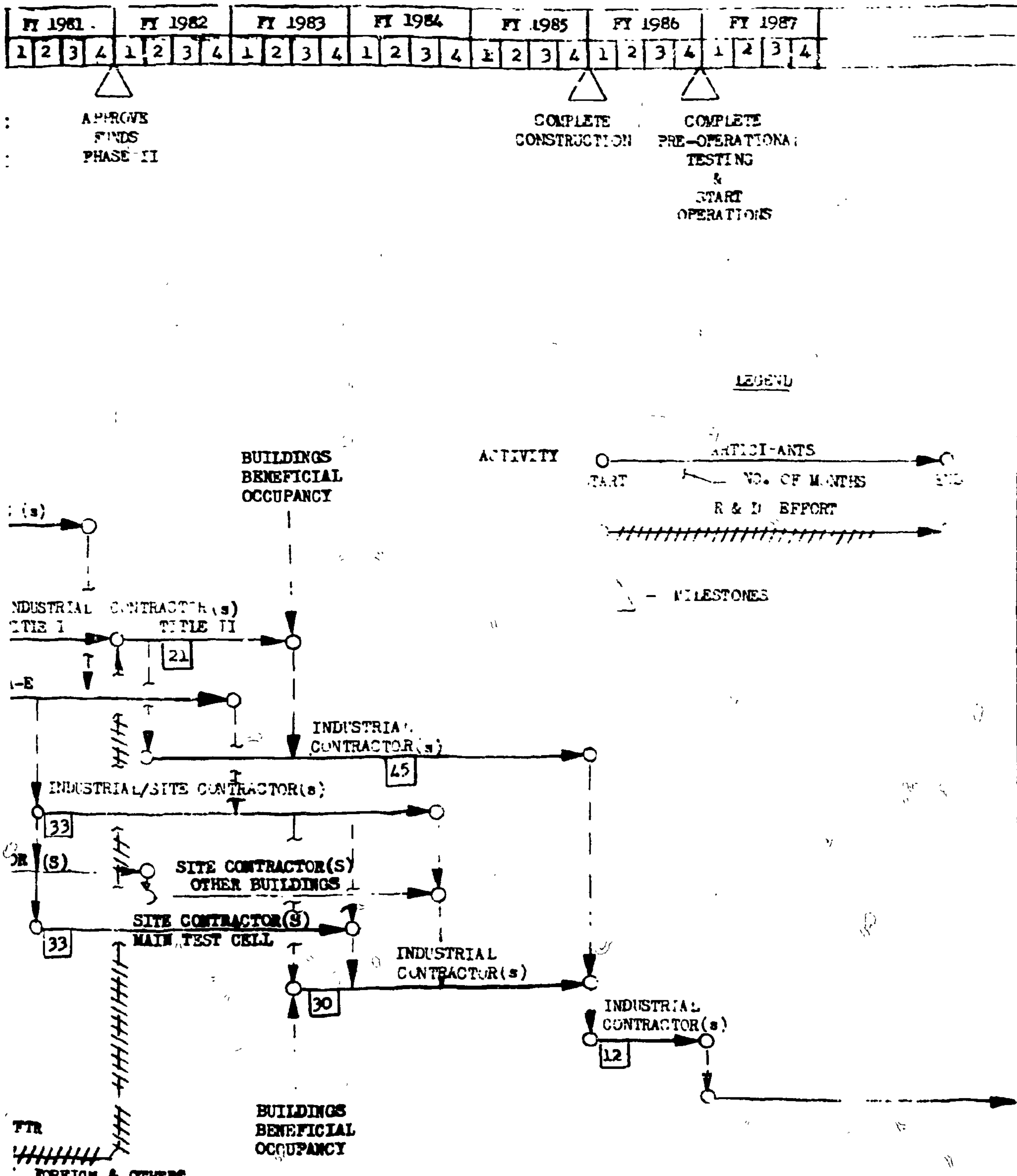

...verall summary schedule.

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A series of major design reviews is planned to ensure the timely integration of criteria for design. The timing and definition of these reviews are discussed in Table 2.

2.5 Project Task Structure

The project tasks are defined in the product (hardware, software, and services) oriented work breakdown structure (WBS) (Fig. 2). All project activities will be related to the WBS. Costs and schedules for each element will form the baseline from which project performance can be measured. The systems baseline in the top three levels will form the basis for reporting, while the lower level subsystems baselines will provide project management with cost and schedule control and visibility.

An indication of the project phase structure is included in Fig. 2 by identifying each element either as 1 or 2 for Phase I or Phase II. The principal logic for designating elements Phase I or Phase II is discussed in footnote *a* to Table 2; the specific selections are discussed in Table 3. The specific work breakdown structure and phase designations illustrated will be reexamined as the design process continues.

The remaining device systems and subsystems, which are considered to require too high a technical and economic risk should procurement or construction be initiated before final reference design integration into the elements final design, form the Phase II project structure.

Table 2. Timing and definition of major design reviews

Date	Review	Definition
5-15-77	Project initiation design review	Once the reference design is agreed upon and analysis indicates that the prerequisite physics understanding and criteria for design are soundly based, this design review will formally define the basis for preconceptual design, which starts following this review.
10-1-77	Conceptual design review	This review will summarize the results of the preconceptual engineering activity and focus the latest R&D on the design.
10-1-78	Conceptual design review	This review will summarize and refine the results of the Phase I conceptual engineering and the continued Phase II conceptual design. It will focus the latest R&D input on the design.
1-1-80	Phase I and II design review No. 1[a]	This review will integrate the Phase I and Phase II conceptual design efforts with the latest R&D input before "breaking ground" for the main test building (site preparation).
1-1-81	Phase I and II design review No. 2	This review will integrate the preliminary device design effort, the main test building design effort, and the latest R&D results before starting construction on the main test cell. It also will serve as an interim device design review.
1-1-82	Final building and interim device design review No. 3	This review will occur at approximately 30% completion of the main test cell building and before start of construction of the other buildings. It will allow integration of the latest R&D input and final device design into the final design of other buildings before start of construction. With TFTR scheduled to be operating with hydrogen before this review, it will allow refinement of device final design to reflect the TFTR R&D results.

Table 2 (continued)

Date	Review	Definition
7-1-82	Final device design review	This review will occur at the completion of the device final design and will focus all R&D input to date on the design before "cutting metal." It will occur after TFTR is scheduled to operate with D-T and will allow timely integration of these test results.

[a]Those activities and subsystems needed for planning or early use (generally facilities) are nominally designated as Phase I. If the uncertainty in design and associated uncertainties in construction costs do not impact the particular activity or subsystem, by definition there is no economic risk associated with designating the item for Phase I using the preliminary (1979-1980) refinement of the reference design as a technical base. The items designated for Phase I are listed in Table 3. Where economic risk does exist, an indication is made in Table 3.

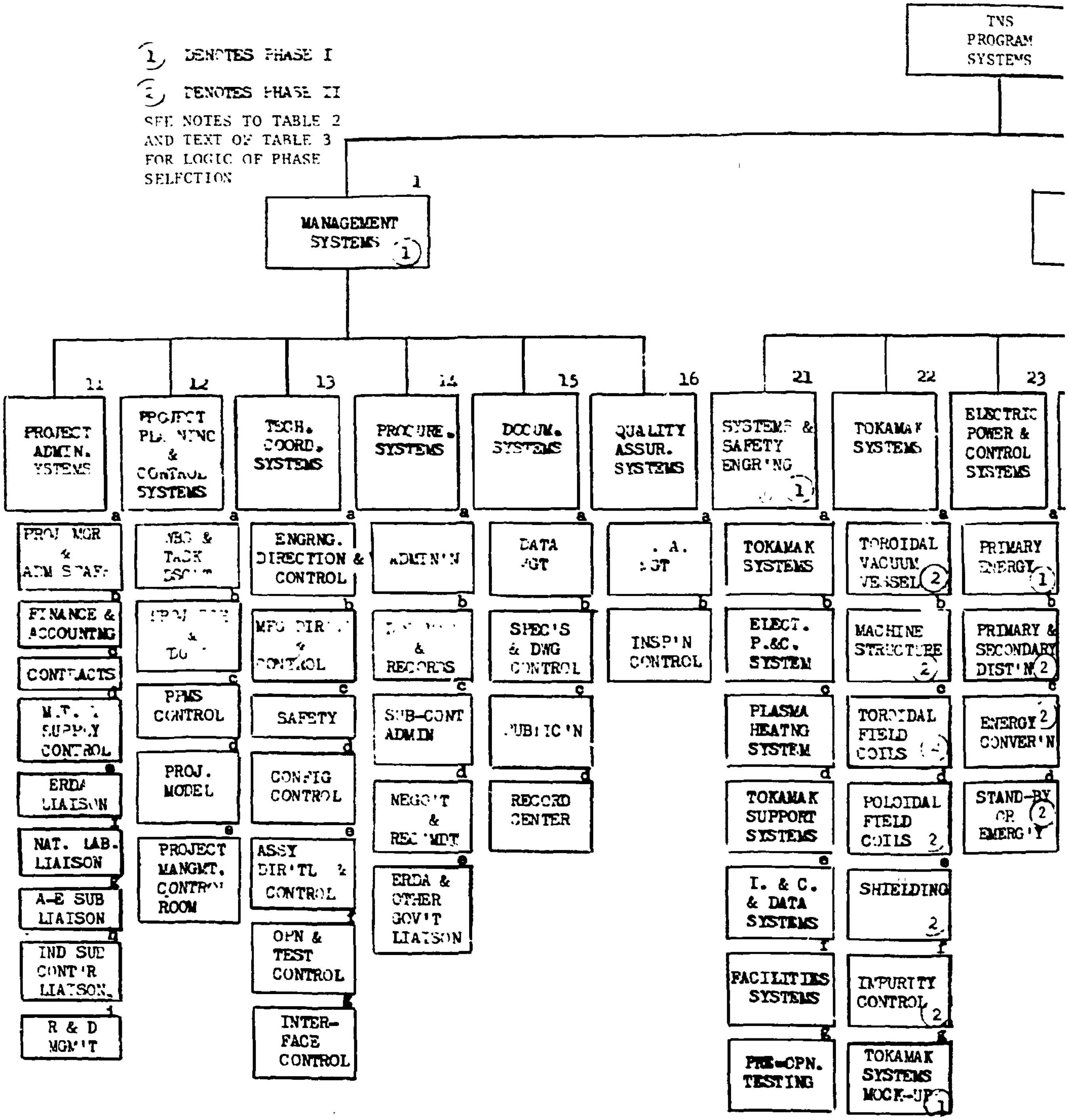

Fig. 2. TNS Program — overall wc

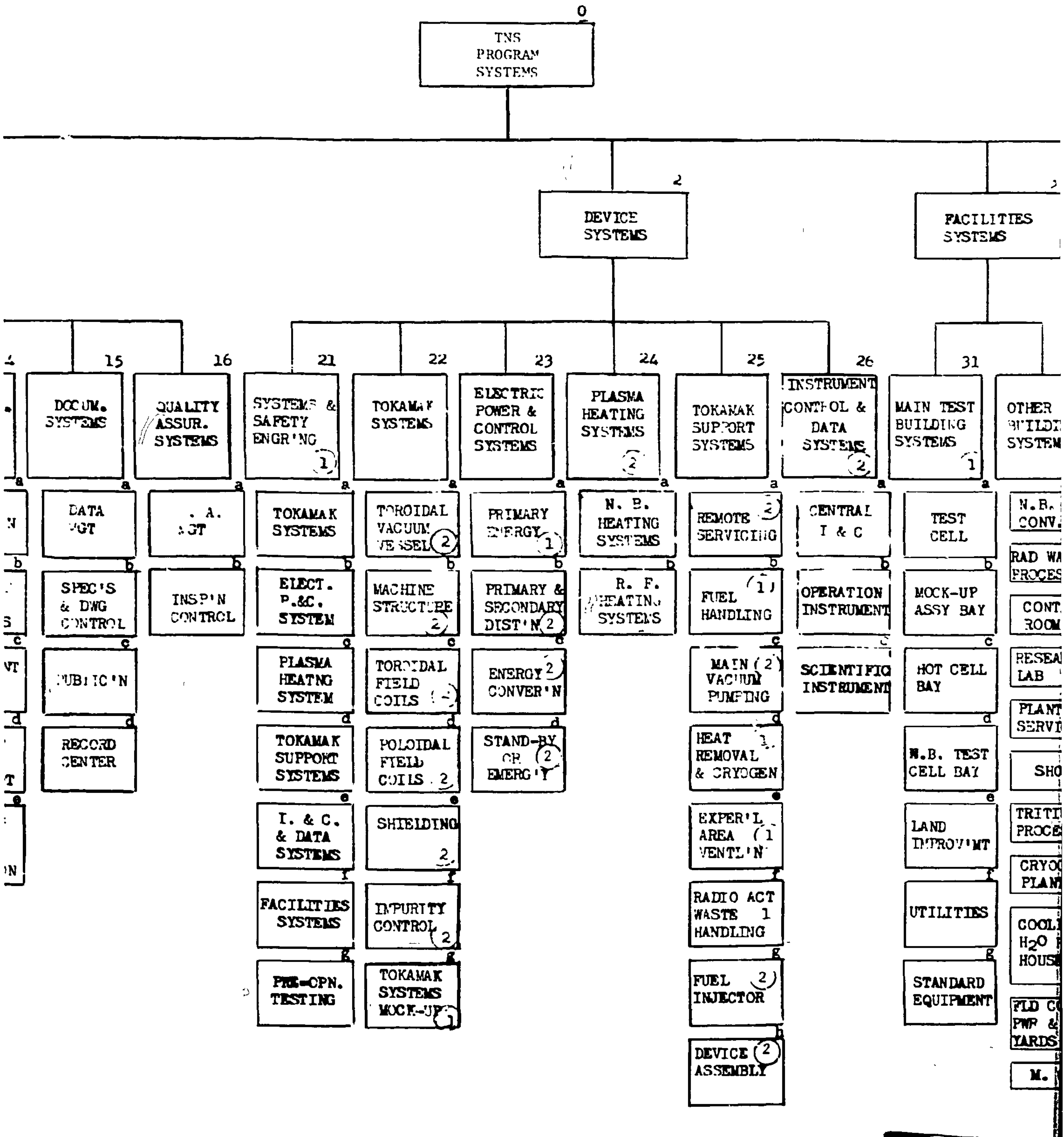

Fig. 2. TNS Program — overall work breakdown structure.

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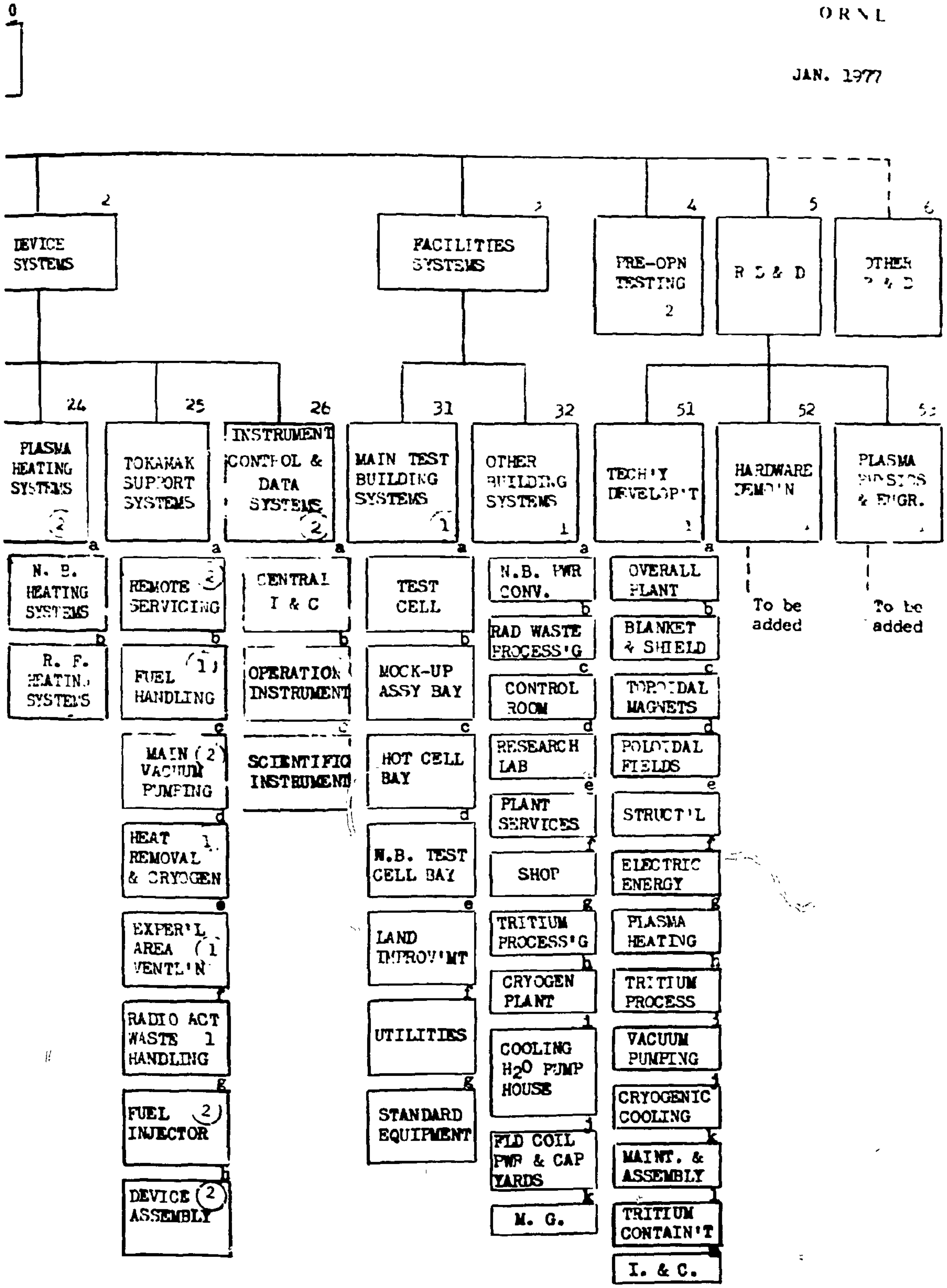

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Table 3. WBS elements designated as Phase I items
(Possible economic risk is discussed with each relevant element)

Element	Comments
Management Systems (WBS No. 1) and Systems and Safety Engineering (WBS No. 21)	These systems and subsystems will be needed at the start of the project. Their initiation at the start will present no economic risk; therefore, they are Phase I elements.
Tokamak systems mock-up (WBS No. 22g)	The mock-up subsystems are needed during preliminary and final design for pipe routing studies, assembly studies, remote maintenance studies, and many more similar uses. Very little economic risk would result if modifications were later indicated, based on the final refinement of the reference design. Therefore, the mock-up subsystems are Phase I elements.
Electric Power — Primary energy (WBS No. 23a)	The six M-G sets require 3 to 4 years for manufacture/delivery/assembly at the construction site, which will require designating the element as Phase I funding for scheduling reasons. The economic impact could be to increase M-G costs, reflecting additional capacity to minimize economic risk.
Fuel handling — tritium and non-tritium (WBS No. 25b)	These subsystems have extensive piping requirements, which will have to be installed as part of the main test cell building and should therefore be designated Phase I elements. Economic risk in this case could involve either some added generality in the building or some "chipping of concrete" to correct a piping problem, but no extensive cost or schedule impact is indicated. The tritium processing equipment final design will be tied to the final reference design so that no economic risk will be involved.
Heat removal — water (WBS No. 25d)	
Experimental area ventilation (WBS No. 25e)	
Radioactive waste handling (WBS No. 25f)	These systems all have piping or equipment to be

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	nomic risk.
Fuel handling — tritium and non-tritium (WBS No. 25b)	These subsystems have extensive piping requirements, which will have to be installed as part of the main test cell building and should therefore be designated Phase I elements. Economic risk in this case could involve either some added generality in the building or some "chipping of concrete" to correct a piping problem, but no extensive cost or schedule impact is indicated. The tritium processing equipment final design will be tied to the final reference design so that no economic risk will be involved.
Heat removal — water (WBS No. 25d)	
Experimental area ventilation (WBS No. 25e)	
Radioactive waste handling (WBS No. 25f)	These systems all have piping or equipment to be installed as part of the main test building construction. In addition, they present very little economic risk because their design is relatively independent of any difference that might exist between the preliminary and final reference design.
Main Test Building (WBS No. 31)	The main test building has a test cell (WBS No. 31a), a mock-up and assembly bay (WBS No. 31b), a hot-cell bay (WBS No. 31c), and a neutral-beam, test-cell bay (WBS No. 31d). This building is essential in the phasing scheme because its beneficial occupancy date needs to occur as soon after Phase I funding as possible. This need is caused by the lengthy device assembly time associated with this highly complex unique device that must be partially assembled and then installed on the machine structure. Any delay in this building construction will cause an equal delay in the end objective, namely, the start-up operational tests. The design of this building might encounter possible reference design change as well as possible allowances in square footage and secondary shiel ing. T se

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funding as possible. This need is caused by the lengthy device assembly time associated with this highly complex unique device that must be partially assembled and then installed on the machine structure. Any delay in this building construction will cause an equal delay in the end objective, namely, the start-up operational tests. The design of this building might encounter possible reference design change as well as possible allowances in square footage and secondary shielding. These allowances might increase construction costs to minimize economic risk.

The land improvement (WBS No. 31c) and utilities (WBS No. 31f) and standard equipment (WBS No. 31g) elements of the main test building system will not be reference-design dependent and will present no economic risk.

Other Building Systems (WBS No. 32)

The buildings in this element are all separate structures. The control room building (WBS No. 32c), research laboratory building (WBS No. 32d), plant services building (WBS No. 32e), and the shop and warehousing building (WBS No. 32f) are not reference-design dependent and should be completed as soon as possible to provide storage and work areas. No economic risk is involved.

Construction of the radioactive waste-handling building (WBS No. 32b), the neutral-beam power-conversion building (WBS No. 32a), the cryogenics plant (WBS No. 32h), the tritium-processing building (WBS No. 32g), the field coil power and capacity yards (WBS No 32j), the cooling-water pump house (WBS No. 32i), and the M-G building (WBS No. 32k) will not begin until after the final facilities design review, which is based upon the final reference design. Therefore, no economic risk is involved. (Some Title II design modification might be required.)

3. FEASIBILITY STUDY AND PRECONCEPTUAL DESIGN PERIODS

3.1 Work Scope

3.1.1 General

The feasibility study period has involved preparation for defining the next logical tokamak confinement device (now known as TNS) following TFTR. The three major components of the activity constituting preparation for the TNS are design studies; definition of research, development, and demonstration needs; and initiation of project engineering tasks. These activities logically lead into preconceptual design, once the device reference design has been established.

The reference design is to be established in May 1977 with preconceptual engineering scheduled to be completed in September 1977 for the start (October 1977) of formal conceptual design.

3.1.2 Feasibility study period (FY 1977)

The three major components of the activity which constitute preparation for TNS are (1) design studies; (2) definition of research, development, and demonstration needs; (3) and initiation of project engineering tasks. Industrial participants are contributing to the activity in each of these three areas.

Closely integrated scientific and engineering design studies are being performed to establish a reference design base from which further planning and design can proceed. The technical assessments being made in the studies are directed toward ensuring that the key ideas conceived on the basis of their theoretical desirability can indeed be made workable in the mid-1980s time frame. The scientific studies make effective use of the knowledge, judgment, and experience available in the broad ORNL fusion program to ensure the relevance and technical feasibility of the design concepts. These studies, applying expertise from fusion theory, confinement and heating experiments, magnet and beam development, engineering, and reactor technology, are focused on the development and evaluation of both new and existing concepts for use in the design. The engineering assessments use the capability developed in the performance of large, complex projects at Oak Ridge and in industry to carry out in-depth analyses and to make experienced judgments of the designs to ensure their practicability and effectiveness.

Using the reference design base, requirements for necessary research, development, and demonstration tasks are identified, defined, and communicated to both the DMFE staff and the relevant field program staff; where possible, recommendations for programs that will satisfy these needs are developed for DMFE's use.

The principal project engineering tasks are the initiation and development of the format and preliminary versions of design descriptions, project plans, schedule, cost estimates, staffing plans, and project organization.

3.1.3 Preconceptual design period (May through September 1977)

The results of the overall feasibility study period will be summarized in the form of the preferred reference design. The preconceptual design period will result in refinement of the reference design in preparation for conceptual design. Initial device system envelopes will be defined, which will allow preliminary facility sizing. Preliminary systems-design descriptions will be prepared.

3.2 Estimated Costs for Feasibility Study and Preconceptual Design Periods

Estimated costs (Thousands of dollars)

FY 1976	Transition quarter	FY 1977
$635[a]	$581	$2400[b]

[a] Includes technical evaluation of the preceding EPR reference design (approximately $300 thousand).

[b] See Schedule 48 in Appendix B — TNS CP&D Funding Detail.

Figure 3 presents the [illegible]g plan, which defines funding amount (expense or CP&D) for eac[illegible]ipant per fiscal year and clearly shows participant split f[illegible]ng. Technical management of the project will be accomplished by UCC.

The feasibility study period is funded with both expense and CP&D funds. This part of the work will be accomplished by UCC and industrial participants under subcontract. The CP&D* effort will focus on those device and device-support systems that require additional construction planning and design because of their complexity and associated technical uncertainties and their large impact on project schedule and cost. This CP&D work will be performed principally by UCC and the industrial subcontractor(s) (IS).

The facility and device preconceptual design will be performed principally by UCC and the IS.

3.3 Work Plan

Figure 4 is a bar-chart work plan defining a schedule of anticipated tasks and key milestones for the feasibility study and preconceptual design periods. Also shown are the task funding type (expense or CP&D) and participant (UCC or IS).

*See Schedule 48 in Appendix B — TNS CP&D Funding Detail.

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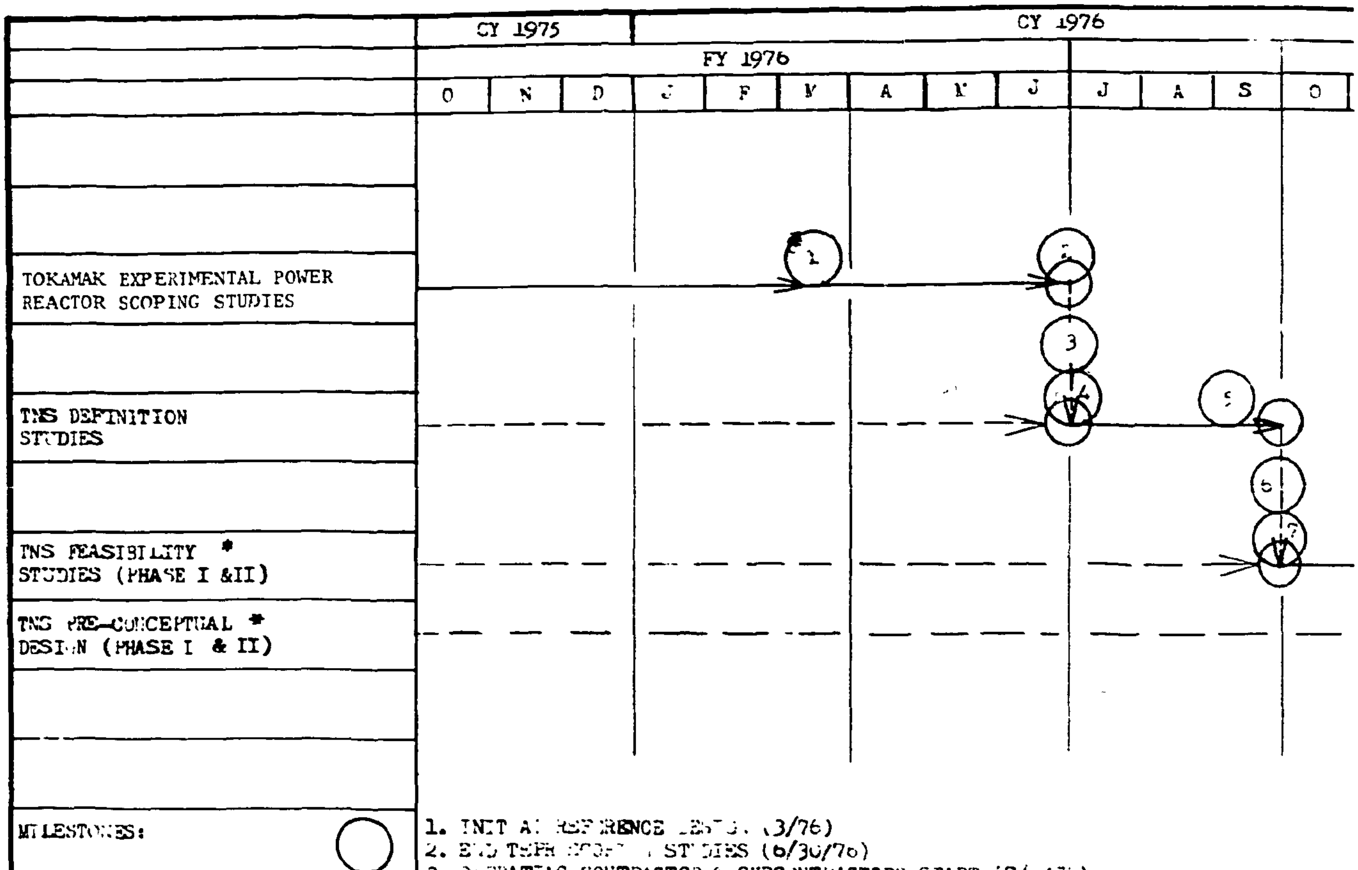
DESCRIPTION	FY 1976		TQ		FY 1977			
					EXPENSE		CP & D	
	EXP.	CP & D	EXP.	CP & D	FEASIB'Y STUDY	PRECONCEPT DESIGN	FEASIB'Y STUDY	PRECONCEPT DESIGN
A. MAJOR PROCUREMENT AND FABRICATION								
1. LABORATORY/INDUSTRIAL TEAM								
2. LABORATORY/UNIVERSITY TEAM								
3. INDUSTRIAL SUBCONTRACTORS	230		415		540	400	850	
4. CONSULTANTS	30		6		24			
B. UCC								
1. DIRECT AND INDIRECT SALARIES	350		140		307	100	150	
C. TECHNICAL SERVICES								
D. COMPUTER AND PROGRAMMING	25		20		26			
E. CAPITAL EQUIPMENT OBLIGATIONS					15			
TOTALS	635		581		912	500	1000	

Fig. 3. TNS funding plan — feasibility study and preconceptual design periods ($ × 1000).



1. INITIAL REFERENCE DESIGN (3/76)
2. END TEPR SCOPING STUDIES (6/30/76)
3. OPERATING CONTRACTOR & SUBCONTRACTORS START (7/1/76)
4. TNS AS FY 79/80 L.I. PROJECT STUDIES START (7/1/76)
5. ISSUE TNS FY 79 L.I. SHORT FORM SCH. 44 DATA SHEET (9/8/76)
6. OPERATING CONTRACTOR AND SUBCONTRACTORS START (10/1/76)
7. TNS AS FY 80/82 L.I. PROJECT STUDIES START (10/1/76)
8. DEVELOPE BASIC REF. DESIGN CHARACTERISTICS OF DIFFERENT SIZE & CONFIG. TNS
9. ISSUE QUARTERLY REVIEW (12/15/76) (3/15/77) (6/30/77) (9/30/77)

10. PREPARE POSITION PAPER ON ROLE OF TNS IN FUSION PROGRAM (2/3/77)
11. DEVELOP PLASMA SENSITIVITIES AND COST METHODOLOGY (2/3/77)
12. ESTABLISH RD&D SCHEDULES AND FUNDING INFORMATION (3/1/77)
14. RECOMMEND PREFERRED REF. DESIGN (4/15/77)
15. COMPLETE PHASE I & II FEASIBILITY STUDIES AND DOCUMENT CRITERIA FOR SELEC
16. OPERATING CONTRACTOR & SUBCONTRACTORS START PHASE I & II PRE-CONCEPTUAL DE
17. COMPLETE PHASE I & II PRE-CONCEPTUAL DESIGN AND DOCUMENT RESULTS (9/30/77

* THIS ACTIVITY INCLUDED THE FY 1976 CP & D EFFORT.

Fig. 4. TNS job plan — feasibility study and

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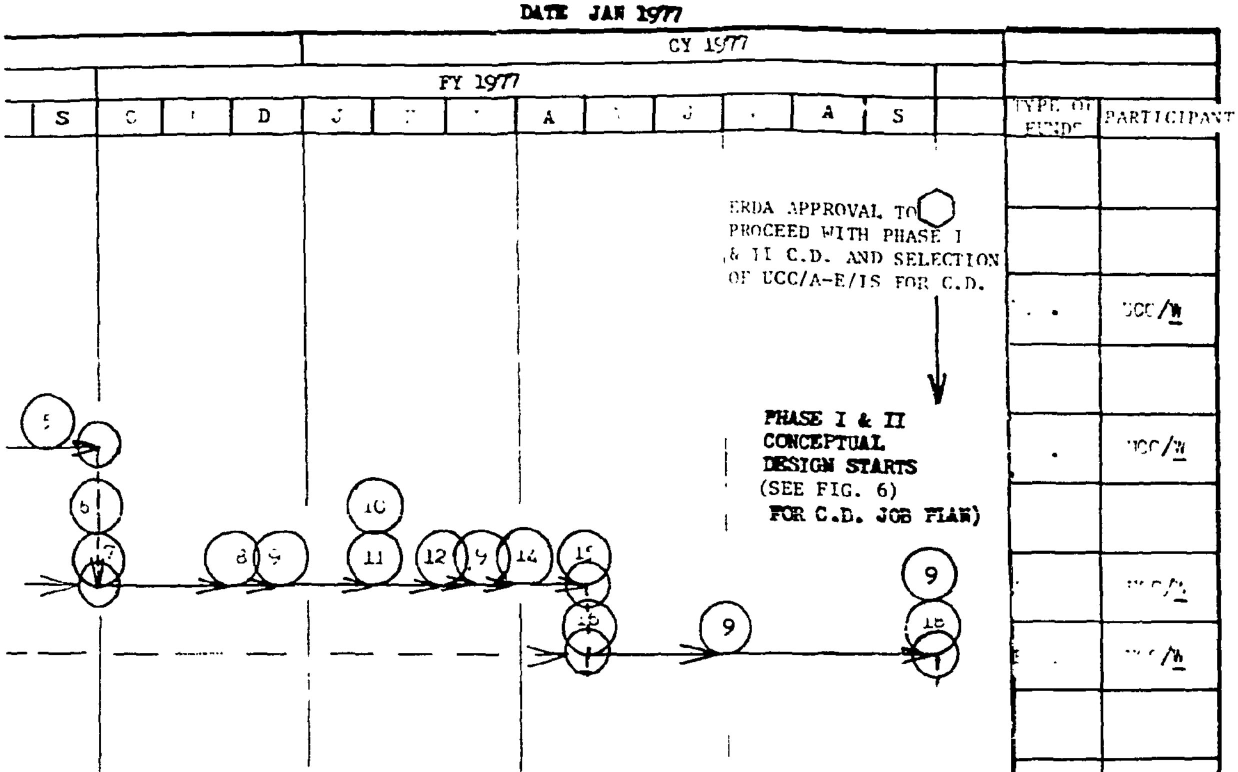
PRELIMINARY
DATE JAN 1977



76)

CONFIG. TNS OPTIONS (12/1/76)
/77)

3/77)

TERIA FOR SELECTED REP DESIGN (4/30/77)
E-CONCEPTUAL DESIGN (5/1/77)
RESULTS (9/30/77)

study and preconceptual design periods.

4. CONCEPTUAL DESIGN PERIOD

4.1 Work Scope

The requirement for TNS project phasing (FY 1980—FY 1982) as indicated in Sect. 2.3 and the procedural requirement that the CDR be available by May in budget year minus two years imply that the Phase I (FY 1980 line item portion) CDR be issued on May 15, 1978, and that the Phase II (FY 1982 line item portion) CDR be issued on May 15, 1980.

The conceptual design efforts will result in the Final CDR (FCDR), which will follow the outline as presented in Table 4 and will meet all DOE procedural requirements.

In addition to the CDRs, Schedule 44 Construction Data Sheets and Cost Estimates will be issued.

The Phase I WBS elements to be covered in the conceptual design include those elements that must be started in FY 1980 for schedule reasons or because they present minimum economic risk. The Phase II conceptual design items are those elements that present a substantial economic risk if their design, procurement, and construction is not based on the final reference design. Both Phase I and Phase II conceptual design efforts will be based on the April 1977 reference design. This commonality in the systems and subsystems technical base should minimize any engineering problems inherent in "phasing" the conceptual design effort. The FCDRs resulting from the two efforts will consider only those elements under consideration. In the area of environmental and safety requirements, the total project will have to be considered; therefore, special handling of these activities is required. During the Phase I initial conceptual design period, a total project environmental assessment will be prepared based on the results of Phase I preconceptual design and preliminary Phase II information derived from the conceptual design as of that date.

Per DOE's recommendations, an interim environmental impact statement will be prepared at the completion of Phase I conceptual engineering. This interim document will form the basis for DOE's procedural environmental activities in preparation for this project, Phase I, FY 1980,

Table 4. Conceptual design report outline

Section No. and activity
1 Purpose of report
2 Brief physical description of project
3 Project purpose and justification
3.1 Project purpose
3.2 Justification of need and scope
3.3 Anticipated operating costs
4 Principal safety, fire, and health hazards
5 Environmental impact
5.1 Environmental considerations
5.2 Energy conservation goals
6 Quality assurance
7 Project schedule
8 Proposed method of accomplishment
9 Summary cost estimate
10 Outline specifications
10.1 General codes, standards, specifications, system design descriptions, and overall plant design description
10.2 Land improvements
10.3 Buildings
10.3.1 Demolition
10.3.2 Fire protection
10.3.3 Structural and architectural
10.3.4 Piping
10.3.5 Heating, ventilation, and air conditioning
10.3.6 Mechanical
10.3.7 Electrical
10.3.8 Instrumentation
10.3.9 Computer applications
10.4 Other structures
10.5 Special facilities
10.6 Outside facilities
10.7 Standard equipment
11 Reference data
12 Appendix

"Approval to proceed" determination. The interim environmental Phase I impact statement will serve as the Phase II environmental assessment document. A final total project environmental impact statement will be published at the completion of Phase II conceptual design and should form the basis for determination to proceed with the total project before construction or procurement has begun.

This final impact statement and the conceptual design safety analysis report will form the basis for publication of the preliminary safety analysis report (PSAR) as indicated on the project logic network (see Fig. 7, Sect. 5). As a result of continued safety analysis as the project progresses from design through construction, a final safety analysis report (FSAR) will be issued before the initiation of preoperational testing.

4.2 Estimated Costs for Conceptual Design Activities ($ thousands)[a]

Fiscal Year	Costs
1978	$ 7,150
1979	9,433
1980	4,000
Total CD effort	$20,583

[a]Includes CP&D funds; see Appendix B for TNS CP&D funding detail.

Figure 5 presents the TNS conceptual design funding plan, with the effort broken down into expense and CP&D cost by major participants. It clearly indicates those participants that are split funded.

4.3 Work Plan

Figure 6 is a bar-chart work plan showing the schedule of anticipated events, and Table 5 presents the associated key milestones for the conceptual design activities. The work plan defines task funding type (expense or CP&D) and task participant. Task descriptions will be presented in the conceptual design job plan to be published within

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DESCRIPTION	FY 1978		FY 1979		FY 1980*	
	EXP.	CP & D	EXP.	CP & D	EXP.	CP & D
A. MAJOR PROCUREMENT AND FABRICATION						
1. INDUSTRIAL CONTRACTORS	1870	400	2375	1250	1000	800
2. CONSULTANTS	24		25			
3. LABORATORY/INDUSTRIAL TEAM	1545		1680			
4. LABORATORY/UNIVERSITY TEAM	100		200			
5. AE FOR PHASE I CD AND SUPPORT EFFORT	1000	400	1500		1000	
B. UCC						
1. DIRECT AND INDIRECT SALARIES	1386	200	1803	250	500	200
C. TECHNICAL SERVICES						
D. COMPUTER AND PROGRAMMING	125		150		100	
E. CAPITAL EQUIPMENT OBLIGATIONS	100		200		400	
TOTALS	6150	1000	7933	1500	3000	1000

*DOES NOT INCLUDE LINE ITEM FUNDS, OR OPERATIONS FUNDS 3-11-77

Fig. 5. TNS funding plan — conceptual design ($ × 1000).

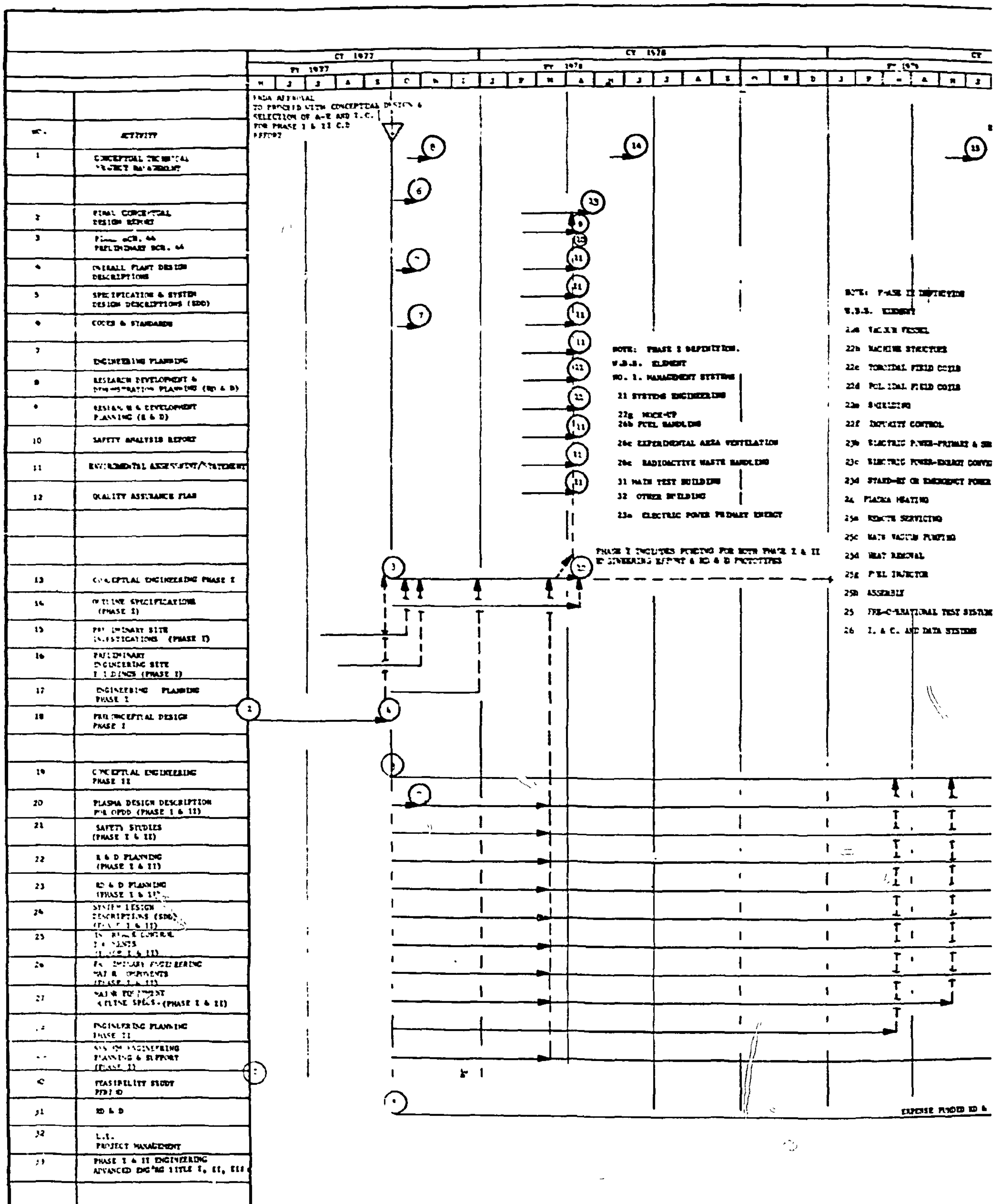
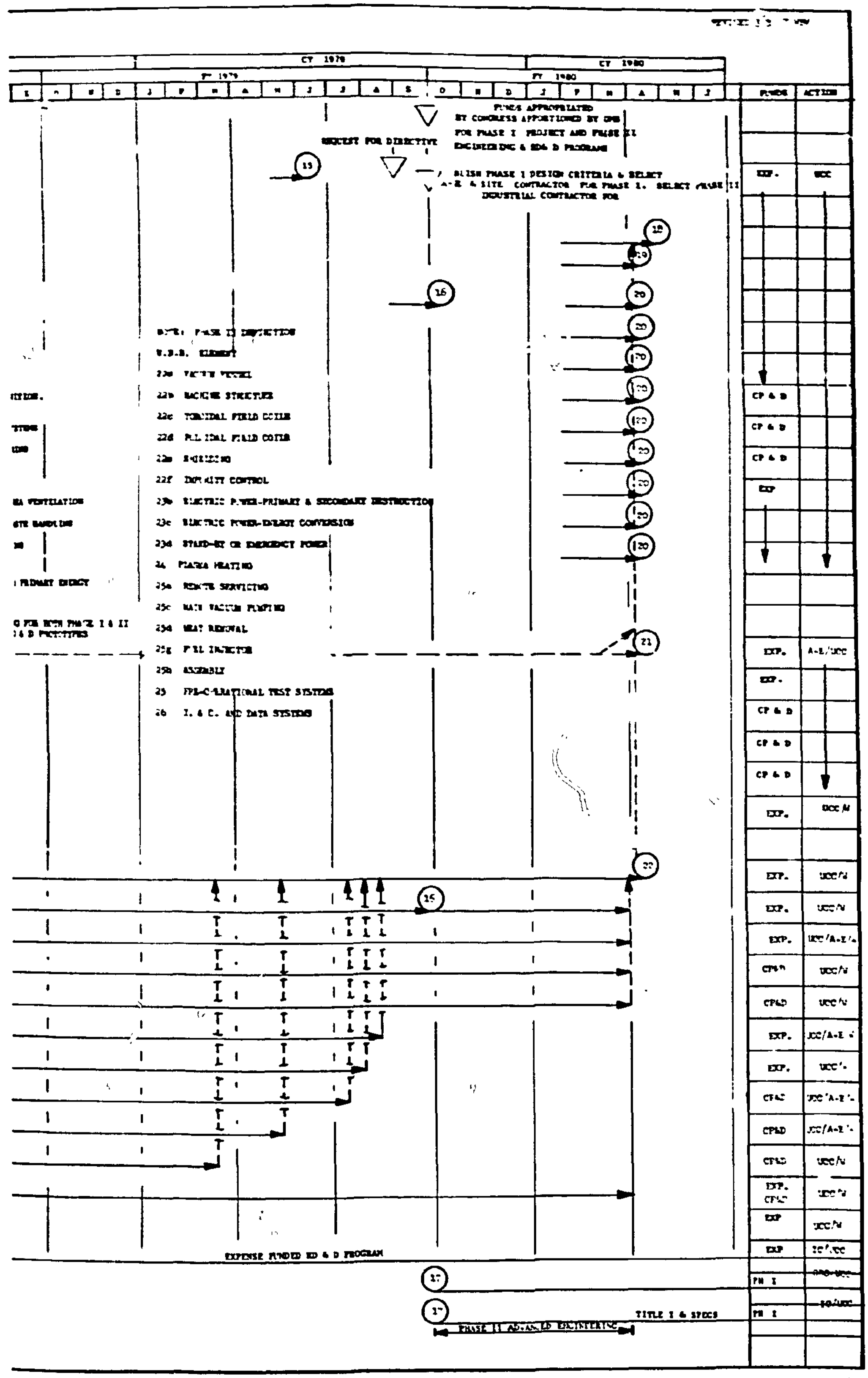


Fig. 6. TNS job plan — conceptual design.



lan — conceptual design.

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Table 5. TNS Program milestones — conceptual design

No.	Milestone	Date
1.	Operating contractor and industrial subcontractor start preconceptual design	5-1-77
2.	UCC and IS complete Phase II feasibility studies	4-30-77
3.	UCC/AE/IS start Phase I and II CD	10-1-77
4.	Preconceptual design complete	9-30-77
5.	Research development and demonstration program begins	10-1-77
6.	Issue conceptual design job plan	10-31-77
7.	Publish TNS OPDD approximate requirements and criteria, codes, and standards	10-31-77
8.	Midyear capital budget sent to ORO	11-15-77
9.	Issue final Schedule 44 and Cost Estimate for Phase I	4-15-78
10.	Issue Preliminary Schedule 44 and Cost Estimate for Phase II	4-15-78
11.	Complete Phase I activity and documents for integration into Phase I final CDR; publish safety analysis report and environmental impact assessment (both Phase I and Phase II)	4-15-78
12.	AE and IS complete Phase I conceptual design, AE starts Phase II support effort	4-15-78
13.	Issue final CDR for Phase I	4-15-78
14.	ORO sends annual budget to headquarters (BY-2 for Phase I line item)	6-15-78
15.	Issue project management plan (and reporting plan)	6-15-79
16.	Update TNS OPDD in support of Phase I design criteria publication	9-30-79
17.	Phase I engineering and advanced engineering for Phase II; line item and program management begin	10-1-79
18.	Publish Phase II CDR (BY-2 for a FY 1982 line item project)	4-15-80
19.	Publish final Schedule 44 and Cost Estimate Phase II	4-15-80
20.	Complete Phase II activity and documents for integration into Phase II CDR; publish safety analysis report and environmental impact statement	4-15-80
21.	AE completes Phase II support effort and documents changes to Phase I CDR	4-15-80
22.	IS completes Phase II conceptual engineering	4-15-80

20 days after start of the conceptual engineering. A participant/activity methodology that represents preliminary thinking follows.

4.3.1 Participant/activity — DOE

1. Review and approve overall plant design descriptions (OPDDs);
2. decide on need for environmental impact statement;
3. provide conceptual design review before completion of CD effort;
4. start selection of permanent industrial subcontractor (IS)/site contractor and review of OPDDs for start of line item project; and
5. with UCC, review, direct, and monitor performance of all engineering supporting organizations associated with CD.

4.3.2 Participant/activity — UCC

1. Publish FCDR (Activity No. 2, Fig. 6);
2. issue final Schedule 44 and cost estimate (Activity No. 3);
3. issue final approved OPDDs (Activity No. 4);
4. issue outline specification, system design descriptions (SDDs), equipment specifications, etc. (Activity No. 5);
5. issue final approved codes and standards (Activity No. 6);
6. issue engineering planning document (Activity No. 7);
7. issue R&D/RD&D supporting programs report (Activities No. 8 and No. 9);
8. issue conceptual SAR (Activity No. 10);
9. issue environmental impact statement (Activity No. 11); and
10. issue quality assurance plan (Activity No. 12).

In addition to the above, UCC will update overall project budgets and schedules, while conceptual design produces more definitive system and component information for Schedule 44 preparation. A management plan will be prepared, which will detail the project division of responsibility for engineering, procurement, and construction and will indicate the procedures to be used for control of design configuration (see WBS No. 13d, configuration control). The management plan will form the basis for the eventual program management plan to be issued May 1980. Also, UCC will monitor and review the performance of work by selected vendors and engineering contractors.

At the completion of formal Phase I CD, the AE will form a Phase II support team that will continue CD activity during the Phase II CD effort by the IS. This team-supporting effort will provide continuing Phase I CD refinement as the Phase II CD is developed.

4.3.3 Participant/activity — AE (Phase 1, building (WBS No. 30) and experimental area ventilation (WBS No. 26c)

1. Complete outline specifications;
2. complete optimization studies for firming up selection and sizing of equipment and facilities;
3. prepare SDDs on major systems with data sheets to permit CD cost estimating;
4. refine and update the equipment arrangement and pipe routing;
5. prepare equipment layouts and piping isometrics for utilities;
6. develop control schemes and concept design of the control equipment and system for the facilities;
7. prepare conceptual schematics and instrument lists;
8. perform casualty study to assess probability and magnitude of potential transients for the SAR;
9. refine the overall plant arrangement and building sizes;
10. perform perliminary structural design of buildings to verify weight-handling capabilities;
11. prepare conceptual plot plan and plans for elevations and sections for the buildings;
12. complete CD of experimental area ventilation and buildings;

13. identify overall utility requirements (water, gas, oil, and electrical power) and complete CD and equipment selection of utility switchgear;
14. develop CD of tritium spill and fire protection systems;
15. prepare drafts of SDDs for the facilities and engineering area ventilation systems;
16. prepare a detailed engineering manpower estimate and schedule for Title I, II, and III engineering for the facilities and engineering area ventilation systems; and
17. prepare cost estimate and schedule for the design and construction of the TNS facilities and engineering area ventilation systems.

The construction schedules should identify which critical components or materials are long-lead items requiring initiation of procurement in advance of start of field construction.

<u>End items — AE-CD</u> (Phase I)

1. Control and process description of facility, experimental area ventilation systems, and utilities (Activity No. 13);
2. conceptual plant layout and building plans, elevation, and sections (Activities No. 12, 15, and 16);
3. equipment arrangement and pipe routing drawing for facility and experimental area ventilation systems, with preliminary information on Phase II systems (Activity No. 13);
4. draft SDDs/outline specifications of facility systems and experimental area ventilation (Activity No. 14);
5. conceptual cost estimate and schedule for design and construction of facilities, systems, and experimental area ventilation (Activity No. 13);
6. final conceptual engineering report for integration into the FCDR (Activity No. 13); and
7. engineering planning document (Activity No. 17).

the procedures to be used for control of design configuration (see WBS No. 13d, configuration control). The management plan will form the basis for the eventual program management plan to be issued May 1980. Also, UCC will monitor and review the performance of work by selected vendors and engineering contractors.

At the completion of formal Phase I CD, the AE will form a Phase II support team that will continue CD activity during the Phase II CD effort by the IS. This team-supporting effort will provide continuing Phase I CD refinement as the Phase II CD is developed.

4.3.3 Participant/activity — AE (Phase I, building (WBS No. 30) and experimental area ventilation (WBS No. 26c)

1. Complete outline specifications;
2. complete optimization studies for firming up selection and sizing of equipment and facilities;
3. prepare SDDs on major systems with data sheets to permit CD cost estimating;
4. refine and update the equipment arrangement and pipe routing;
5. prepare equipment layouts and piping isometrics for utilities;
6. develop control schemes and concept design of the control equipment and system for the facilities;
7. prepare conceptual schematics and instrument lists;
8. perform casualty study to assess probability and magnitude of potential transients for the SAR;
9. refine the overall plant arrangement and building sizes;
10. perform perliminary structural design of buildings to verify weight-handling capabilities;
11. prepare conceptual plot plan and plans for elevations and sections for the buildings;
12. complete CD of experimental area ventilation and buildings;

13. identify overall utility requirements (water, gas, oil, and electrical power) and complete CD and equipment selection of utility switchgear;
14. develop CD of tritium spill and fire protection systems;
15. prepare drafts of SDDs for the facilities and engineering area ventilation systems;
16. prepare a detailed engineering manpower estimate and schedule for Title I, II, and III engineering for the facilities and engineering area ventilation systems; and
17. prepare cost estimate and schedule for the design and construction of the TNS facilities and engineering area ventilation systems.

The construction schedules should identify which critical components or materials are long-lead items requiring initiation of procurement in advance of start of field construction.

End items — AE-CD (Phase I)

1. Control and process description of facility, experimental area ventilation systems, and utilities (Activity No. 13);
2. conceptual plant layout and building plans, elevation, and sections (Activities No. 12, 15, and 16);
3. equipment arrangement and pipe routing drawing for facility and experimental area ventilation systems, with preliminary information on Phase II systems (Activity No. 13);
4. draft SDDs/outline specifications of facility systems and experimental area ventilation (Activity No. 14);
5. conceptual cost estimate and schedule for design and construction of facilities, systems, and experimental area ventilation (Activity No. 13);
6. final conceptual engineering report for integration into the FCDR (Activity No. 13); and
7. engineering planning document (Activity No. 17).

4.3.4 Participant/activity — industrial subcontractors (IS)

The IS will:

1. perform conceptual engineering during the Phase I CD on the systems engineering (WBS No. 21), mock-up systems (WBS No. 22g), fuel handling (WBS No. 26b), radiation waste handling (WBS No. 26a), and electric power — primary energy (WBS No. 23a);
2. accomplish conceptual engineering on the remaining Phase II systems;
3. as system and component data are developed from the Phase II CD effort, the equipment layout and piping routing for the Phase II systems and subsystems will be updated and refined to provide interface data to the AE support activity;
4. equipment support and pipe hanger concepts will be evaluated and developed;
5. steady-state and transient overall plant-control requirements for the total plant system will be refined through studies with a computer model;
6. a preliminary causability study will be performed for the entire plant to verify adequacy of the plant protection system and to provide input to the SAR;
7. instrumentation for the systems and subsystems will be identified, and conceptual schematics and instrumentation lists will be prepared;
8. component engineering of major components and related auxiliaries will be completed;
9. mock-up detail and layouts with equipment tests will be completed;
10. critical components will be evaluated to assure compliance with design requirements;
11. drafts of SDDs for the systems and subsystems and related auxiliaries and for the overall plant control and protection systems will be prepared;

12. interface control documents (ICDs) will be prepared to show physical and functional interfaces between the hardware and the facility; and

13. a detailed engineering manpower estimate and schedule for Title I, II, and III engineering for the systems and subsystems will be prepared.

<u>End items — IS-CD</u>

1. Engineering planning document for systems and subsystems (Activity No. 28),

2. preliminary casualty study (for SAR) (Activity No. 21),

3. ICDs (Activity No. 25),

4. SDD drafts of systems and subsystems (Activity No. 24),

5. conceptual electrical and piping routing and distribution drawings (Activity No. 19),

6. major equipment outline specifications (Activity No. 27),

7. final CD engineering report for integration into the FCDR (Activities No. 13 and 19), and

8. cost estimate and schedule for systems and subsystems design and construction (Activities No. 13 and 19).

4.3.5 <u>Participant/activity — AE (supporting Phase II activity)</u>

1. While Phase II systems and subsystems are formed and communicated to the AE supporting team via the interface control documents (ICD) review-board system, modifications and changes to the facility will be made as directed by a UCC/DOE change-review board.

2. If the review board determines that changes have caused major cost or schedule modifications, UCC will revise the Phase I CDR/cost estimate/Schedule 44.

3. If only minor changes result or if facility optimization is required to lower costs, this activity would be accomplished during Phase I, Title I design.

The Phase I facility design review scheduled for January 1, 1980, is intended to amplify and clarify any modifications or changes to the Phase I CD design that occurred during Phase II CD.

5. LINE ITEM DESIGN, CONSTRUCTION, AND PREOPERATIONAL PERIOD

5.1 Project Schedule

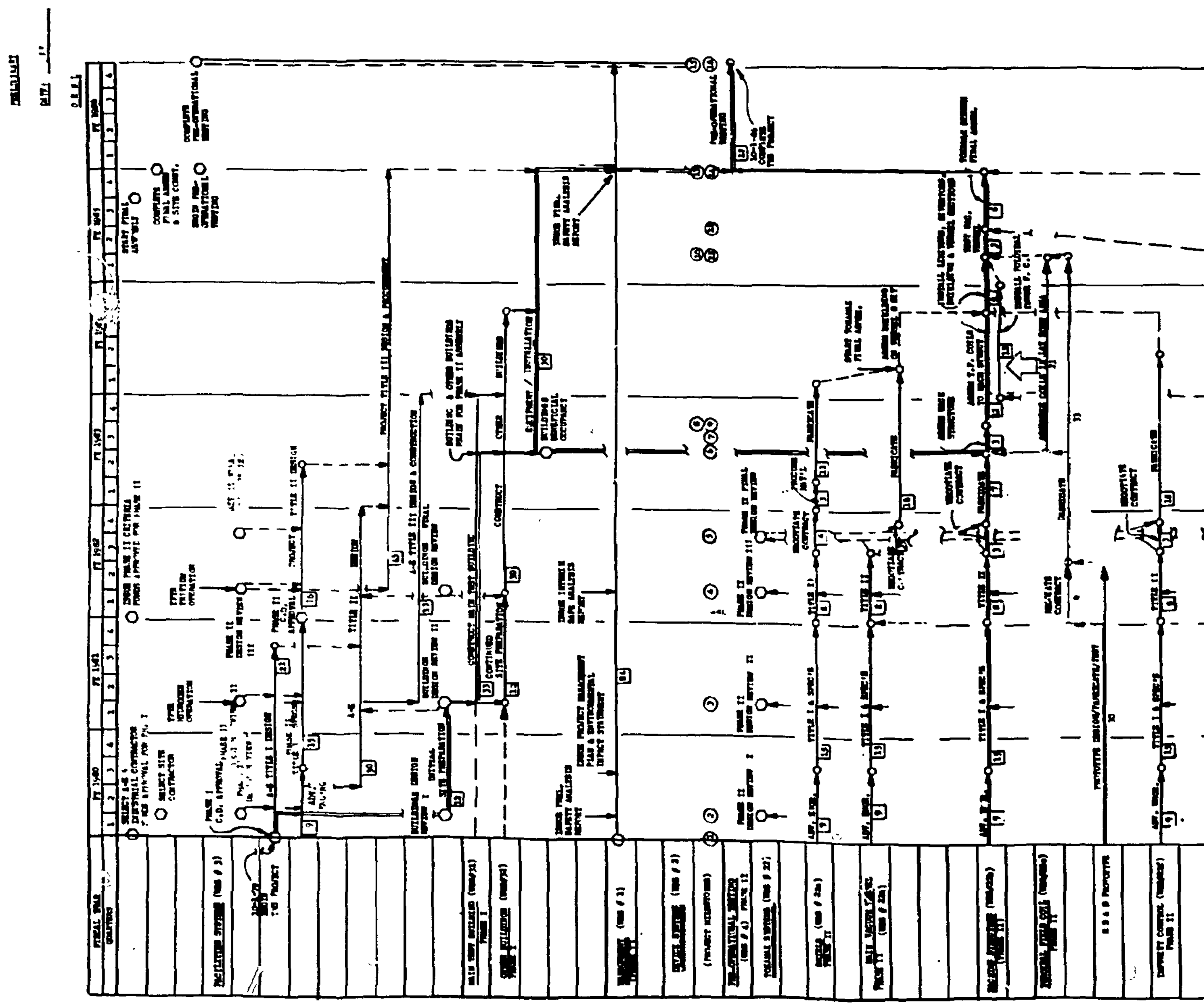
Figure 7, a comprehensive logic network* that is the TNS Project master schedule, presents TNS as a phased FY-1980 facilities-portion and a FY-1982 device-portion project. The overall project schedule with some key milestones is as follows:

May 1978	Phase I conceptual design complete
October 1980	Phase I funds approved
May 1980	Phase II conceptual design complete
December 1980	Start site construction; issue PSAR
May 1980	Phase II funds approved
October 1985	Construction complete; issue FSAR
October 1986	Complete preoperational testing

The TNS project milestone schedule (Table 6) is defined at level 3 within the context of the work breakdown structure and flags those key milestones on the schedule critical paths, inasmuch as these are the events that, if allowed to slip, will cause the objective end event (preoperational testing complete) to slip an equivalent time period.

The TNS project logic network defines all major activities for each of the work breakdown structure tasks. The network identifies time periods for management; systems engineering; advanced engineering; Titles I, II, and III design; procurement; fabrication; assembly; construction; installation; test and checkout; and preoperational test. As a logic network, it shows the interrelationships and interdependencies of activities for *all* project tasks of the work breakdown structure. This includes research development and demonstration task activities as they relate to specific tasks. In addition, the network focuses the total

*This and other related schedules were derived via PERT Programs PMS-4, 360 IBM computer, E-Z PERT graphics. These PERT tools are used for detailed program analysis and organization.



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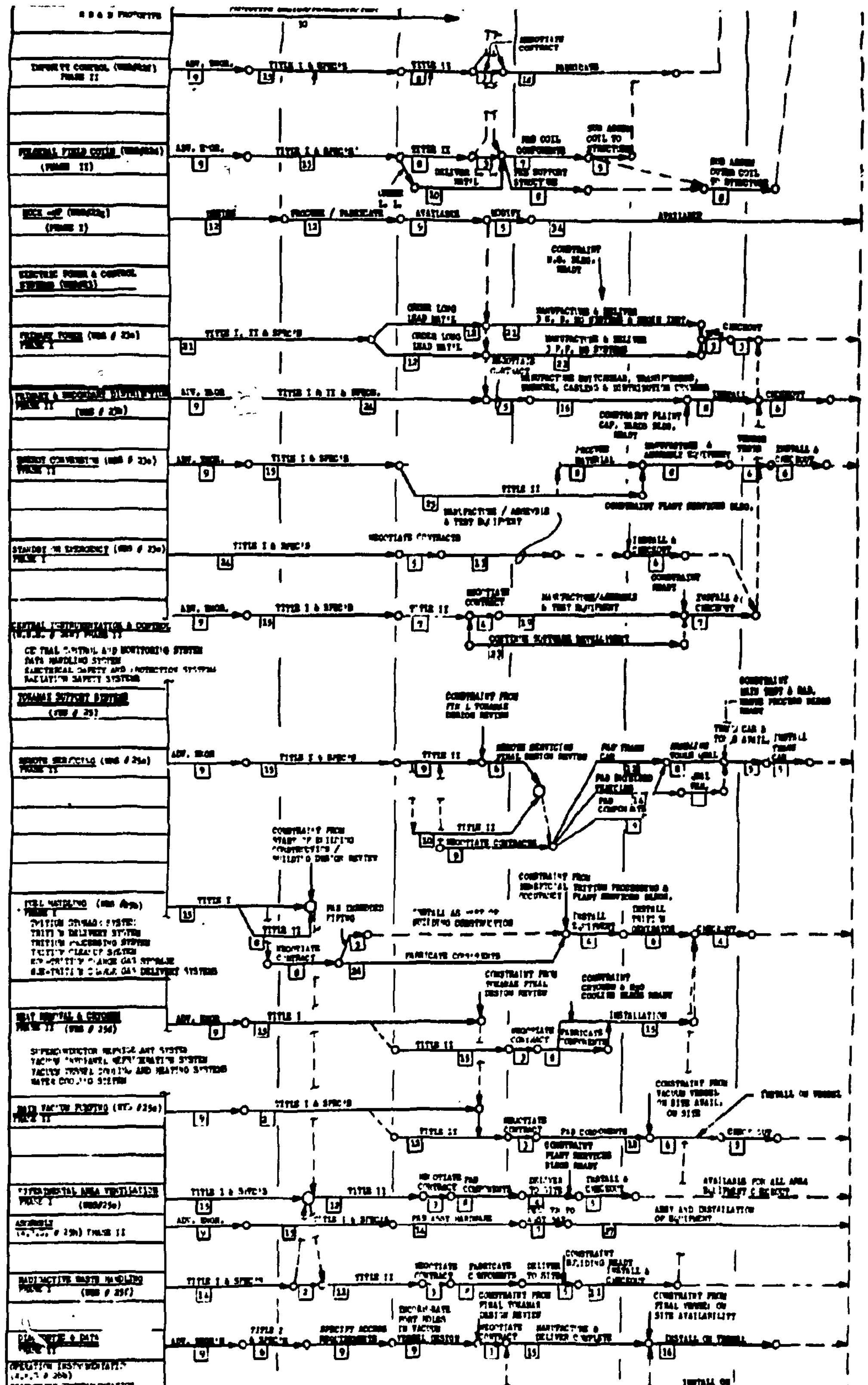
TITLE I & SPEC'S
TITLE II
NEGOTIATE CONTRACT
CHECKOUT
INSTALL ON VESSEL

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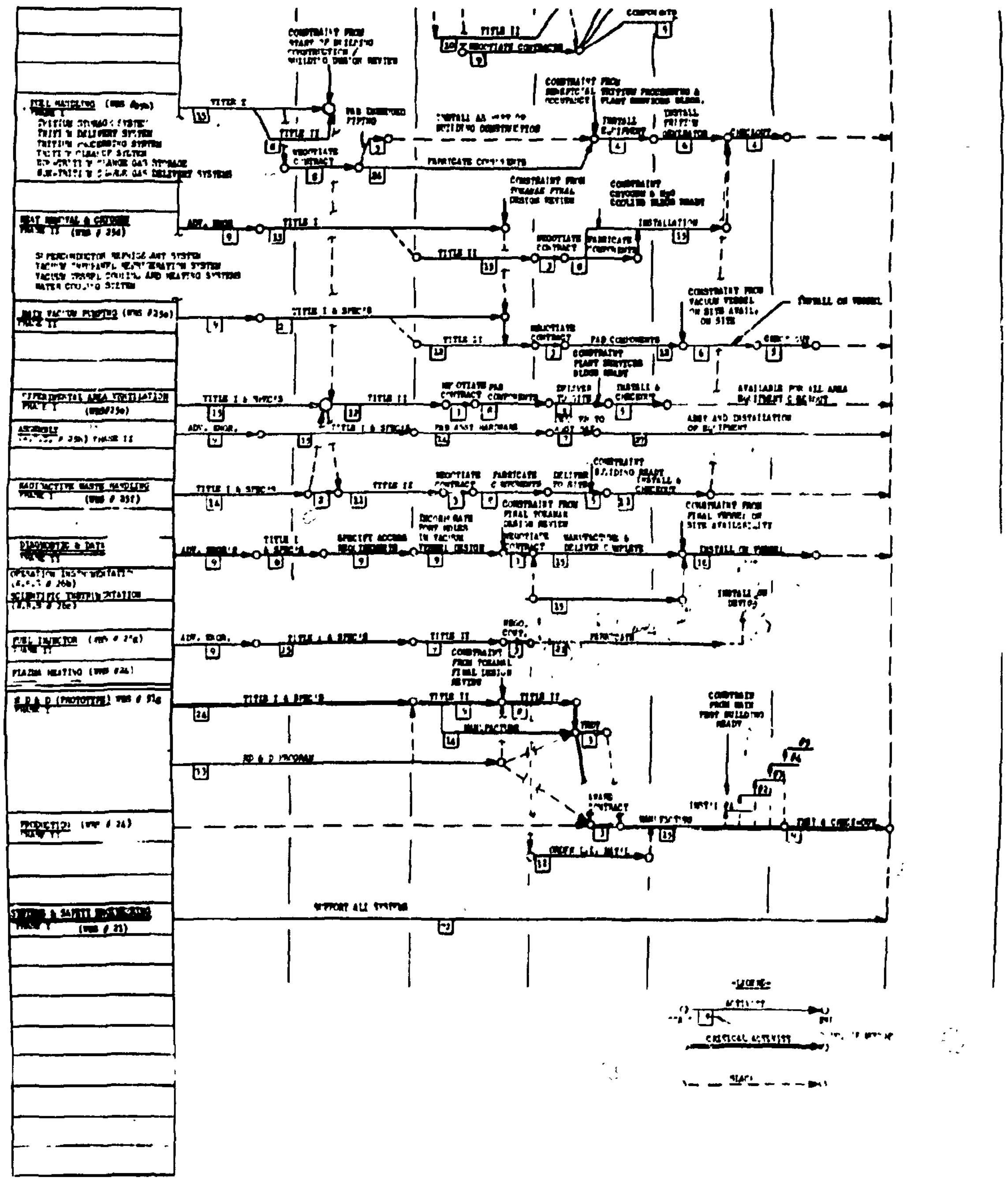

Fig. 7. TNS Project — master schedule.

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5. LINE ITEM DESIGN, CONSTRUCTION, AND PREOPERATIONAL PERIOD

5.1 Project Schedule

Figure 7, a comprehensive logic network* that is the TNS Project master schedule, presents TNS as a phased FY-1980 facilities-portion and a FY-1982 device-portion project. The overall project schedule with some key milestones is as follows:

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*This and other related schedules were derived via PERT Programs PMS-4, 360 IBM computer, E-Z PERT graphics. These PERT tools are used for detailed program analysis and organization.

Table 6. TNS Project — milestone schedule (WBS level 3)

Milestone No.	Description	Date
1	Phase I CD approval and funds approval	10-1-79
2	Begin site preparation	1-1-80
3	Begin main-test building construction	1-1-81
4	Complete building systems final design review	1-1-82
5	Complete device final design review	9-30-82
6	Main test building beneficial occupancy; ready for device assembly	4-1-83
7	Complete test of neutral-beam prototype	5-15-83
8	Macine structure installed	7-1-83
9	Award production neutral-beam contract	7-11-83
10	TF coils assembled to machine structure	1-1-85
11	Limiters, diverters, shield, inner poloidal coils, and vacuum vessel sections assembled and installed	1-1-85
12	Complete vacuum vessel testing	4-1-85
13	Complete device final assembly	9-30-85
14	Complete manufacture/installation/test and check-out of neutral beams No. 1, 2, 3, 4, and 5	9-30-85
15	Preoperational testing complete	9-30-86
16	TNS project operations start	10-1-86

fusion community R&D effort for TNS by identifying each task R&D input as currently planned and by showing the relationship of this input to the related dependent task activity. TNS will be designed primarily on the basis of existing technology. R&D effort is, however, necessary to support those areas indicated to make TNS credible to the physics community and, of most importance, to minimize the economic risk to the nation.

Analysis of the network problem reveals two opposing, critical paths. The forward critical path is the timing of the R&D input, which acts to *delay* the project until the device design can be based on solid physics information. The backward critical path is the path starting with an "available operating facility" by the mid-1980s, working back through building beneficial occupancy. The timing of this backward path acts to accelerate the building/construction phase because of the time-consuming device assembly/installation activity that must take place in the building lay-down areas and bays (unlike equipment that can be fabricated, delivered, and installed in a finished building). Because of these two opposing requirements, the decision was made to start the main test building task and those tasks that carry a minimum economic risk as soon as possible and to call them the Phase I facility portion of the project with a FY-1980 funding date. The Phase II device portion of the project includes those principal to high technological and economic risk tasks that must wait for additional R&D input (final reference design) before firming up task design. The task/phase definitions in the context of the work breakdown structure are given in Fig. 2.

To minimize economic risk, a series of facilities and device design reviews are tied into both the available generic and specific R&D input; these reviews, in turn, constrain critical design, fabrication, and construction. The device and facilities final design reviews occur at about 50% completion of the main test building, but at 0% completion of the other buildings (that are reference-design dependent). This means that innovative and flexible design will be required for the main test building with probably increased costs in terms of square footage and interface consideration to allow for some degree of device-envelope change. By the above technique, this device/building construction overlap is not expected to lead to excessive delays, changes, or significant cost increases. The alternative is to delay the total project 18 months by delaying the start of building construction to the final device design review time period. This would delay the object-end event an equivalent 18 months, inasmuch as beneficial building occupancy is on a critical path. The result would be "TNS project starts operations" April 1, 1988, rather than October 1, 1986, with a potentially equal delay in the succeeding demonstration plant startup date.

Further analysis of the network indicates that, in addition to the basic plasma physics uncertainties that form the critical path of understanding, the neutral beam task also defines a critical path with no activity slack. With neutral beam experience on such projects as PLT, ORMAK Upgrade, TFTR, etc., it is thought that this zero slack situation will not cause cost or schedule problems. The toroidal field coils and vacuum vessel tasks are also critical-path items. The LCS and LCP R&D programs are expected to minimize these problems.

The logic network as defined represents a very aggressive and optimistic project. The presence of several major critical paths indicates above-average possibilities for schedule slippage and cost overruns. The noncritical path tasks, in addition, have abnormally short slack periods. These problems will be analyzed in detail in the conceptual design effort to ascertain how much risk is involved.

5.2 Project Costs

The TNS project cost estimate, to be based on the May 1977 reference design and its refinements, will be derived as part of the conceptual design activity.

5.3 Work Breakdown Structure

The TNS Project has been broken down into tasks that represent the project hardware, software, and services that will be accomplished to satisfy the contract statement of work. Figure 2 defines the work breakdown structure with elements at the 1st, 2nd, 3rd, and 4th levels. Levels 1, 2, and 3 define the project system, and level 4 and below define project subsystems.

By using the work breakdown structure and the principles and criteria of the project performance measurement system (PPMS), effective project planning and control will be possible.

5.4 Overview of Task Responsibility and Scope

Figure 8 identifies the organizations responsible for accomplishing the following aspects of work for each of the WBS elements: management, R&D management, RD&D, engineering and design, procurement, fabrication, assembly, construction, installation, checkout, and preoperational testing.

5.5 Enginering and Design Task Responsibility and Scope

Engineering activities for the Phase II systems and associated systems will be performed by UCC and the industrial subcontractor to be selected at the start of the FY-1980 Phase I portion of the project. (It is assumed that this can be the same industrial subcontractor selected to accomplish the device conceptual design.)

1. Conceptual design will be conducted from October 1, 1977, through April 30, 1980. These efforts will establish project objectives, scope and feasibility, basic conceptual design configuration by means of trade-off studies of major subsystems, and preliminary cost and schedule estimates. During these periods, the final environmental impact statement will also be produced.

   The major participants in the Phase I conceptual design will be UCC, IS, and an AE selected by ORO at the time of facility conceptual design start.

   The major participants in the Phase II conceptual design will be UCC and the IS.

JAN. 1977

WORK BREAKDOWN STRUCTURE	ELEMENT	WBS 1 MANAGEMENT	WBS 5 RESEARCH DEVEL. & DEMONSTR.	ENGINEERING ADVANCED ENGRG. TITLE I, II, III	PROCUREMENT FABRICATION	ASSY CONSTRUCTION INSTALLATION CHECKOUT	WBS 6 PRE-OPERATIONAL TESTING (4)	P & L MANAGEMENT WBS 111
21	SYSTEMS ENGINEERING	(ONE MEMBER CONTRACT HS) UCC	— — — —	— — — —	— — — —	— — — —	— — — — —	UCC/ERDA
22A	TOROIDAL VACUUM VESSEL		UCC/IC	IC	IC	IC	IC	
22B	[illegible] STRUCTURE		— — — —					
22C	[illegible]		[illegible]					
22D	[illegible]		[illegible]					
22E	SHIELDING		— — — —					
22F 22G	IMPURITY CONTROL SYSTEM		[illegible]					
23A	PRIMARY ENERGY		— — — —					
23B	PRIMARY [illegible] DISTRIBUTION		— — — —					
23C	ENERGY CONVERSION		— — — —					
23D	STANDBY OR EMERGENCY POWER		— — — —					
24A	N.B. HEATING		UCC/IC	UCC	UCC	UCC	UCC	
24B	R.F. HEATING		— — — —	UCC				
25a	REMOTE [illegible]ING		UCC/IC	IC	IC	IC	IC	
25b	FUEL HANDLING	[illegible]	— — — —	A-E				
25c	MAIN VACUUM PUMPING		UCC/IC	IC				
25d	HEAT REMOVAL		— — — —	IC				
25e	[illegible] AREA VENTILATION	[illegible]	— — — —	A-E (1)	CC	CC	CC	
25f	RADIOACTIVE WASTE HANDLING	ORO	— — — —	A-E (1)	IC	IC	IC	
25g 25h 26a	FUEL INJECTOR ASSEMBLY CENTRAL I & C	UCC	UCC, IC	UCC	UCC	UCC	UCC	
26b 26c	OPERATION INSTRUMENT SCIENTIFIC INSTRUMENT		UCC/IC	UCC	UCC	UCC	UCC	
3A	MAIN TEST BUILDING	ORO	— — — — —	A-E (1)	CC	CC	CC	
3B	OTHER BUILDINGS	ORO	— — — —	A-E (1)	CC	CC	CC	

NOTE:

(1) UCC WILL PROVIDE THE A-E (THROUGH ORO) WITH DESIGN REQUIREMENTS INFORMATION FOR THE INTERFACE BOUNDARY BETWEEN THE DEVICE & FACILITIES.

(2) UCC WILL SUBCONTRACT MANAGEMENT, ENGINEERING, PROCUREMENT, ASSEMBLY, CONSTRUCTION, FABRICATION, INSTALLATION, CHECKOUT, & TESTING FOR THEIR PORTION OF THE PROJECT AS REQUIRED.

(3) IC— INDUSTRIAL CONTRACTOR (COULD BE MORE THAN ONE)

CC— CONSTRUCTION CONTRACTOR (COULD BE MORE THAN ONE)

A-E—ARCHITECT-ENGINEER (COULD BE MORE THAN ONE)

(4) UCC WILL HAVE OVERALL PRE-OPERATIONAL TESTING RESPONSIBILITY & WILL COORDINATE PARTICIPANTS' ACTIVITIES DURING THIS TIME.

Fig. 8. TNS Project — responsibility matrix.

2. Phase II advanced engineering will start October 1, 1977, and continue to the completion of the device conceptual design effort, April 30, 1980 (7 months). This effort is expected to start preliminary Title I drawings and specifications.

3. Preliminary design Title I, starting October 1, 1979, for the facility and May 1, 1980, for the Phase II systems, is expected to produce preliminary drawings and specifications; engineering studies (soil investigations, seismic studies, etc.); preliminary cost estimates; equipment lists; procurement plans, preliminary proposal/Title I report, design, construction, and procurement schedules; and the PSAR.

   The periods for performing the preliminary design effort range from 15 to 33 months for the various subsystems of the WBS.

4. Final design is expected to produce working and fabrication drawings and specifications; final construction cost estimates; and materials, equipment, and supplies for the device and associated systems. This design will be the responsibility of UCC, which will use the procurement services of industrial contractors/subcontractors it deems to be in the best interest of the project. Procurement of materials, equipment, and supplies for facility construction (WBS No. 3) will be the responsbility of the construction contractor(s) (with the possible exception of long-lead equipment and supplies). Fixed-price contracts will be used whenever possible.

5. Inspection and acceptance — A comprehensive set of acceptance test requirements and test plans will be prepared by AE, UCC, and industrial contractor/subcontractor for the conventional facilities and special equipment, consistent with a master acceptance test plan to be developed by UCC during preliminary design.

Acceptance testing will be performed on each critical component, subsystem, and system of the TNS device and facilities. Acceptance test plans and procedures will be developed during the design phase. Acceptance test requirements for purchased components will be defined in the procurement packages. Acceptance testing in vendor shops will be performed by the vendor and witnessed by qualified personnel of the procuring organization and/or by third-party inspectors. On-site acceptance testing of systems and subsystems will be performed by the organization responsible for installation and witnessed by designated UCC and industrial contractor/subcontractor personnel.

AE will perform Title III inspections of the conventional facilities. Acceptance testing of the systems and components in the conventional facilities will be performed by the construction contractor(s) and witnessed by ORO, UCC, and AE. Final acceptance of the facility will be made by ORO after final inspection of construction.

Figure 8 further illustrates the responsibilities for the activities described above.

5.6 Task Descriptions

Definitions are required for the tasks to be accomplished by the TNS Project Team on completion of the advanced engineering, preliminary design, final design, procurement, fabrication, construction, installation, and checkout of the TNS. Also to be included are the supporting program tasks for research and development, research development and demonstration, and preoperational testing.

The work breakdown structure (WBS) is used as a basis for dividing the project into related work packages for project planning and control. A system will be used similar to that developed by PPPL for the TFTR Project. The WBS establishes a numbering system for cost control and for scheduling and reporting purposes.

The WBS consists of four levels of detail. For TNS, the project is first divided into six systems (2nd level), which are then broken into 19 major systems (3rd level). The project will be planned and controlled at this level. Detailed tasks will be described at the 4th level of the WBS. The WBS is shown graphically in Fig. 2 and is listed in Appendix C. Task descriptions have been prepared for the management systems, using a portion of the TFTR descriptions where similar and including new task descriptions by ORNL for the systems that are new or revised for the TNS Project; these descriptions are presented in Appendix C.

The task descriptions for the device systems will be developed as part of the conceptual design.

APPENDIXES

Appendix A

INITIATION OF PLANNING EFFORTS

EXCERPT FROM ERDA, WASHINGTON, MEMORANDUM

OCT 28 1976

Robert J. Hart, Manager
Oak Ridge Operations Office

FY 1979 CONSTRUCTION PROJECT IDENTIFICATION

We have reviewed the short form data sheets submitted by Oak Ridge National Laboratory.

With respect to the Prototype Experimental Power Reactor design effort, we have recently provided $1.4 million for the continuation of this design study (previous design effort was supported by the EPPI). According to the DMFE program plan, this design effort is essential to support a budget request for Title 1 capital funding in FY 1980.

Edwin E. Kintner, Director
Division of Magnetic
Fusion Energy

TITLE: Development and Technology - Fusion Systems Engineering Advance Design-EPR/TNS Conceptual Studies

ACTIVITY NO. ED 02 04
189 No. 00037

14. PROJECT GOALS FOR FY 1977

The Key Objective is

To Provide a Strong, Supported Recommendation on the Nature of The Next Step After TFTR.

In support of this Key Objective, five Critical Objectives can be identified

C.O. 1.0 To clarify role of TNS in fusion program vis-a-vis TFTR and possible upgrades, parallel efforts, and the EPR, Demo, and CPR steps.

This objective is to identify the minimum overall risk, minimum cost, and time route to commercialization which forms the context for TNS. The method used is active participation with the Demo study wherein the extrapolation from TNS is provided by the Demo study and projections of TNS are provided to the Demo study.

Milestone

1.1	Prepare a position paper on role of TNS in fusion program	2/1/77

C.O. 2.0 To define the essential characteristics of TNS design option space.

This objective is to characterize the design space between TFTR and EPR/Demo in such a way that selection of a TNS Reference Design can be made with both aggressive goals and acceptable, minimum costs. The method used is a combination of plasma engineering judgments, design engineering conceptions of different coil systems, examination of key sensitivities, and optimization of certain costly systems trying to characterize the essentials of the design space in as few separate systems as possible.

Milestones

2.1	Develop basic characteristic representations of different size and configuration options covering the practical range from LHX-EPR	12/1/76
2.2	Quarterly review	1/15/77
2.3	Develop plasma sensitivities and cost methodology	2/1/77
2.4	Select reference design	4/1/77
2.5	Quarterly review	4/15/77
2.6	Document criteria for selected reference design	7/15/77
2.7	Document design consideration of reference design	10/1/77

C.O. 3.0 To develop RD&D input timing and sequence information

The objective is to identify essential information along with its source and timing for TNS with the output being a rational schedule in which critical items become highly visible. The method used is iteration of a central sequence chart with each supporting group.

Milestones

3.1	Establishment of a basic schedule chart	3/1/77

UCN-4414A (13 3-75)

TITLE: Development and Technology - Fusion Systems Engineering Advance Design-EPR/TNS Conceptual Studies

ACTIVITY NO. ED 02 04
189 No. 00037

14. PROJECT GOALS FOR FY 1977 (Continued)

3.2	Development of specific information needs and logical sources and timing	5/1/77
3.3	Development of additional facilities requiring incremental funding	8/15/77

C.O. 4.0 To communicate the findings of this work to the technical community and ERDA

This objective is to ensure prompt and adequate technical communication of TNS findings within the relevant sectors of the fusion community specifically including scientific and technical staff, ERDA fusion program staff, interested engineering, industrial, and decision making bodies. The method used combines frequent oral presentations with internal documentation and external written reports.

Milestones

4.1 Written Monthly TNS Status Reports to ERDA-DMFE

C.O. 5.0 To perform all these activities in a manner supporting establishment of a Project Base.

The objective here is to conduct the TNS Program in such a manner that all relevant information is documented and that a secure basis for the Line Item project is laid. The method used is to conduct wherever possible the Program as if it were actually a Project in a manner compatible with the actual budget, personnel, and time resources.

Milestones

5.1	Prepare a Job Plan for use of FY 76 CP&D funds for intensive study of key peripheral items	11/1/76
5.2	Prepare a Request for FY 77 CP&D funds to continue study of key peripheral items	11/15/76
5.3	Prepare a written administrative plan applicable to pre-title I project activities	6/1/77
5.4	Prepare a Schedule 44 - short form construction project data sheet for a FY 80 Line Item Project	9/1/77

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
OAK RIDGE OPERATIONS
P. O. BOX E
OAK RIDGE, TENNESSEE 37830

12-14-76, GRJ

AREA CODE 615
TELEPHONE 483 8611

December 10, 1976

Union Carbide Corporation
Nuclear Division
ATTN: G. R. Jasny
Post Office Box Y
Oak Ridge, Tennessee 37830

Gentlemen:

TNS PHASED LINE ITEM PROJECT

As you know, work is proceeding rapidly in a number of different areas of the subject project. These include continuing R&D activities, feasibility studies related to a reference design, conceptual criteria development, and CP&D (Title I design).

In all of the information and documentation received from your staff, there is no overall planning document showing the overall project scope related to time, funding, and project participants. The project is proceeding on an accelerated schedule that is somewhat contrary to the normal ORO philosophy and methods for the development, management and control of major capital projects. For example, substantial sums of CP&D money are scheduled to be expended before a reference design is selected and a full-scale conceptual effort gets underway on the selected design.

Perhaps the normal approach will not suffice for this project due to its complexity, the time for meeting program objectives, and funding availability. Whether that is the case or not, we want to be absolutely certain that: (1) all members of the "Project Team" are generally in agreement with the approach taken, (2) planning is based on sound engineering and operational procedures with a certain degree of realism due to the complex nature of the effort, and (3) the project proceeds expeditiously but in accordance with ERDA management, engineering, budget, contract, and financial procedures and controls.

In that regard, we feel it is imperative that some type of document be prepared to show the full scope of the project, and all program activities related to the project, as currently perceived and definitive plan for accomplishing all of the work required in a realistic time frame. Therefore, we request that you begin immediately to develop a comprehensive logic diagram for the TNS phased (FY 80 and FY 81) Line Item project. The diagram should identify time periods for pre-conceptual, conceptual, CP&D, Titles I and II, and III design, procurement, and construction. In addition, the logic diagram should be set up to clearly define the roles of the various participants, such as UCC-ND, Westinghouse, Architect-Engineer(s), etc. The logic diagram should show the interrelationships and interdependencies of major activities, including required R&D. Such relationships and dependencies between the FY 1980 facility portion and the FY 1981 device portion should clearly be delineated. One concern we have in this area relates to a draft bar chart which was furnished us by your staff. The chart shows the facility construction approximately 2/3 completed before the Tokomak design is finished. Experience has shown that this type of overlap can lead to delays, changes, and significant cost increases.

Based on discussions with members of the ORNL engineering staff, there seems to be a rather narrow description of what is included in the facility part of the project. Therefore, we would like to have a detailed statement of the scope of work to be accomplished under the FY 1980 Line Item portion of the TNS project. A similar scope statement should be included for the FY 1981 portion.

Accompanying the above, we would like a detailed funding plan for the entire project broken down into expense, CP&D, and Line Item capital costs by major participants. It should be clearly indicated if any of the participants other than UCC-ND will be split funded; and a description of the work to be performed under each funding category should be included.

While we realize the complexity of TNS and the difficulty in planning out the project in the detail requested above based on the status of the work, such a step must be taken at this time to provide a foundation from which the full ORO Project Team can efficiently and effectively become involved in the management and control of the project.

Receipt of the above information will permit us to take meaningful action on your request for an additional $500,000 of CP&D funding in FY 1977. Therefore, we suggest that a high priority be placed on this.

Sincerely,

John T. Milloway

John T. Milloway, Assistant Manager
for Construction and Engineering

EER:GWB

cc: J. A. Lenhard
T. W. White

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

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C. Baker, GA
M. Roberts, ORNL

CONCEPTUAL DESIGN PLANS FOR PROPOSED CONSTRUCTION PROJECTS

During recent conversations the subject of a conceptual design plan (CDP) for TNS has come up several times. This plan is called for by ERDAM 6101 Appendix after project selection by a program division. As a minimum, the CDP should be available ∿ one year prior to submission of the long form Schedule 44.

For your information, I am enclosing a letter from the Division of Facilities and Construction Management (FCM). This enclosure details the outline of a CDP and gives two examples of plans meeting the FCM requirements.

As the TNS design efforts evolve, the development of a CDP will be necessary and the design teams should establish a specific schedule. I suggest that this topic be included on the agenda of the TNS quarterly design review now scheduled for mid-January 1977.

J. O. Neff
Systems and Applications
Studies Branch
Division of Magnetic
Fusion Energy

Enclosure:
[illegible]tated

cc: R. Fr[illegible]nck, FCM
B. Edgerton, FCM
S. Waddle, ORO
E. Temple, SAN

EXCERPT FROM ERDA, WASHINGTON, MEMORANDUM

OCT 14 1975

Heads of Divisions and Offices, HQ
Managers of Field Offices
(PNR and SNB, THRU: Director, NR)

CONCEPTUAL DESIGN PLANS FOR PROPOSED CONSTRUCTION PROJECTS

F.O. plans for accomplishing conceptual designs for proposed construction projects are to be submitted to HQ 30 days after project selection by program divisions. The present guidance in ERDAM 6101 Appendix on these plans is brief, and several requests were made during last years budget cycle for a more definitive outline of a conceptual design plan.

Enclosed is a proposed conceptual design plan outline for F.O. use in developing conceptual plans for proposed FY 78 projects. Program divisions' guidance to the F.O. on selected projects is due by October 15. The depth and extent of detail incorporated in the conceptual design plans should be commensurate with the scale and nature of the proposed project.

Samuel L. Hack, Director
Division of Facilities and
Construction Management

PROPOSED EXHIBIT (for AECM 6101 APPENDIX, PART IV) REPORTING ELEMENTS FOR A CONCEPTUAL DESIGN PLAN

I. PROJECT SUMMARY

A. TITLE - Official name of the project including abbreviation to be used.

B. PURPOSE - Indicate briefly how the project fits into the program that it supports as to scope, timing and need.

C. DESCRIPTION - Briefly describe the facility, its proposed location and size, process capacity, power level, etc., to characterize the magnitude and nature of the project.

D. ESTIMATE - Provide the current planning TEC for project.

E. SCHEDULE - Indicated: (1) planned Budget FY
(2) planned construction completion
(3) planned initial operation date

F. CP&D - Provide estimate and scheduled use of CP&D which are currently allocated or which will be requested.

II. CONCEPTUAL DESIGN SUMMARY

A. SCOPE - Describe the work to be accomplished in the following areas:

(1) Establishment of facility functions, requirements, and criteria
(2) Facility design
(3) Development of equipment lists
(4) Studies of major engineering alternatives
(5) Site evaluation and selection
(6) Development of cost and schedule baselines
(7) Establishment of management plans and project control procedures
(8) Safety analysis
(9) Environmental assessments

The extent of development should be indicated in each area together with the expected output documents.

B. METHOD OF ACCOMPLISHMENT - Indicate the organizations that will perform the conceptual design work, A-E selection plans if required, and the type of contracts contemplated.

C. SCHEDULE - Indicate by bar chart or CPM network the required activities, key milestone dates, work durations, and interrelationships between the major conceptual design activities and necessary prerequisite R&D.

D. COST - Indicate the estimated cost for the conceptual effort broken down by FY, by functional work scope and by organization. The approximate scheduled levels of engineering manpower by organization should be provided. Requirements for CP&D or directly associated R&D funds should be identified.

E. WORK PLANS - On major engineering or developmental efforts (normally conceptual efforts of over $1 million), a work breakdown structure should be formally established and work scopes, estimates and schedules delineated for the work packages. This detailed planning documentation should be included with the plan at the option of the program division.

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

OAK RIDGE OPERATIONS
P.O. BOX E
OAK RIDGE, TENNESSEE 37830

C
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December 7, 1976

Union Carbide Corporation
Nuclear Division
ATTN: R. F. Hibbs
Post Office Y
Oak Ridge, Tennessee 37830

Gentlemen:

IMPROVEMENT IN CONSTRUCTION PROJECT SCOPE AND DEFINITION

Our present method of assuring the completeness and adequacy of line item construction project definition needs reassessment. The full effects of operational interfaces, safety and environmental considerations, energy conservation, and the full extent of prerequisite research and development can easily be overlooked during the conceptual design and estimating phases of the project, only to be brought to light during the design and construction phase when there is less flexibility in accommodating changes.

In broad terms, these interfaces are recognized in the budget instructions. However, there is a need for improved communication between the engineering groups trying to develop the project scope and estimate, and the pertinent operating, research and development, safety and environmental, finance, and other groups that must work in unison to provide complete related information during the conceptual design stage. When conceptual design was initiated some years ago, the major interest was of an engineering nature to establish a reliable project scope and estimate. It is now more clearly recognized that the conceptual design efforts should be broadened to encompass fuller requirement of construction project definition.

Schedule 44 Construction Project Data Sheet instructions provide reference to the above interfaces but it appears timely for us to collectively reassess the complete effort that is necessary on the part of all concerned to adequately comply with these interface requirements. The justification portion of the data sheet instruction makes numerous references to research and development, operational, and safety interfaces but it does not appear that they have been given full and adequate attention during the conceptual design phase of project definition and estimating. These interfaces are not solely "engineering" matters and require coordinated attention from all contributing participants in ORO and the operating contractor organizations.

Attached for your ready reference are Pages 91-93 of OR Appendix 1301, Part II, giving the Schedule 44 Item 9. Instructions, and Pages 106-110 of the same appendix providing similar additional data for projects with TEC's of $25 million or more. Also attached are Pages 99-101 of the same appendix that specify the information needed concerning environmental and safety matters. Compliance with these instructions will provide -- on a budget basis -- the interrelationship of the project with research and development, operations, safety, and other related activities. It should be stressed that the development of adequate information in all of these areas cannot and should not be accomplished solely by engineering personnel but require an overall integrated programmatic, R&D, and finance input by the contractor's staff and ORO.

The budget instructions referenced above represent ERDA's intent that the various elements of the contractors and field office organizations communicate effectively on these matters. However, these instructions do not represent the full depth of the discussions that must take place among all interested parties at the conceptual design stage to fully explore all the potential problem areas and/or uncertainties.

To assure that the above matters are adequately considered during the conceptual stage of a project, we propose that additional sections be added to all future conceptual design reports to cover the operational and development aspects of each project, and that those groups responsible for the operational and the development aspects of the project review and attest to the completeness and adequacy of the report prior to the submission of the CDR to ORO for review and approval. In addition, the sections of the CDR relating to environmental and safety considerations should be upgraded to provide a more comprehensive treatment of the potential safety and environmental problems associated with the project. The information to be provided in these sections is specified in ERDA Appendix 6101, Part III, Exhibit I. All those responsible for input into the conceptual design report should recognize that timeliness in the completion of these reports is of the essence because changes in project estimates are extremely difficult -- if not impossible -- to make once the project reaches certain levels of review and approval at ERDA Headquarters.

These added sections in the conceptual design report should be prepared in such a manner as to accommodate all pertinent requirements in the Schedule 44 and 44a. The operational statement should also include an assessment of the project's impact on operations, an analysis by operations of the work that has been accomplished to define the project scope and an analysis of the work still needed to be done; and a clear definition of the purpose of the project from the standpoint of operations. The research and development statement should include a statement of the development work to date; a clear statement of the development work yet to be accomplished and its impact on future scope and costs; an assessment of project systems and equipment as outlined in the CDR; assessment of future R&D work impact on schedule, cost, and manpower; and a clear statement of project definition from the viewpoint of research and development. Where further R&D work is required, this effort should be identified in the R&D portion of budget documents and cross referenced to the project.

Details of implementing these new requirements will be coordinated by our respective staffs.

Sincerely,

R. J. Hart
Manager

C O P Y

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

JAN 6 1977

Dr. J. F. Clarke
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee 37831

Dear John:

SUBJECT: TNS R&D REQUIREMENTS

Over the last several months there have been many discussions among the DMFE contractors and program managers on the need to identify the R&D necessary to support the design and construction of a TNS. These R&D needs exist across the entire spectrum of the DMFE program from the plasma physics area to the plant maintenance area. One of the most important aspects of TNS has always been thought to be the focus and discipline that such a project can bring to the DMFE R&D program.

During the next year, there will be many reviews and assessments relative to what can and cannot be supported in the DMFE program. During these discussions it is essential that there be a strong and well-based understanding of the TNS R&D requirements and the tasks which are necessary to achieve a 1986-88 operation date. Additionally, there is a need to understand the potential costs to complete these tasks.

We would like to prepare a first draft of a TNS R&D plan by February 18 for possible use in upcoming Congressional Hearings. This schedule is very tight and I have asked F. Coffman and J. Neff to work closely with you and your people to determine what areas should be focused upon and to assist in obtaining information about the technical programs outside ORNL. They plan on being at Oak Ridge on January 7, 1977, to discuss the specifics of this task.

Enclosed are several pieces of information which give some ideas on how we might approach an R&D plan for TNS. These include a list of objectives, a plan of action, a suggested format for the R&D tasks and a schedule for completing the work. These should serve as a basis for discussion.

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I look forward to reviewing your progress in this area at the January 28 TNS quarterly review. Should you have any questions, please call J. Neff of my staff.

Sincerely,

James M. Williams
Assistant Director for
Development and Technology
Division of Magnetic
Fusion Energy

Enclosures:
As stated

cc: M. Roberts, ORNL
G. Benedict, OR
S. Waddle, OR

Appendix B

CP&D FUNDING DETAIL

UNION CARBIDE CORPORATION - NUCLEAR DIVISION

($ x 1000)

Schedule 48

	Item	FY 1977	FY 1978	FY 1979	FY 1980	Total
1. a.	The Next Step (TNS) CP&D Funding Requirements	$1,000	$1,000	$1,500	$1,000	$4,500

b. Description:

The Next Step is proposed as the next logical step in the development of fusion power after the TFTR project which is to be operational in the FY 81-82 time period. The ERDA/DMFE Logic III Plan test reactor (TNS), is scheduled to be operational by FY 86. TNS is a research fusion reactor which will generate a reactor core plasma using moderate extensions of the technology that will be qualified by 1980. The device will be designed to ignite deuterium-tritium plasma and thus produce fusion energy in a manner extrapolative to a fusion reactor. In addition to the basic device, the facility includes peripheral equipment, support systems, controls, data analysis equipment, and buildings.

Project estimated cost is between $400M and $1000M.

c. Justification:

Four years of increasingly detailed design studies, which culminated in the EPR study, have indicated that a deuterium-tritium ignition experiment should precede EPR and have laid the groundwork for a recent major programmatic decision to begin conceptual design of such a facility.

Fusion programs are no longer level-of-effort research activities, but mission oriented with near, mid, and long term goals aimed at achieving a practical, real energy option.

The Fusion Energy Option is a major concern to the general public and to the technical community involved in mid and long term energy goals.

This project's primary goal is production of a fusion reactor core from which systems integration experience can be gained; provision of a forcing function of fusion technology is a secondary objective.

In order to assure the technology base for TNS, the design is being tied closely to the qualified outputs (expected about 1979-1980) of the two principal technologies involved, i.e., beams and magnets, through the ORNL beam program and the ORNL Large Coil program.

The foregoing considerations support the conclusion that construction and operation of the TNS is essential to the EPR and will be of great benefit in the timely, orderly development of fusion power in the U.S. The TNS program is, therefore, a necessary part of the overall research and development program leading to successful demonstration of commercial feasibility.

In general, due to the research and developmental nature of this experimental project and the magnitude of the expenditures related to new technology such as superconducting magnet systems, large tritium systems, and large pulse energy systems, the project is considered of such a complex nature that it is necessary to perform additional engineering and design (preliminary engineering Title I design) on the facilities and other areas of the device, in advance of normal timing.

d. Feasibility studies are currently being accomplished, leading to a preferred reference design to be issued in May, 1977. Pre-conceptual design engineering is scheduled to begin in May, 1977 and continued through September, 1977. On 10/1/77, formal conceptual engineering will start on both the Phase I, facility portion, and the Phase II, device portion, of the project. Phase I conceptual design will be completed in May, 1978 for the facilities FY 1980 line item portion, and Phase II conceptual design will be completed in May, 1980 for the device FY 82 line item portion of the project.

e. Description of Tasks and Estimated Costs:

	($ x 1000)					
	FY 1977	FY 1978	FY 1979	FY 1980	Total	Action
Task No. 1: Perform preliminary Title I engineering design on the following TNS support systems: 1) Remote maintenance and assembly systems 2) Tritium handling and processing systems 3) Vacuum systems 4) Cryogenic refrigeration systems	$ 500					UCC/W
Task No. 2: Perform preliminary Title I engineering design on the following TNS device systems: 1) Toroidal field coil 2) Polordal field systems 3) Shielding systems 4) Electrical power supplies	500					UCC/W
Task No. 3: A-E Effort 1) Land Improvement - Site investigations, including specific core drillings and seismic analysis, will be performed to provide data for the design of the building foundations and structures.		75				UCC-AE
2) New Buildings - Preliminary design of the buildings including containment, foundations, superstructure, building services, and interfaces with the experiment will be performed to improve the cost estimate.		100				UCC-AE

Task No. 3: (continued)	FY 1977	FY 1978	FY 1979	FY 1980	Total	Action
3) Utilities - Preliminary drawings and specifications will be prepared for the power system, steam, water, etc., required to support the TNS facility to better define the scope and improve the cost estimate. Likewise, preliminary design will be done for the TNS cooling water system.		75				UCC/A-E
4) Phase II Conceptual Design Support - At the completion of Phase I conceptual design, a Phase I support team will be formed to assist in the Phase II conceptual design effort.		100				UCC/A-E
Task No. 4:						
Engineering planning - preliminary estimates of engineering manpower requirements for Titles I, II, and III design will be generated.						
1) Phase I - facilities		25	50			UCC/A-E
2) Phase II - device		50	50			UCC/W
3) Systems engineering		50	50			UCC/W
Task No. 5:						
RD&D planning - preliminary planning will be performed on those TNS design specific RD&D programs to define better their impact on TNS project cost and schedule.		50	500	500		UCC/W
R&D planning - preliminary planning will be performed on those existing R&D programs to insure timeliness of needed data input, and preliminary planning will be performed on those R&D programs that exist but need to be modified for TNS, or which do not exist and must be started new for the TNS project.						

Task	FY 1977	FY 1978	FY 1979	FY 1980	Total	Action
Task No. 6: Major components and equipment planning-preliminary engineering will be performed on those major components and equipment systems to generate specifications.		200	600	250		UCC/W
Task No. 7: Perform preliminary Title I engineering design on the following TNS device systems: I&C and Data Handling; Vacuum Vessel; Fuel Injector; Impurity Control; Plasma Heating		275	250	500		UCC/W

f. Schedule of Start and Completion Dates for CP&D Task:

		Start Date	Completion Date
Task 1.	Support Systems Design	3/01/77	9/30/77
Task 2.	Device Systems Design	5/01/77	9/30/77
Task 3.	A-E Effort	8/01/77	1/01/78
Task 4.	Engineering Planning	10/01/77	5/01/79
Task 5.	RD&D/R&D Planning	10/01/77	5/01/80
Task 6.	Major component/equipment planning	10/01/77	5/01/80
Task 7.	I&C and data handling systems	10/01/77	5/01/79

g. Method of Accomplishment:

Participants are defined under the action column of section e, "Description of Tasks and Estimated Costs."

A. On all tasks, Union Carbide will participate with the A-E or Westinghouse as the overall technical management. Carbide will provide criteria for design, be responsible for cost and schedule control, review and direct work of the A-E or Westinghouse, assimilate and publish data requirements, and formalize all cost and schedule estimates.

B. An A-E, selected by ERDA-ORO, will furnish the labor and material to complete the facilities related tasks (tasks No. 3 and 4-1) and work with UCC & ORO per accepted ERDA procedures. They will furnish Carbide with bills of material, preliminary Title I engineering design, and other input information for the preparation of preliminary costs and schedules.

C. Westinghouse Electric Company, under subcontract 7117, to Carbide will furnish labor and material to perform the device related tasks (Tasks No. 1, 2, 4-2, 4-3, 5, 6, and 7). They will furnish Carbide with bills of material, preliminary Title I engineering design, and other input information for the preparation of preliminary costs and schedules.

Appendix C

DETAILS OF WORK BREAKDOWN STRUCTURE

Appendix C-1

SPECIFIC TASK STATEMENT OF WORK BREAKDOWN STRUCTURE SYSTEMS 11–16

WBS No. 1. Management Systems (The system to be designed in accordance with ERDA Rdd-MCS-1/6101)

This task includes the application of established management systems to assure that all program objectives are on schedule and within proposed cost. The Project management effort is defined by the following activities.

WBS No. 11. Project Administration

This task includes the effort necessary to manage, direct, and control the program. Finance and contract administration will provide assistance to assure maintenance of proper cost planning and accounting records and to assure the smooth implementation of contract requirements to support the Project Office effort in working with DOE and with other operating sections, to perform liaison with DOE and architectural and engineering contractor, and to establish and maintain planning and control interface with industrial subcontractors. Effort by other functions is not included here. Specific effort for this task is defined in the following subtasks.

a) Project Manager and Support Staff — This task provides for the Project Manager and support staff to manage and direct project activities to accomplish project objectives.

b) Finance and Accounting — Financial and accounting support will provide for the maintenance of proper cost planning and accounting records to support the Project Office in working with subcontractors and with operating sections.

c) Contracts — Contract control will provide for the maintenance of contract requirements to support the Project Office in working with subcontractors and with operating sections. This work will include monitoring project performance, participating in negotiation of changes, and ensuring that subcontract requirements are met.

This task includes the fee paid to the industrial subcontractor.

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d) Material and Supply Control — Identify and evaluate long-lead items including subcontractor components, materials, tooling, special test equipment, and facilities to determine the effect on fabrication and procurement cycles and program schedules; authorize procurement of long-lead items and maintain cognizance of critical materials and supplies.

e) DOE Liaison — This task provides the Project Office effort for project review meetings with DOE. Other activities supporting this function will include this effort in their specific task/subtask.

f) Fusion Program Liaison — This task provides the Project Office effort for project review meetings with other participants in the National Fusion Energy Program. This task will provide the project with close interaction with those other agencies to ensure timely and meaningful project support from those agencies.

g) Architectural and Engineering Subcontractor Liaison — Perform liaison with the architectural and engineering contractor to assure timely delivery of quality designs within established costs. Provide on-site liaison to assure proper construction of the buildings.

h) Industrial Subcontractor Liaison — Perform liaison with the industrial subcontractor as required to assure timely delivery of quality hardware within cost.

i) Research and Development (R&D)/Research Development and Demonstration (RD&D) Management — This task provides the Project management with the assurance that required RD&D and R&D programs are carried forth consistent with TNS technological requirements and schedules.

WBS No. 12. Project Planning and Control

This task includes efforts to establish and maintain a management information system, to monitor program activity, and report to UCC management and DOE.

a) Work Breakdown Structure (WBS) and Task Descriptions — The WBS and task descriptions will be revised to incorporate changes resulting from contractual negotiations and to expand specific tasks in scope and depth.

b) Project Schedule and Budgets — This task is to establish, monitor, and maintain a program for schedule and budget requirements. Included here is the effort to define requirements of work for responsible organizations, maintain a project budget, integrate cost and schedule monitoring and status system, and issue periodic reports to provide overall project visibility for project analysis and corrective action.

c) Project Performance Management Systems (PPMS)* — This task is to establish and maintain a PPMS that not only integrates a balanced consideration for cost, schedule, and technical program factors but also maintains a discipline flexibility for incorporation of basic changes in program work content and evolving technology. The system will provide these features:

- A single, formal integrated system for program planning and control directed toward meeting the contract requirements of cost, schedule, and technical performance.
- Summary program cost, schedule, and performance data for submittal to DOE.
- Visibility and control through the work breakdown structure (WBS) by subdividing contract requirements into logical work units and measuring actual accomplishment against planned values to determine cost and schedule status.
- A framework of contract limits or targets for cost, schedule, and technical performance through integration of the contract baseline budget, program milestones, and technical performance parameters.

*The PPMS developed by UCC for TNS adopts the criteria developed and used successfully by DOD.

- Detailed cost and schedule reports for both program and performing department management.
- Traceability of the effect of program changes on baseline budgets, program schedules, and technical performance goals.
- Compatibility with other internal UCC operating systems through use of the same data base that supports internal operations.

The system should consist of five operating modules that integrate ten highly interdependent subsystems (see Fig. C-1). The system defines a baseline plan for: performing contractual requirements, authorizing the plan, measuring performance against the plan, replanning and redirection to changed work scope or corrective action, and overseeing system application and ensuring its operation integrity.

d) Project Model — This is the specific task of establishing and maintaining a cost and schedule computer model to provide immediate response to "what if" questions.

e) Project Management Control Room — This is the task to provide the project with a control room where project meetings can be formally held. It will provide updated schedules and cost visual aids, projection capabilities, and a communications operations center and will be staffed at all times for project use. The project records center (WBS No. 15d) will be located close to this area with the control room staff controlling records upkeep. The control room will be the responsibility of the data manager.

WBS No. 13. <u>Technical Coordination</u>

Effort in this task is to provide technical support to the Project Manager in areas of engineering, manufacturing, safety requirements, configuration control, assembly direction and control, operations and test control, and configuration interface control.

a) Engineering Direction and Control — Includes engineering project technical coordination effort and fiscal and manpower control.

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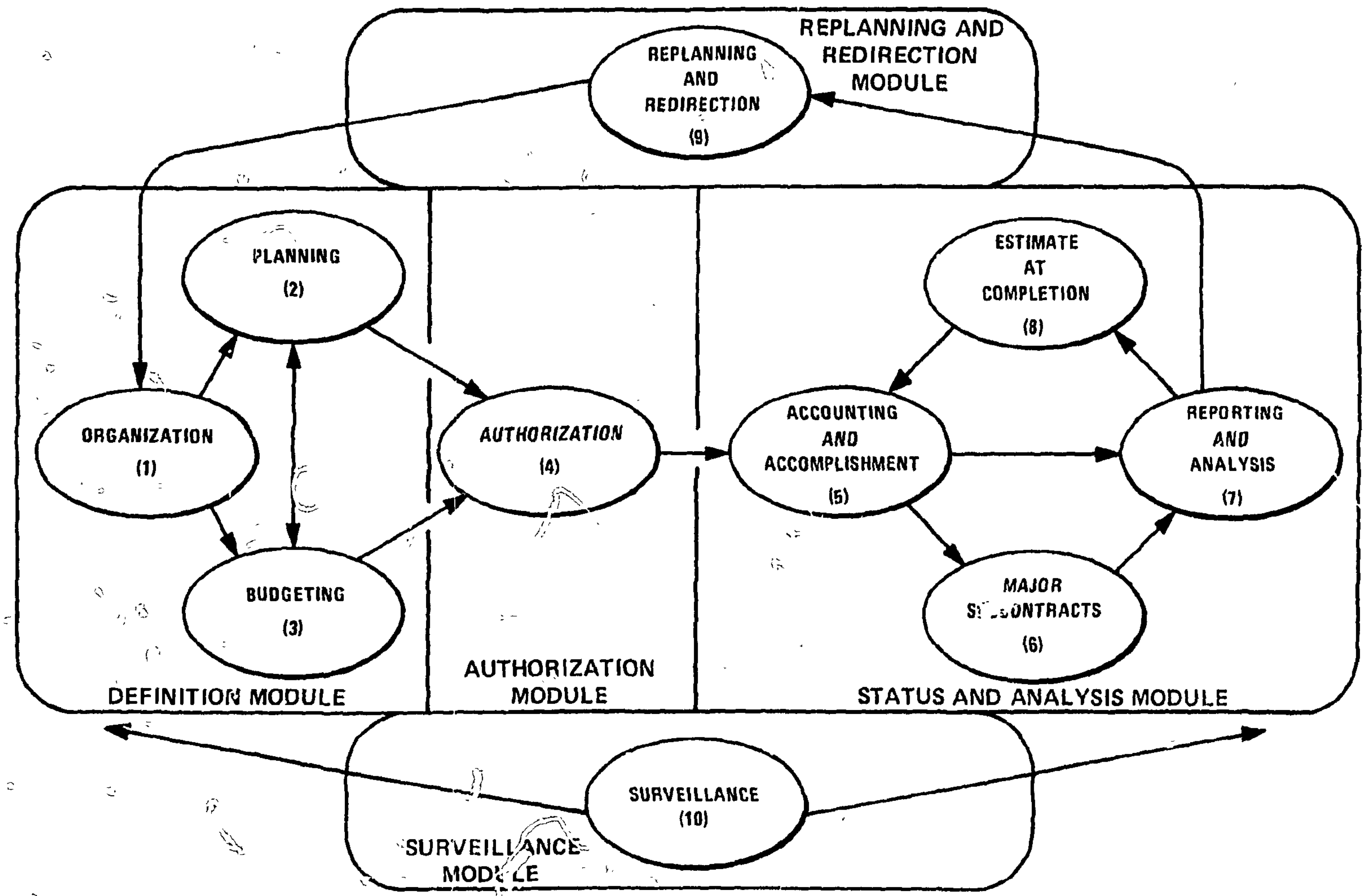

Fig. C-1. Outline of project performance management systems logic (PPMS).

b) Manufacturing Direction and Control — Includes manufacturing project coordination effort and fiscal and manpower control.

c) Safety — Includes safety project control effort associated with assurance that adequate safety has been designed into the system and that design meets contractual requirements covering safety. Development of safety plans and support of the safety program by design organizations is included as part of the Systems Engineering Task (WBS No. 21).

d) Configuration Control — The configuration manager will have the responsibility of assuring that the TNS end product meets contractual technical design requirements. This is accomplished through an SDD/ICD formal change system and the interface control task that the configuration institutes, manufactures, and controls. The systems engineer chairs the change review board and interface control document review board system.

e) Assembly Direction and Control — Includes assembly project coordination effort and fiscal and manpower control.

f) Operations and Test Control — Includes preoperational test and test and checkout coordination effort and fiscal and manpower control.

g) Interface Control — This task establishes, directs, and controls the interface control document system. A formal ICD review board will be chaired by the configuration manager.

WBS No. 14. <u>Procurement Systems</u>

Includes procurement project control effort plus the establishment of a system to review supplier acceptability and performance.

a) Procurement Administration — Establish procedures, methods, and routings for the necessary reviews, approvals, and recordings of requests for quotations, requisitions, purchases and subcontracts, and changes, terminations, and order closeouts. Establish authorized requisitioners and categories for authority to requisition and dollar level of authority. Establish procedures and practices for the solicitation of bids and proposals, review and evaluation of same, and negotiation and award of resultant orders and subcontracts. Establish the procedures, practices, and documentation required by DOE for timely approval of procurement actions. Establish monitoring and audit controls to assure compliance with the policies, practices, and procedures identified above. The industrial subcontractor will follow approval procedures to be provided by UCC.

b) Procurement Documentation and Records — Establish the requirements for documenting procurement activities and identify the participants in the process responsible for preparing, obtaining approval, distributing, and filing procurement documents. Establish the responsibility in the procurement document for the master file and and for subsidiary supporting data files in the technical operations or administrative departments. Establish the period required for maintenance of original documentary procurement records and any review requirements prior to microfilming or other long-term storage means and/or destruction. Establish the necessary controls for safekeeping, access by authorized users, and loan for appropriate purposes.

c) Subcontract Administration — Prepare specific solicitations for bids or proposals, with appropriate documentation and requirements for response by offerors. Receive bids and proposals and appropriately administer the analysis, evaluation, and selection of sources for award or negotiation of orders or subcontracts. Place awards and carry out the necessary tasks of expediting and monitoring performance liaison with cognizant industrial subcontractor personnel and vendor personnel until satisfactory completion or termination of the related orders and subcontracts in accordance with their requirements and terms and conditions through visits, meetings, reports, correspondence, and other communication as necessary. Using cognizant program administrative and technical personnel, assess progress and performance against established plans. When departures from plan occur, obtain revised plans and schedules and management attention at the appropriate level to optimize a program of special action to regain the schedule or obtain the results specified in the order or subcontract. Negotiate appropriate consideration for failure to deliver stipulated performance. Issue changes and negotiate equitable adjustments in price, delivery, and other terms and conditions as appropriate. Close out completed or terminated contracts, taking action to obtain the necessary certifications and other appropriate documents, and dispose of residual property, excess material, tooling, etc., as may be appropriate to the rights and interests of the parties, in accordance with the order or subcontract.

d) Procurement Negotiations and Recommendations — Establish negotiating teams composed of persons cognizant of the technical requirements, program controls aspects, and financial and contractual terms of the prospective subcontract. Identify for each negotiation the technical, cost, schedule, and other performance objectives and the prerogatives of the negotiators to depart from specified goals in reaching agreements for procurement. Designate a chief negotiator. Conduct negotiations, prepare record of results, obtain necessary approvals, and confirm with other parties as required and approved.

e) Procurement Liaison with DOE and Other Cognizant Government Representatives — In accordance with UCC established policy and procedures and the requirements of the contract, prepare and submit for DOE's approval the necessary documentation. Conduct such liaison as required to obtain appropriate responses. Prepare responses to satisfy DOE requests for information, status reports, documentation, meeting, etc. Provide to program personnel notice of new or changing DOE or other government requirements that might affect procurement activities. Industrial contractor liaison with DOE and other cognizant government representatives to be conducted via UCC unless otherwise provided in the subcontract provisions with the industrial subcontractor.

WBS No. 15. Documentation Systems

Includes the effort to establish a focal point for integrating the data management effort.

a) Data Management Program — Control and production of contractual data required by the program includes data responsibility assignments, project correspondence, procedures, data retrieval, editing, final art work, publication, and distribution of the data. This task is considered limited to actual publication activities and any groups assigned specifically for data control and data library.

b) Specification and Drawing Control — Includes the specific effort to maintain all specifications and drawings in an updated form as directed by the configuration manager.

c) Publications — Includes the effort for preparation and publication of contracted data as directed by the data manager. This effort includes technical writers, art draftsmen, and the hardware and software for publishing documents.

d) Records Center — Includes the central contractual document records maintenance and control effort to be managed by the data manager.

WBS No. 16. Quality Assurance Systems

Includes the effort to establish and implement a Quality Assurance Program as well as performance of various functions such as review, audit, surveillance, and inspection.

a) Quality Assurance Management — This task provides planning and support effort for the establishment and implementation of a Quality Assurance Program. Quality Assurance will prepare an overall system quality control plan, work instructions, and process control instructions. Inspection and testing is included in each fabrication and and fabrication support task.

b) Inspection Control — This task includes the effort to manage the inspection and testing effort, which is included in each fabrication and fabrication support task.

Appendix C-2

DETAILED LISTING OF TNS WORK BREAKDOWN STRUCTURE ELEMENTS (PATTERNED AFTER THE TFTR MODEL*)

1. Management Systems

11. Project Administration Systems
- *a*) Project manager and administration staff
- *b*) Finance and accounting
- *c*) Contracts
- *d*) Material and supply control
- *e*) DOE liaison
- *f*) National laboratory liaison
- *g*) AE subliaison
- *h*) Industrial subcontractor liaison
- *i*) R&D management

12. Project Planning and Control Systems
- *a*) WBS and task description
- *b*) Project schedule and budget
- *c*) PPMS control
- *d*) Project model
- *e*) Project management control room

13. Technical Coordination Systems
- *a*) Engineering direction and control
- *b*) Manufacturing direction and control
- *c*) Safety
- *d*) Configuration control
- *e*) Assembly direction and control
- *f*) Operations and test control
- *g*) Interface control

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*PPPL-TFTR-3073, Tokamak Fusion Test Reactor Work Breakdown Structure, Princeton Plasma Physics Laboratory, Sept. 15, 1976.

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14. Procurement Systems
    - *a*) Administration
    - *b*) Documentation records
    - *c*) Subcontract administration
    - *d*) Negotiation and recommendations
    - *e*) DOE and other government liaison

15. Documentation Systems
    - *a*) Data management
    - *b*) Specification and drawing control
    - *c*) Publications
    - *d*) Record center

16. Quality Assurance Systems
    - *a*) Quality assurance management
    - *b*) Inspection control

2. <u>Device Systems</u>

21. Systems and Safety Engineering
    - *a*) Tokamak systems
    - *b*) Electrical power and control systems
    - *c*) Plasma heating systems
    - *d*) Tokamak support systems
    - *e*) Instrumentation and controls and data systems
    - *f*) Facilities systems
    - *g*) Preoperational testing

22. Tokamak Systems
    - *a*) Toroidal vacuum vessel
        - 1) Vacuum vessel shell
        - 2) Penetrations
        - 3) Segmented joints or closures
        - 4) Limiters
        - 5) Neutral beam adapters
        - 6) Liner or shroud

b) Machine structure

c) Toroidal field coils

d) Poloidal field coils

e) Shielding

f) Impurity control

g) Tokamak systems mock-up

23. Electrical Power and Control Systems

a) Primary energy

b) Primary and secondary distribution

c) Energy conversion

1) Toroidal field power-conversion equipment

2) Poloidal field coil power-conversion equipment

d) Standby or emergency

24. Plasma Heating Systems

a) NB heating systems

b) RF heating systems

25. Tokamak Support Systems

a) Remote servicing

b) Fuel handling

1) Tritium storage

2) Tritium delivery

3) Tritium processing

4) Tritium cleanup

5) Non-tritium charge gas storage

6) Non-tritium charge gas delivery

c) Main vacuum pumping

d) Heat removal

1) Superconductor refrigerant

2) Vacuum cryopanel refrigeration

3) Vacuum vessel cooling and heating

4) Water cooling

e) Experimental area ventilation

f) Radioactive waste handling

g) Fuel injector

h) Assembly

26. Instrumentation and Controls and Data Systems
    a) Central instrumentation and controls
    b) Operational instrumentation
    c) Scientific instrumentation

3. Facilities System

31. Main Test Building Systems
    a) Test cell
    b) Mock-up assembly bay
    c) Hot-cell bay
    d) NB test cell bay
    e) Land improvement
    f) Utilities
    g) Standard equipment

32. Other Building Systems
    a) NB power conversion
    b) Radiation waste processing
    c) Control room
    d) Research laboratory
    e) Plant services
    f) Shop
    g) Tritium processing
    h) Cryogenic plant
    i) Cooling H_2O pump house
    j) Field coil power and capacitor yards
    k) Motor-generator

4. Preoperational Testing

5. RD&D

51. Technology Development
    a) Overall plant
    b) Blanket and shield system
    c) Toroidal magnets system

d) Poloidal field system

e) Structural system

f) Electric energy storage and pulse systems

g) Plasma heating system

h) Tritium processing

i) Vacuum pumping system

j) Cryogenic cooling system

k) Maintenance and assembly system

l) Tritium containment system

m) Instrumentation and controls

52. Hardware Demonstration

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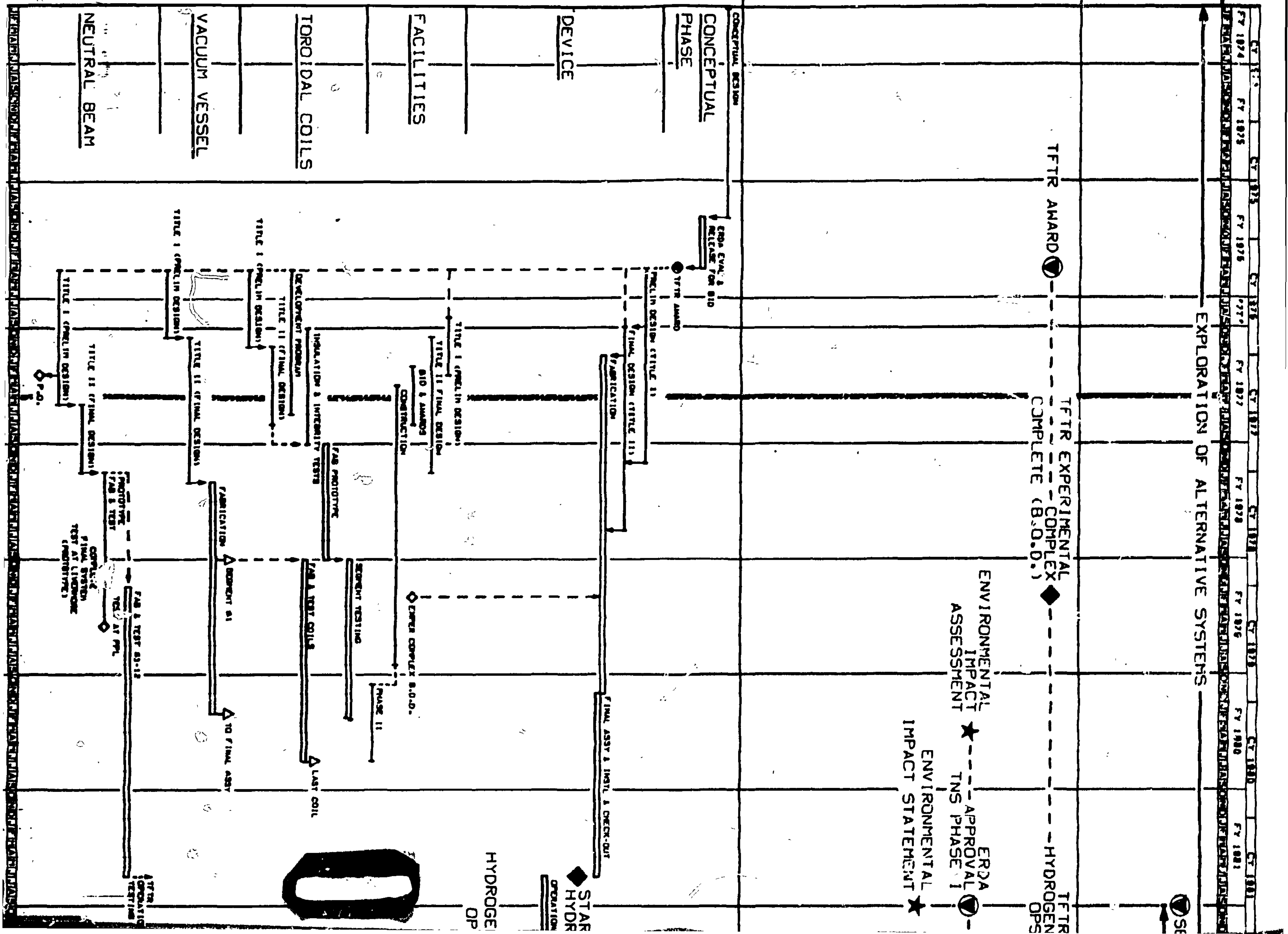
OKAMAK FUSION TEST REACTOR (TFTR)

D-T PHYSICS

(IN DESIGN/HARDWARE)

PROGRAM MILESTONES

PROGRAM PHASING



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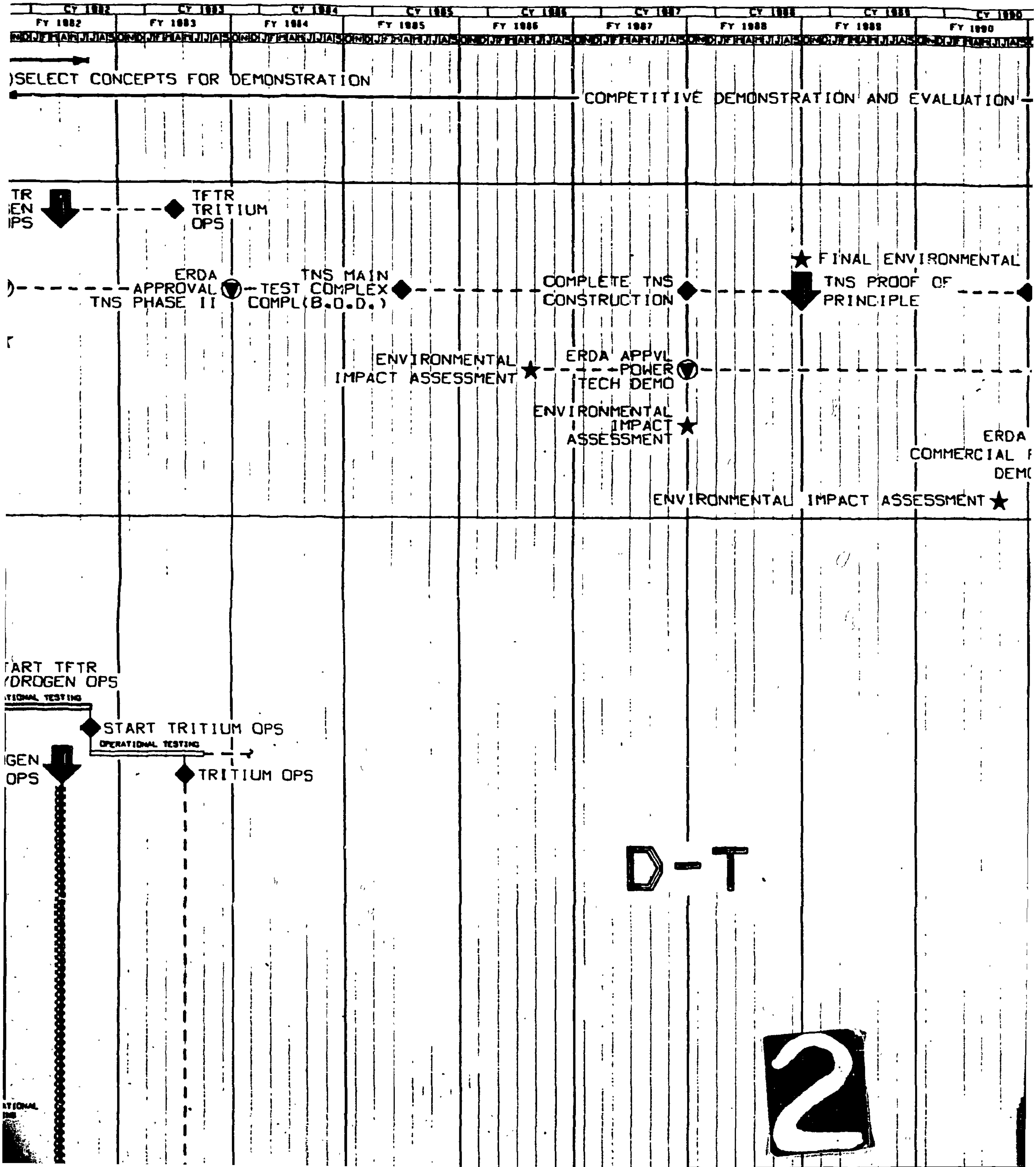
MAGNETIC FUSION POWER ACQUISITION PLAN



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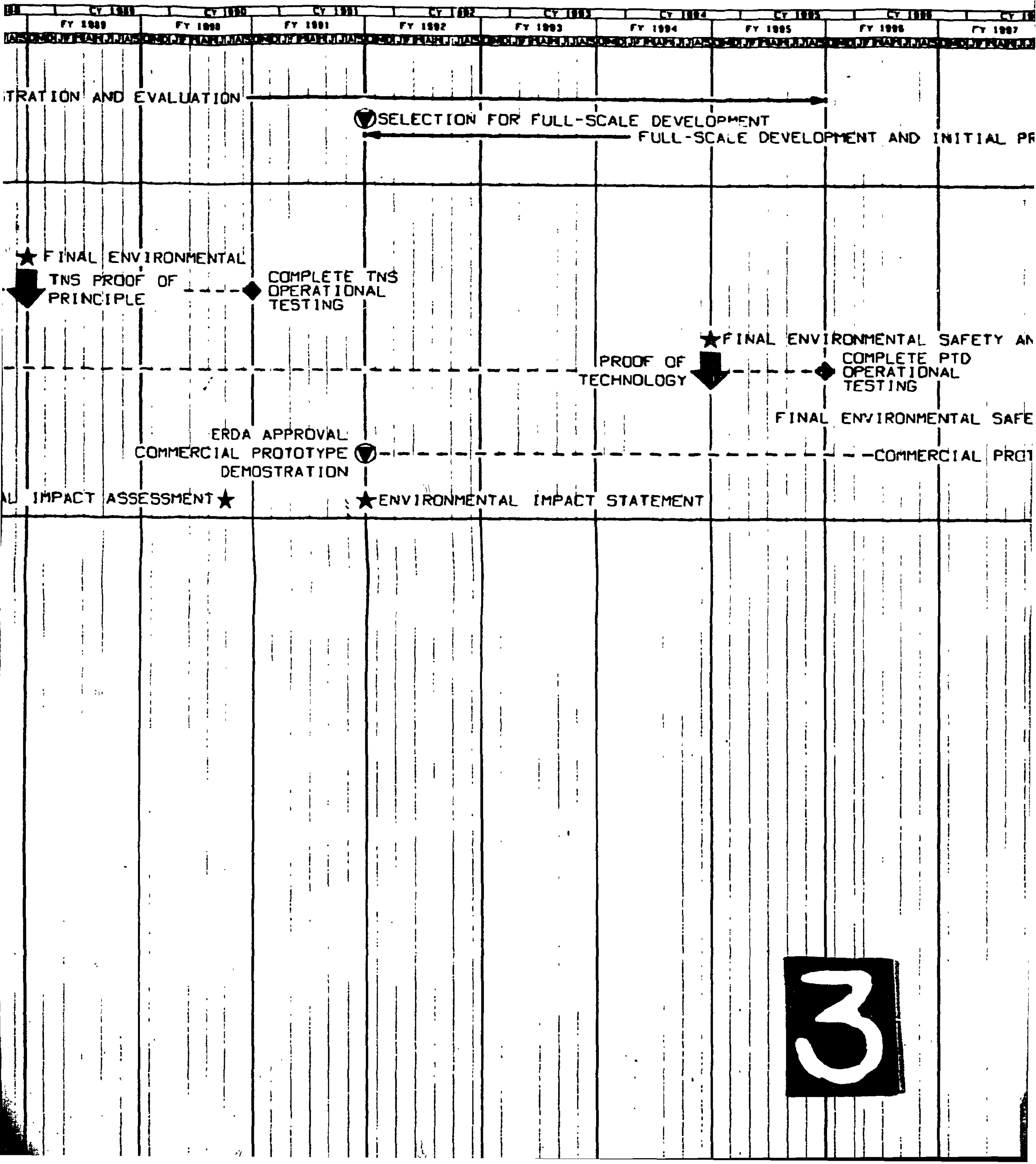
PLANNING



FY 1989
FY 1990
FY 1991
FY 1992
FY 1993
FY 1994
FY 1995
FY 1996
FY 1997
TRATION AND EVALUATION
SELECTION FOR FULL-SCALE DEVELOPMENT
FULL-SCALE DEVELOPMENT AND INITIAL PR
FINAL ENVIRONMENTAL
TNS PROOF OF PRINCIPLE
COMPLETE TNS OPERATIONAL TESTING
FINAL ENVIRONMENTAL SAFETY AN
PROOF OF TECHNOLOGY
COMPLETE PTD OPERATIONAL TESTING
FINAL ENVIRONMENTAL SAFE
ERDA APPROVAL
COMMERCIAL PROTOTYPE DEMOSTRATION
COMMERCIAL PROT
AL IMPACT ASSESSMENT
ENVIRONMENTAL IMPACT STATEMENT
3

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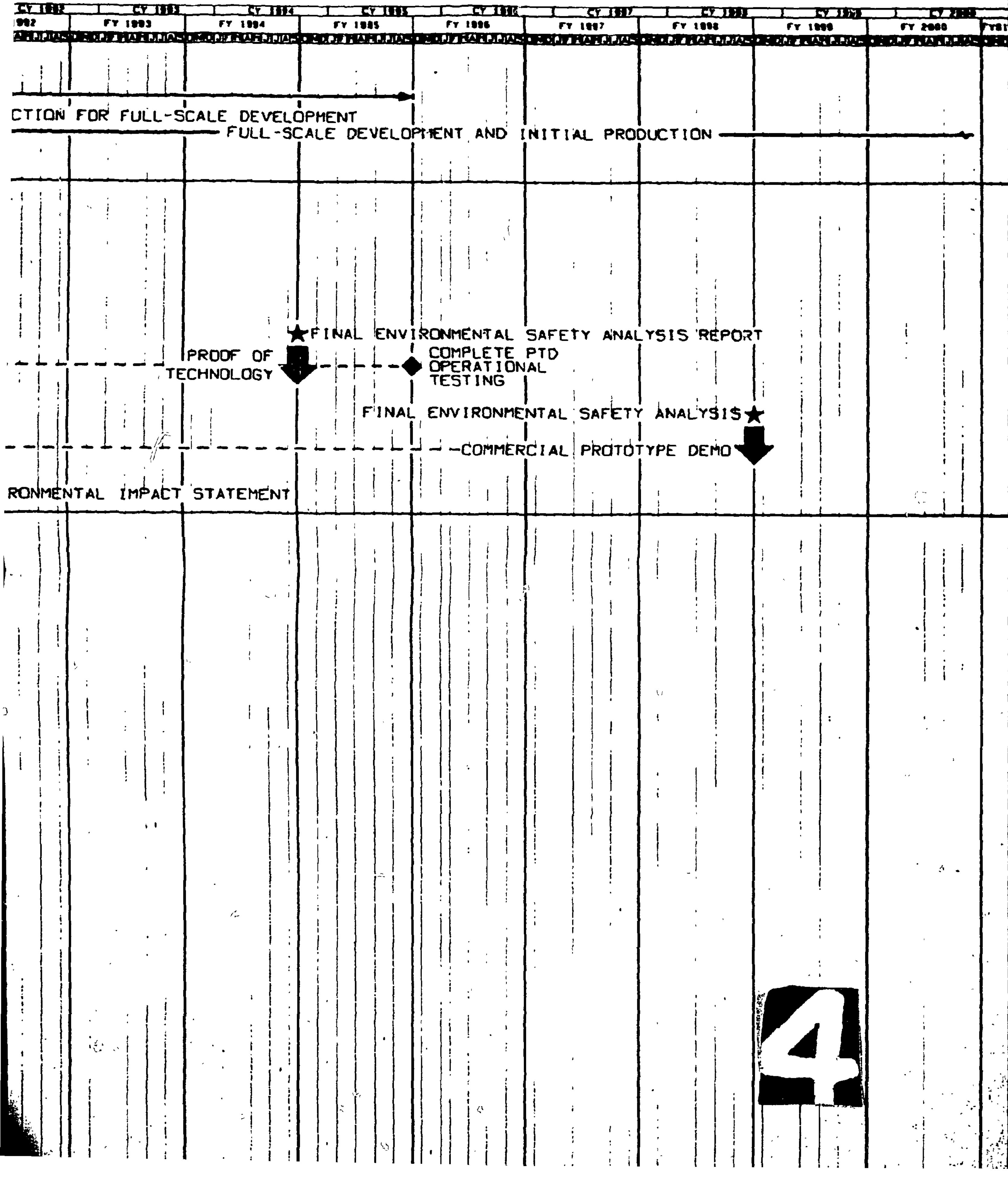
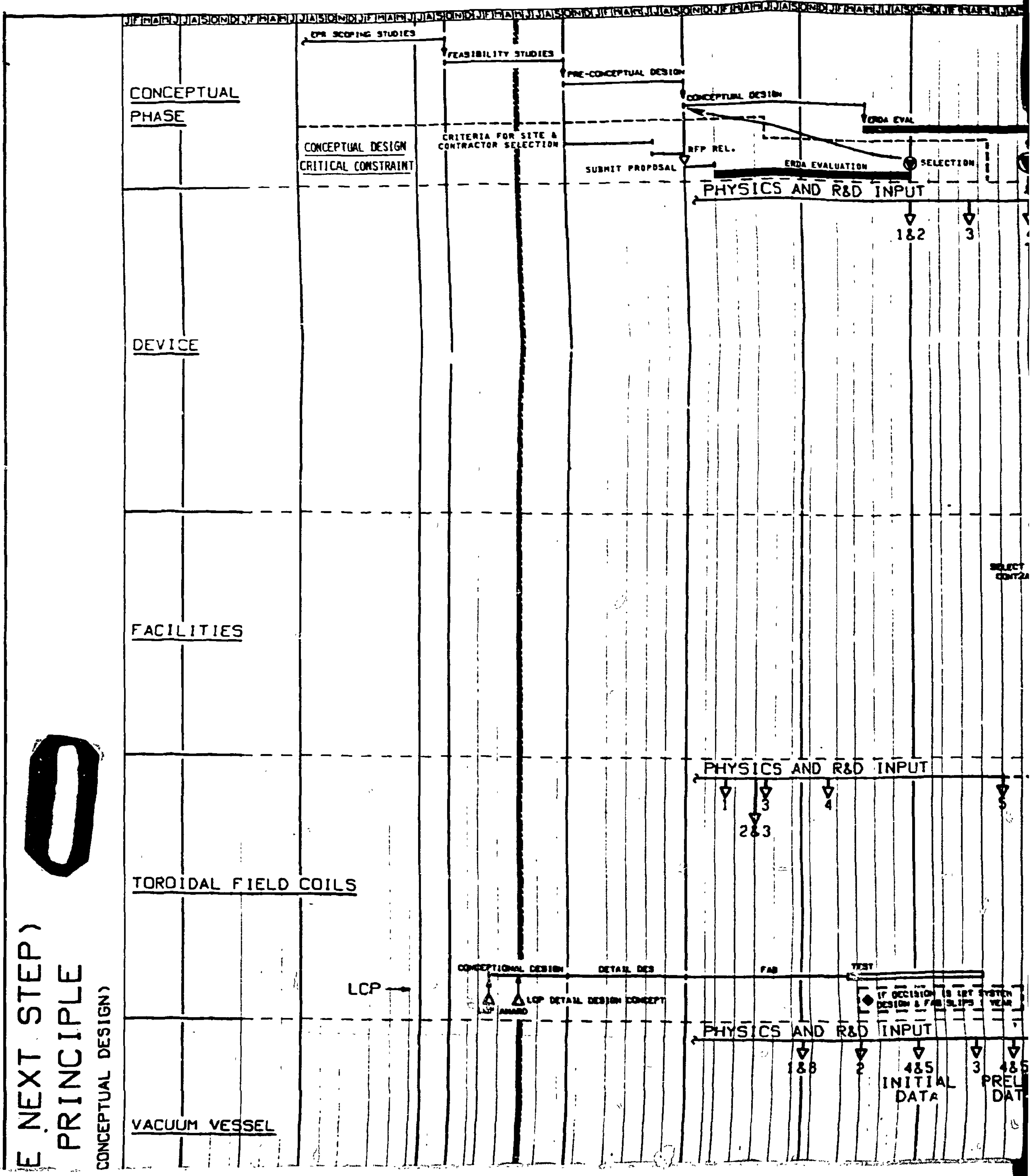
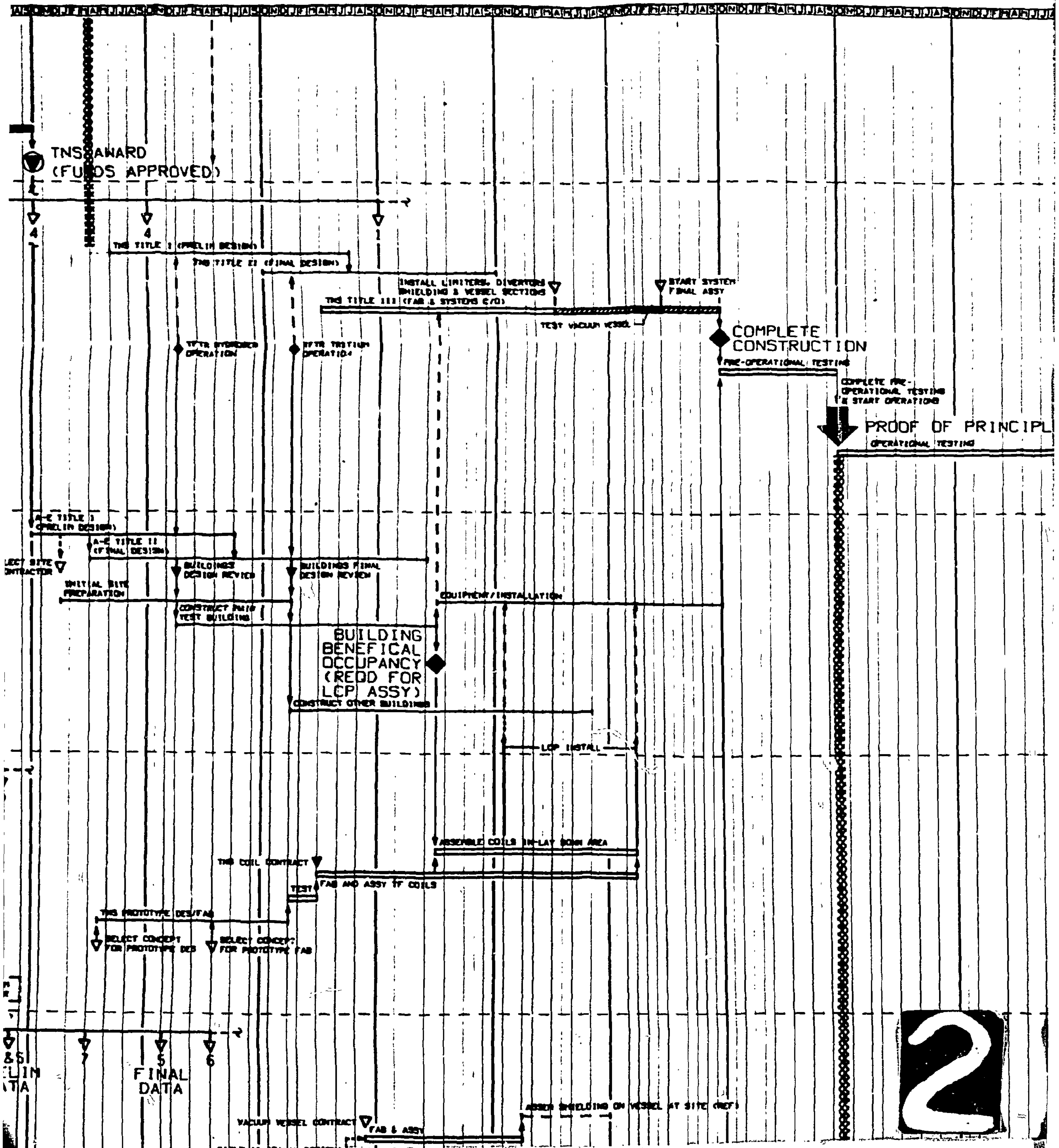
PLANNING PURPOSES ONLY



E NEXT STEP)
PRINCIPLE
CONCEPTUAL DESIGN)




TNS AWARD (FUNDS APPROVED)
TNS TITLE I (PRELIM DESIGN)
TNS TITLE II (FINAL DESIGN)
INSTALL LIMITERS, DIVERTORS SHIELDING & VESSEL SECTIONS
START SYSTEM FINAL ASSY
TNS TITLE III (FAB & SYSTEMS C/O)
TEST VACUUM VESSEL
COMPLETE CONSTRUCTION
PRE-OPERATIONAL TESTING
COMPLETE PRE-OPERATIONAL TESTING & START OPERATIONS
PROOF OF PRINCIPL
OPERATIONAL TESTING
TFTR HYDROGEN OPERATION
TFTR TRITIUM OPERATION
A-E TITLE I (PRELIM DESIGN)
A-E TITLE II (FINAL DESIGN)
BUILDINGS DESIGN REVIEW
BUILDINGS FINAL DESIGN REVIEW
INITIAL SITE PREPARATION
EQUIPMENT/INSTALLATION
CONSTRUCT MAIN TEST BUILDING
BUILDING BENEFICAL OCCUPANCY (REQD FOR LCP ASSY)
CONSTRUCT OTHER BUILDINGS
LCP INSTALL
ASSEMBLE COILS IN LAY DOWN AREA
TNS COIL CONTRACT
TEST
FAB AND ASSY TF COILS
TNS PROTOTYPE DES/FAB
SELECT CONCEPT FOR PROTOTYPE DES
SELECT CONCEPT FOR PROTOTYPE FAB
FINAL DATA
ASSEM SHIELDING ON VESSEL AT SITE (REF)
VACUUM VESSEL CONTRACT
FAB & ASSY
2

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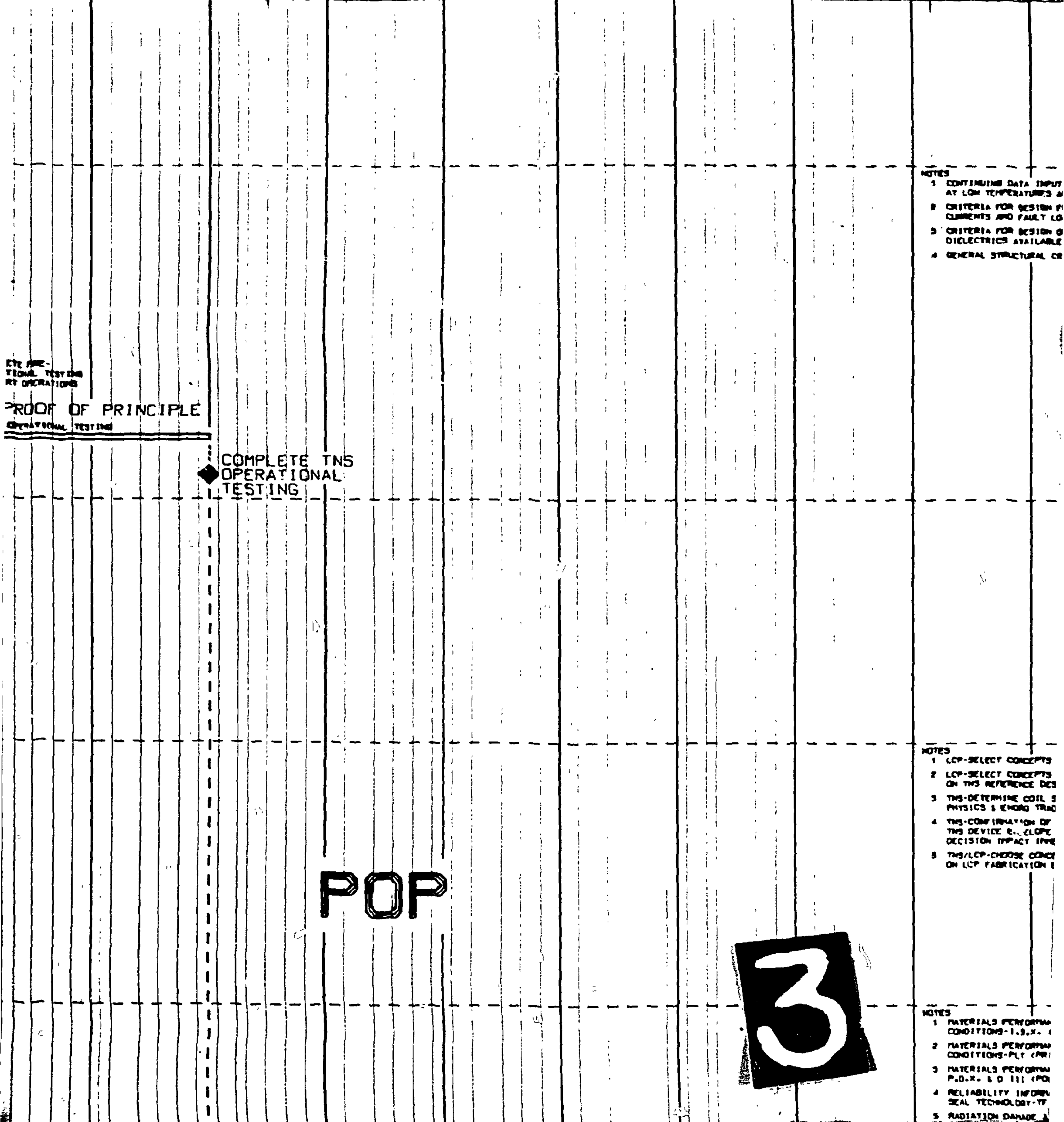

PROOF OF PRINCIPLE
OPERATIONAL TESTING
COMPLETE TNS OPERATIONAL TESTING
POP
3
NOTES
1 CONTINUING DATA INPUT
AT LOW
2 CRITERIA FOR DESIGN
CURRENTS AND FAULT
3 CRITERIA FOR DESIGN
DIELECTRICS AVAILABLE
4 GENERAL STRUCTURAL
NOTES
1 LCP-SELECT CONCEPTS
2 LCP-SELECT CONCEPTS
ON TNS REFERENCE
3 TNS-DETERMINE COIL
4 TNS-CONFIRMATION OF
TNS DEVICE
DECISION IMPACT
5 TNS/LCP-CHOOSE
ON LCP FABRICATION
NOTES
1 MATERIALS
2 MATERIALS
3 MATERIALS
4 RELIABILITY
SEAL
5 RADIATION DAMAGE

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NOTES

1. CONTINUING DATA INPUT FROM NBS/ORNL/BNL FOR MECHANICAL PROPERTIES OF MATERIALS AT LOW TEMPERATURES AND ELEVATED TEMPERATURES IN A NEUTRON ENVIRONMENT
2. CRITERIA FOR DESIGN FOR ENERGY DUMP AND LOADING DUE TO EDDY CURRENTS AND FAULT LOADING FROM ISX (IMPURITY STUDY EXPERIMENT)
3. CRITERIA FOR DESIGN OF CERAMIC INSULATORS FOR STRUCTURAL DIELECTRICS AVAILABLE FROM TFTR (TOKAMAK FUSION TEST REACTOR)
4. GENERAL STRUCTURAL CRITERIA DATA AVAILABLE FROM TFTR/D III

NOTES

1. LCP-SELECT CONCEPTS FOR COILS, CONCEPTUAL DESIGNS BASED ON EPR STUDIES
2. LCP-SELECT CONCEPTS FOR DETAILED DESIGN AND FABRICATION, BASED ON TNS REFERENCE DESIGN CHOICE AND LCP CONCEPTUAL DESIGNS
3. TNS-DETERMINE COIL STRENGTH, SIZE & TECHNOLOGY BASED ON EVALUATION OF TNS PHYSICS & ENGRG TRADE-OFF STUDY, DMFE (DIVISION OF MAGNETIC FUSION) REVIEW
4. TNS-CONFIRMATION OF S/C VS. CU, TI VS. SN, BASED UPON CONTINUING TNS DEVICE ENVELOPE DESIGN AND DETAILED LCP DESIGN. DECISION IMPACT IMMEDIATE LCP PROCUREMENT AND OVER-ALL DIRECTION
5. TNS/LCP-CHOOSE CONCEPTS FOR TNS PROTOTYPE CONCEPTUAL DESIGN BASED ON LCP FABRICATION EXPERIENCE AND CONFIRMATION OF INFORMATION

NOTES

1. MATERIALS PERFORMANCE AVAILABLE UNDER PLASMA CONDITIONS-I.S.X. (IMPURITY STUDY EXPERIMENT)
2. MATERIALS PERFORMANCE AVAILABLE UNDER PLASMA CONDITIONS-PLT (PRINCETON LARGE TORUS)
3. MATERIALS PERFORMANCE AVAILABLE UNDER PLASMA CONDITIONS-P.D.X. & D III (POLOIDAL DIVERTOR EXPERIMENT & DOUBLET III)
4. RELIABILITY INFORMATION AVAILABLE FOR MECHANICAL SEAL TECHNOLOGY-TFTR (TOKAMAK FUSION TEST REACTOR)
5. RADIATION DAMAGE & MATERIALS PROPERTIES INFORMATION

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PROOF OF PR
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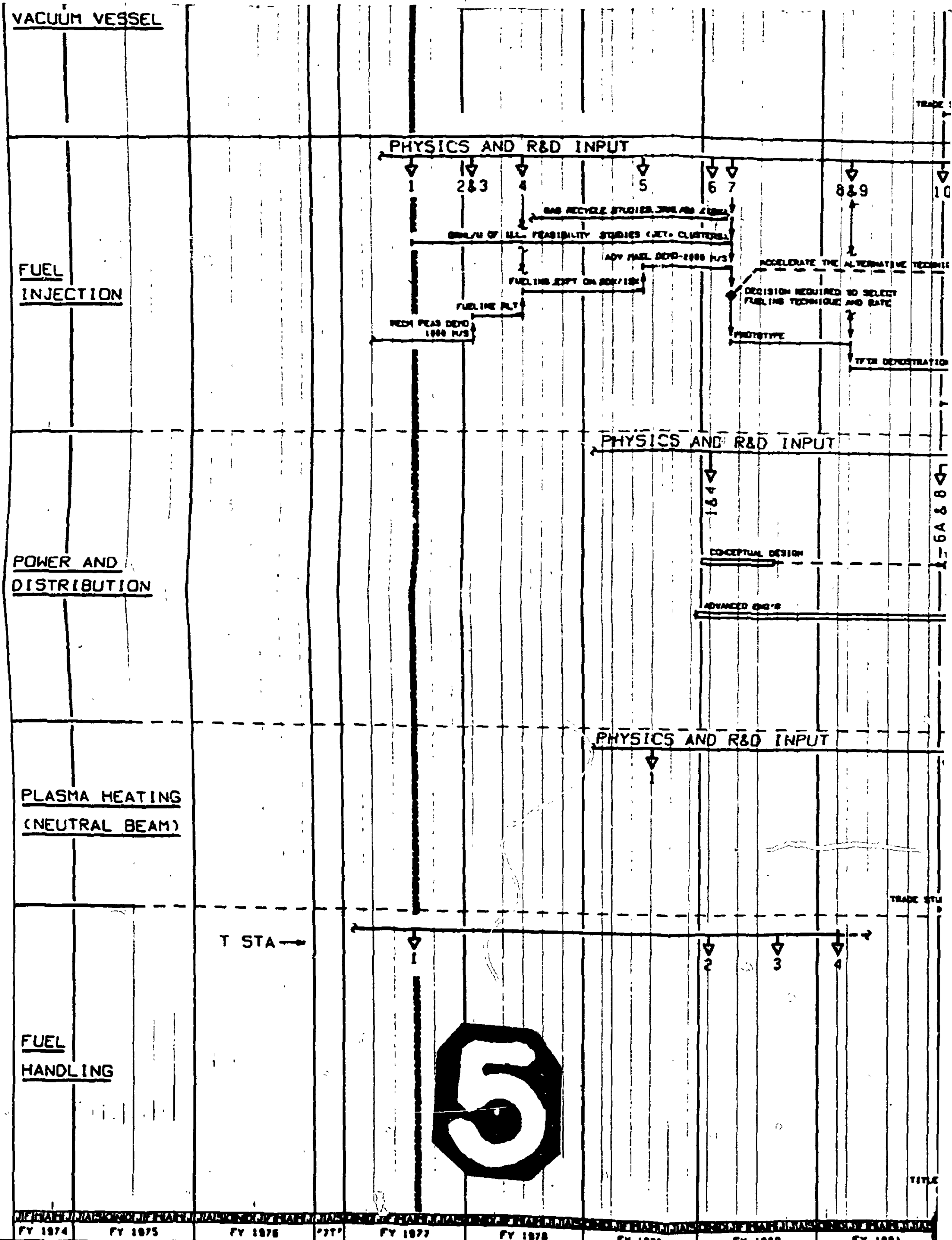

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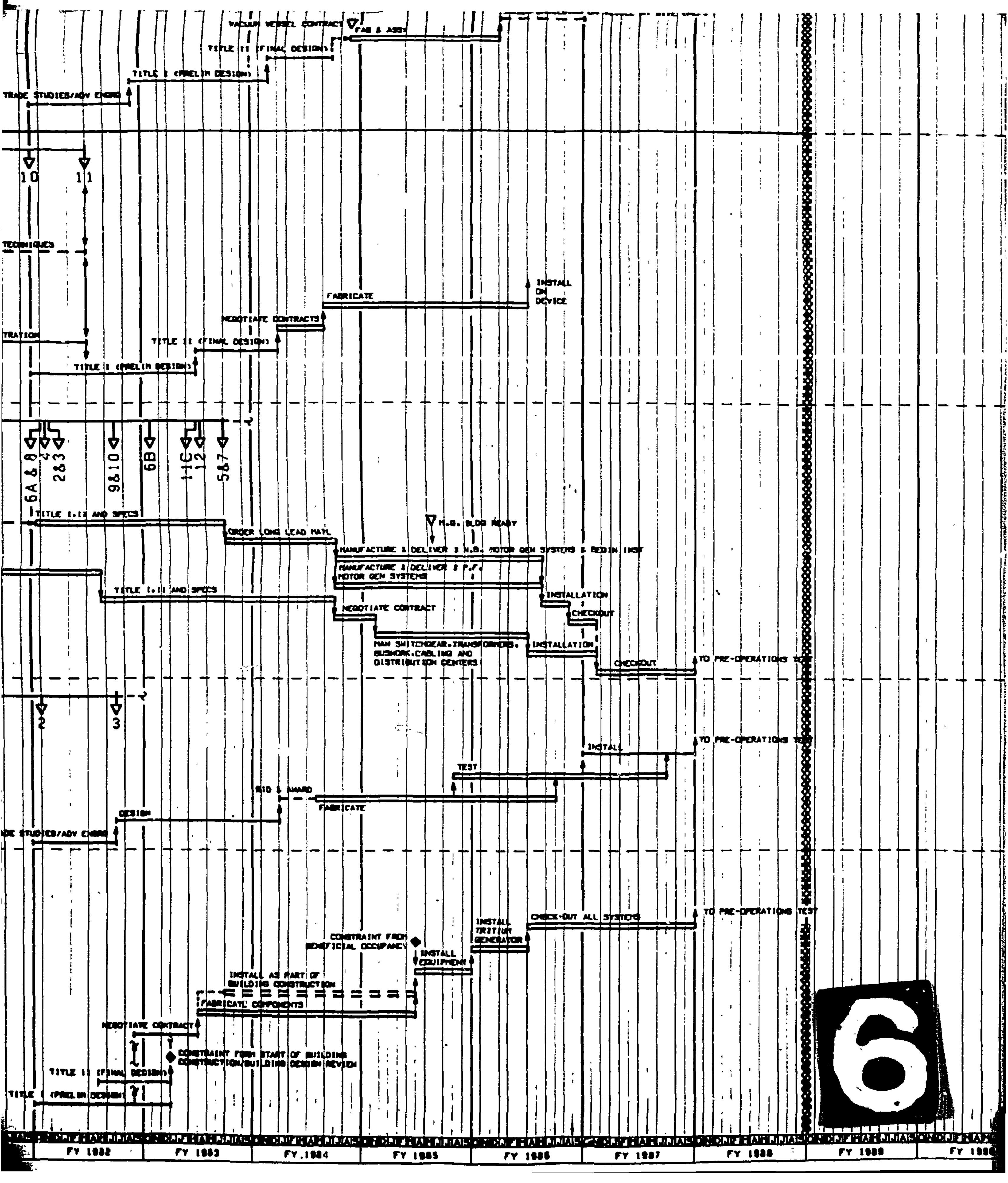
VACUUM VESSEL CONTRACT
FAB & ASSY
TITLE II (FINAL DESIGN)
TITLE I (PRELIM DESIGN)
TRADE STUDIES/ADV ENGRG
10
11
TECHNIQUES
INSTALL ON DEVICE
FABRICATE
NEGOTIATE CONTRACTS
TRATION
TITLE II (FINAL DESIGN)
TITLE I (PRELIM DESIGN)
6A & 8
4
2&3
9&10
6B
11C
12
5&7
TITLE I,II AND SPECS
M.G. BLDG READY
ORDER LONG LEAD MATL
MANUFACTURE & DELIVER 3 M.G. MOTOR GEN SYSTEMS & BEGIN INST
MANUFACTURE & DELIVER 3 P.F. MOTOR GEN SYSTEMS
TITLE I,II AND SPECS
INSTALLATION
NEGOTIATE CONTRACT
CHECKOUT
MAN SWITCHGEAR,TRANSFORMERS, BUSWORK,CABLING AND DISTRIBUTION CENTERS
INSTALLATION
CHECKOUT
TO PRE-OPERATIONS TEST
2
3
INSTALL
TO PRE-OPERATIONS TEST
TEST
BID & AWARD
FABRICATE
DESIGN
DE STUDIES/ADV ENGRG
CHECK-OUT ALL SYSTEMS
TO PRE-OPERATIONS TEST
INSTALL TRITIUM GENERATOR
CONSTRAINT FROM BENEFICIAL OCCUPANCY
INSTALL EQUIPMENT
INSTALL AS PART OF BUILDING CONSTRUCTION
FABRICATE COMPONENTS
NEGOTIATE CONTRACT
CONSTRAINT FROM START OF BUILDING CONSTRUCTION/BUILDING DESIGN REVIEW
TITLE II (FINAL DESIGN)
TITLE I (PRELIM DESIGN)
FY 1982
FY 1983
FY 1984
FY 1985
FY 1986
FY 1987
FY 1988
FY 1989
FY 1990
6

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SEAL TECHNOLOGY-TFTR (TOKAMAK FUSION TEST REACTOR)

5 RADIATION DAMAGE & MATERIALS PROPERTIES INFORMATION AVAILABLE FROM ORNL/LMFBR TEST PROGRAM

6 NEW PROGRAM REQUIREMENTS: T.N.S. FEATURE TEST DATA AVAILABLE TO DEMONSTRATE TEMPERATURE AND FLOW DISTRIBUTION IN FIRST WALL

7 DEVELOPMENT & DEMONSTRATION DATA AVAILABLE FOR STRUCTURAL DIELECTRICS (& NON NICKLE BASE ALLOYS)

8 COMPLETION OF PCD LEADING TO VACUUM TOPOLOGY: IF VACUUM BUILDING THEN NO WELDING TECHNOLOGY NEEDED

9 MATERIAL SELECTION FROM PCD: IF LMFBR INPUT IS NOT SUFFICIENT, THEN TNS MATERIALS PROGRAM TO BE INITIATED

NOTES

1 S-PRELIMINARY SELECTION OF PRINCIPAL FUELING TECHNIQUE BASED ON FUELING TECHNOLOGY SCOPING (ORNL/U OF ILL.)

2 TNS-SELECT PRELIMINARY FUELING RATE BASED ON FUELING TRADE-OFF STUDIES & PHYSICS CRITERIA

3 TNS-REQUIRES MECHANICAL FEASIBILITY DEMO-1000 M/S BASED ON ORNL PROGRAM

4 TNS-REQUIRES INJECTION DEMONSTRATION ON P.L.T. BASED ON P.L.T. PROGRAM PLAN

5 TNS-REQUIRES DEMONSTRATION ON I.S.X./P.D.X. BASED ON I.S.X./P.D.X. PROGRAM PLAN DISCUSSIONS

6 TNS-REQUIRES MECHANICAL FEASIBILITY DEMONSTRATION USING ADVANCED MATERIALS-2000 M/S BASED ON ORNL FUELING PLAN

7 TNS-SELECT FUELING TECHNIQUE AND RATE BASED ON ISX/PLT/PDX FUELING EXPERIMENTS, CONCEPTUAL DESIGN AND PHYSICS CRITERIA AVAILABLE

8 TNS-REQUIRE CONFIRMATION OF PELLET PROTYPE BASED ON SIMULATION TESTING

9 TNS-DECIDE IF PROTOTYPE IS NOT ADEQUATE, THEN PROGRAM FOR ALTERNATE TECHNIQUE WILL BE ACCELERATED

10 TNS-REQUIRES QUALIFICATION OF SELECTED ALTERNATIVE TECHNIQUES

11 TNS-REQUIRES INJECTION DEMONSTRATION OF T.F.T.R.

NOTES

1 ASSESSMENT OF N.B. (NEUTRAL BEAM) POWER REQUIREMENTS (EXCEED 150 KV)

2 DEMONSTRATION OF 150-180 KV VACUUM TUBE ELECTRONIC SWITCH-OPTIONAL NEW PROGRAM

3 DEMONSTRATION OF POLOIDAL FIELD SWITCH-NEW PROGRAM

4 P.F. ANALYSIS-M.P.G. VS. M.G.F.
- PRELIM DECISION NEED AND START DETAILED TRADE-OFF STUDIES
- COMPLETE TRADE-OFF STUDIES AND FINAL DECISION, M.P.G. OR M.G.F.

5 IF M.P.G. COMPLETE DEVELOPMENT AND DEMONSTRATION PROGRAM

6 COMPLETE ANALYSIS
- A • PRIMARY POWER NETWORK ANALYSIS
- B • RECTIFIER INTERACTION STUDY
- C • T.F. FAULT DETECTOR

7 DEVELOPE AND DEMONSTRATE T.F. PROTECTION INTERUPT SWITCH

8 PHYSICS INPUT-PLASMA DESCRIPTION

9 COMPLETE SYSTEM DEFINITION-FAULT PROTECTION (P.F. SYSTEM)

10 COMPLETE CODE DEVELOPMENT-P.F. PLUS PLASMA

11 DEVELOPMENT & DEMONSTRATION PROGRAM FOR GANGING (NEW)
- IGNITION SWITCHES
- A.C. CURRENT SHARING
- MECHANICAL SUNDRIES

12 DEVELOPMENT AND DEMONSTRATION PROGRAM FOR THYRISTOR MTBF (NEW)

NOTES

1 TNS SELECT REFERENCE ROLL OF N.B. & R.F.

2 R.F. SELECT FREQUENCY & SYSTEM (TUBE, ENERGY, LAUNCHING)

3 TNS CONFIRM N.B.-R.F. PLASMA HEATING CONTRIBUTIONS

NOTES

1 INFORMATION FLOW FROM REGULAR QUARTERLY DESIGN REVIEWS WITH TNS/TSTA (THE NEXT STEP/TRITIUM SYSTEM TEST ASSEMBLY AT LASL)

2 START OF TSTA OPERATION-DATA STARTS-BASIS ESTABLISHED

3 RESULTS FROM TSTA-FIRM DESIGN INPUT

4 FINAL TSTA RESULTS-CORROBORATION OF NORMAL AND OFF-NORMAL OPERATIONS

7

POWER TECHNOLOGY DEMONSTRATION (P.T.D.)
(FEASIBILITY STUDIES)

CONCEPTUAL PHASE

DEVICE

BLANKET SYSTEM

FUEL HANDLING

TRITIUM PROCESSING BUILDING

POWER GENERATING BUILDING

POWER GENERATING AND DISTRIBUTION SYSTEMS

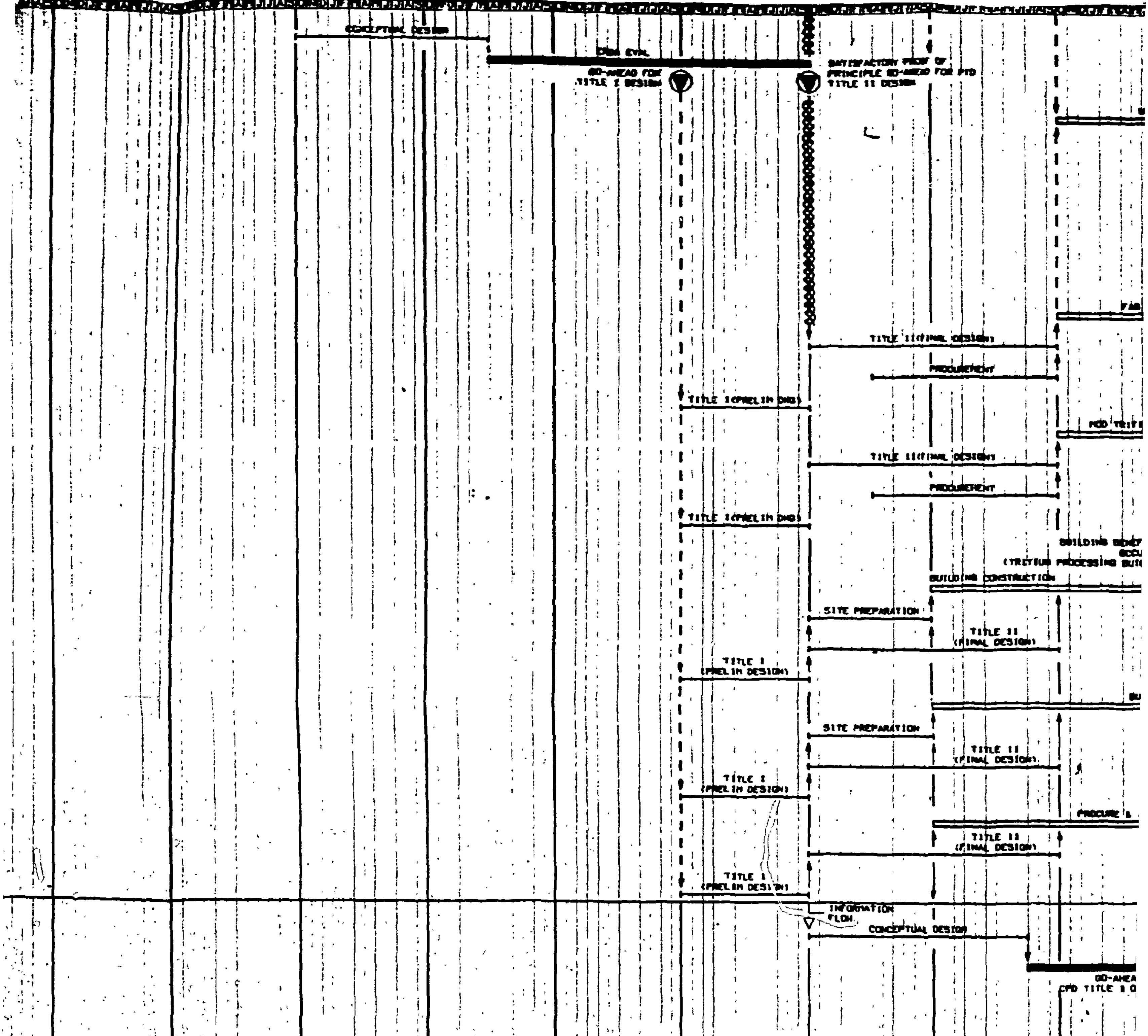
COMMERCIAL PROTOTYPE DEMONSTRATION (C.P.D.)
(FEASIBILITY STUDIES)

CONCEPTUAL PHASE

DEVICE SYSTEMS

ELECTRICAL PLANT

FY 1974 | FY 1975 | FY 1976 | FY 1977 | FY 1978 | FY 1979 | FY 1980 | FY 1981


CONCEPTUAL DESIGN
GO-AHEAD FOR TITLE I DESIGN
SATISFACTORY PROOF OF PRINCIPLE GO-AHEAD FOR PTD TITLE II DESIGN
TITLE II(FINAL DESIGN)
PROCUREMENT
TITLE I(PRELIM DWG)
TITLE II(FINAL DESIGN)
PROCUREMENT
TITLE I(PRELIM DWG)
BUILDING CONSTRUCTION
SITE PREPARATION
TITLE II (FINAL DESIGN)
TITLE I (PRELIM DESIGN)
SITE PREPARATION
TITLE II (FINAL DESIGN)
TITLE I (PRELIM DESIGN)
TITLE II (FINAL DESIGN)
TITLE I (PRELIM DESIGN)
INFORMATION FLOW
CONCEPTUAL DESIGN

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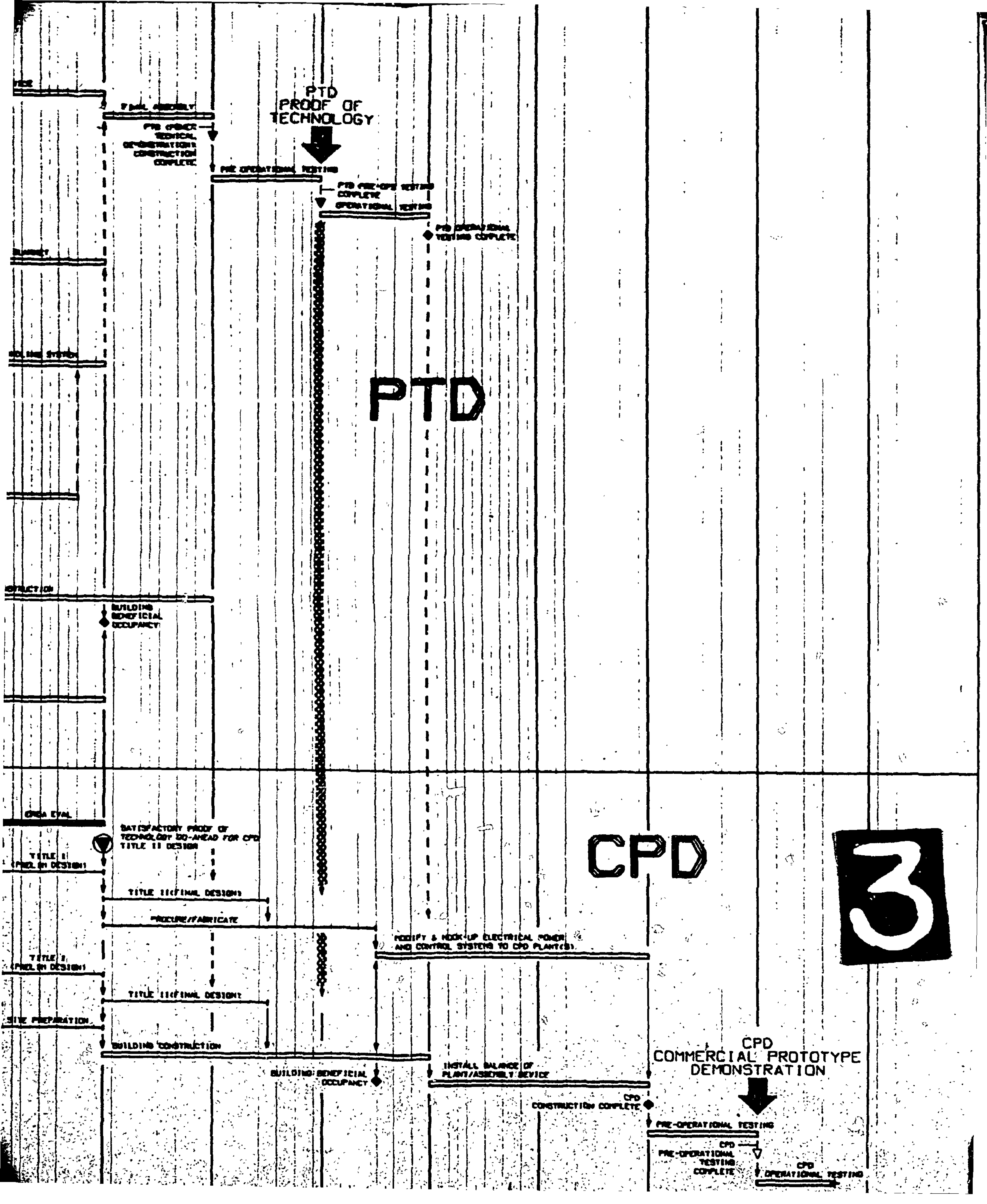

PTD
PROOF OF
TECHNOLOGY
FINAL ASSEMBLY
PRE-OPERATIONAL TESTING
PTD PRE-OPS TESTING COMPLETE
OPERATIONAL TESTING
PTD OPERATIONAL TESTING COMPLETE
CONSTRUCTION
BUILDING BENEFICIAL OCCUPANCY
PTD
SATISFACTORY PROOF OF TECHNOLOGY GO-AHEAD FOR CPD TITLE II DESIGN
TITLE I (PRELIM DESIGN)
TITLE II (FINAL DESIGN)
PROCURE/FABRICATE
CPD
3
MODIFY & HOOK-UP ELECTRICAL POWER AND CONTROL SYSTEMS TO CPD PLANT(S)
TITLE I (PRELIM DESIGN)
TITLE II (FINAL DESIGN)
SITE PREPARATION
BUILDING CONSTRUCTION
BUILDING BENEFICIAL OCCUPANCY
INSTALL BALANCE OF PLANT/ASSEMBLY DEVICE
CPD
COMMERCIAL PROTOTYPE
DEMONSTRATION
CPD CONSTRUCTION COMPLETE
PRE-OPERATIONAL TESTING
CPD PRE-OPERATIONAL TESTING COMPLETE
CPD OPERATIONAL TESTING