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INTEGRATED OPERATIONS PLAN

FOR THE

VOLUME I - ORGANIZATION PLAN

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MFTF-B

ORGANIZATION PLAN

This plan and the accompanying MFTF-B Integrated Operations Plan are submitted in response to UC/LLNL Purchase Order 3883801, dated July 1981. The Organization Plan also addresses the specific tasks and trade studies directed by the Scope of Work. The Integrated Operations Plan, which includes a Reliability, Quality Assurance, and Safety Plan and an Integrated Logistics Plan, comprises the burden of the report.

Organizational structure is fundamental to management. In the first section of this volume, certain underlying assumptions and observations are discussed setting the requirements and limits for organization. Section B presents the recommended structure itself. Section C "Device Availability vs Maintenance and Support Efforts" and Section D "Staffing Levels and Skills" provide backup detail and justification.

Section E is a trade study on maintenance and support by LLNL staff vs subcontract and Section F is a plan for transitioning from the construction phase into operation.

A brief summary of schedules and estimated costs concludes the volume.

SECTION A

ASSUMPTIONS AND RATIONALE

SECTION A

ASSUMPTIONS AND RATIONALE

1. TEST SCHEDULING

A very critical and fundamental assumption underlying this study is expressed in the following quotation from K. I. Thomassen's memo MFE/CP/79-277.

"With these considerations we envision a 13 week operating time and 5 weeks for warmup, maintenance, and cooldown, giving an 18 week cycle time. Two 8-hour shifts and an 8-hour minimal maintenance shift are envisioned each day of the week. Weekends are scheduled for more extensive operational system checks and maintenance. The 5 week shutdown will also be used for minor machine reconfiguration, and diagnostic installations or changes."

It is our understanding that this scenario has been reviewed periodically and that it represents LLNL's current thinking. We have found no inherent flaws in it and accept it as a basis for planning, given that certain consequent conclusions are implemented. (See Item 2, Maintenance Concepts).

An alternative approach deserves some consideration. Accelerated testing, of up to nine consecutive run shifts of 8 hours each, has two important advantages:

- o Elimination of daily beam conditioning
- o Reduction of component failures due to the transients associated with shutdowns and startups

We have not pursued this alternative, for the following reasons:

- o More personnel would be required to man 24-hour per day run teams (and similarly accelerated maintenance teams).
- o It builds peaks and valleys into personnel utilization.

- o It is not amenable to planning or scheduling, of either operations or maintenance.
- o In the absence of some new development, MTBF of some power supplies is expected to be a matter of hours.
- o We conceive that this plan should be descriptive of a routine extending over several years.

We do expect that some such accelerated test mode will be in effect when the device first comes on line. There will be intense interest in driving toward the Lawson Criterion as quickly as possible and formal planning will defer to urgency and enthusiasm. After some period of time, regardless of the degree of success, we would expect a management decision to transition into the long term program described herein.

2. ORGANIZATION AND STAFFING

It became apparent early in the study that the project involved three separate and distinct functions.

- o Definition, conduct, and analysis of physics experiments
- o Operation and maintenance of the experimental device, its components, and related systems
- o Engineering support for both the experiments and the device

In addition to these line functions, the novelty of all aspects of the project and its status as a major Government investment led to identifying two staff functions. These are (1) to integrate the details and procedures of project operations and to provide the mechanisms for coordination and flow of internal processes and (2) to prepare budgets, track expenditures, and perform other administrative tasks. The Project Manager will be assisted in performing these duties by a Project Planning and Control Office.

Two subtasks requiring physics expertise were defined later - planning for new device configuration and the development of new diagnostic techniques.

Analysis of the maintenance function and its place in the overall project scheme led to three significant conclusions:

- o To sustain the desired experimentation rate, online maintenance must be greatly simplified.
- o Engineering must be divorced from online maintenance.
- o Extensive engineering and logistic support must be available offline.

Flexibility and economy in the use of personnel has been a serious consideration. The plans presume that engineering and physics personnel will provide consultation services to operations and maintenance and to each other, rather than providing standby resource people within each department. Also, skilled technical support is generally available within LLNL. A small cadre of specialized personnel will be dedicated to identifiable work in offline maintenance. Other or additional skills will be called upon for overload assistance as required. These efforts are to be formalized by support requests or work orders.

3. MAINTENANCE CONCEPT

From the assumption of one "8-hour minimal maintenance shift" per day there follows the assumption that device availability can be maintained in an 8-hour shift. It follows further that the designs must provide for maximum maintainability and that extensive on- and offline maintenance support will be available. Maintenance planning should assume the most conservative case, utilizing all available access time.

The maintenance problems of the MFTF-B under the assumed scenario are to a large extent unknown since many components will be pressing the state-of-the-art and many will be the first of their kinds. Analysis indicates greater confidence in the large, expensive items (cryogenics, magnets, vacuum) than in the smaller ones (beams, heaters, and, in particular, the 275 diagnostic instruments and a comparable number of indicators and controls).

The expressed desire of MFTF-B planners is to achieve 16 hours per weekday of productive physics runs, which leaves 8 hours per weekday and 48 hours on weekends for maintenance. Access time is limiting for daily maintenance inside the vault. Maintenance personnel may not enter until radioactivity resulting from the preceding experimental runs has diminished to an acceptable level and must depart prior to the start of beam conditioning for the following experimental shift. It is assumed that all available maintenance access time should be fully utilized and a schedule has been devised to meet this objective. (See section C.)

The terms preplanned and preventive maintenance imply the assumption that all practical efforts to define and characterize maintenance problems will have been made. These include:

- o Designs should be reviewed for maintainability.
- o Sparing factors, parts availability, handling equipment, a repair/replace rationale, and in-house/outside repair criteria must be developed.

- o An engineering capability for failure analysis, automated fault isolation, trend analysis, and other failure prediction techniques should be in place.
- o Operators' and maintenance manuals will be available.

4. PERSONNEL QUALIFICATION AND UTILIZATION

Given that operation and maintenance of the device will be simplified and streamlined to the greatest practical extent, skill requirements of online personnel will be moderate. Technicians will perform routine inspection, testing, and adjustment; professional engineering skills and judgment will be on call but not physically present, except as noted. A formal training program for O&M personnel will not be needed (except for safety indoctrination).

MFTF-B equipment is located in the vault, on four floors of building 431, and in building 439. A minimum manning level is set by the necessity for surveillance of an investment representing hundreds of millions of dollars and significant national potential.

Project organization and skill levels reflect a desire to integrate fully with LLNL's engineering and support matrix. We have taken advantage of the flexibility afforded by being able to assign people directly to the project or to use people from other laboratory divisions either full or part time.

Direct and continuing manpower and skill requirements were developed by identifying the tasks required to operate the facility and to perform routine preventive and scheduled daily and weekly maintenance. Guarding against leaks of potentially explosive gases, loss of cryogenic storage, power fluctuations, and the like has also been considered.

Development of requirements for online personnel is based primarily on documentation now available and on detailed discussions with MFTF-B managers concerned with the various subsystems. Supplementing this information, experience with similar systems - cryogenic fuels, vacuum chambers and seals, distributed computer nets and automated controls, spacecraft instrumentation, and data handling - has been called upon.

5. AVAILABLE LLNL SERVICES

The following services now available within LLNL will support MFTF-B as needed for routine and special tasks, up to the point where unique or additional equipment, facilities, training, or personnel are required.

- o Budget office
- o Accounting and finance office
- o Business services (mail, forms, and records)
- o Motor pool
- o Supply and distribution (supply, inventory, and materials distribution)
- o Procurement (contracts and purchases)
- o Hazards control
- o Security administration
- o Plant engineering shops (specifications, standards, quality assurance, material fabrication, and pressure calibration)
- o Electronic engineering (specifications and standards)
- o Electronic shops (fabrication, instrumentation, calibration, and repair, ultrasonics NDE, X-ray, and fiber optics)
- o Technical information (photo, audio, TV, and printing)

6. MISCELLANEOUS

The Laboratory's standard forms and procedures (except for paragraph 5, above) are not well suited for management of a project like MFTF-B, being tailored to laboratory administration rather than to controls and processes for a major project. We are providing forms and flow charts to aid in filling this gap.

We have assumed that documentation (in particular, operator's and maintenance manuals and the several logistics plans) will be in place by the time operations begin in January 1985.

It is, of course, basic to the entire plan that all parts, components, and assemblies will "work"; that project funding will be provided as now anticipated; and that present schedules will be followed. This plan is primarily for the period beginning with test operations in early 1985. It calls attention to various actions which should be undertaken prior to that time and in many cases assumes that they will be completed. The plan does not address these actions in detail.

We have accepted direction from the LLNL Technical Contact which will result in a rather uneven Operations Plan. At his request, we have spent additional effort on budgets and manpower skills and levels, with lesser attention being given to Project Management, Configuration Management, and Documentation Control Plans. All aspects of the Work Statement are covered, but to different degrees.

SECTION B

ORGANIZATION

SECTION B

STRUCTURE

1. CRITERIA

An organizational structure should, primarily, put the assigned capabilities to their most advantageous use. Second, the structure should assemble functions into as nearly homogeneous groups as is practical, so that tasks and skills are most closely matched. A corollary of this criterion is that the interfaces between departments should be as clear and simple as possible. Third, the aggregation of functions should allow sequential delegations of authority commensurate with responsibilities for performance. Management analysts usually recommend that a manager have three to seven submanagers reporting to him. In most of the cases herein the recommended number is at the lower limit - three; this results simply from a count of the separate tasks within the respective managers' responsibilities.

2. STRUCTURE

For the MFTF-B Project, we recommend an organizational structure having four distinct entities (see figure B-1):

- a. Project Manager
- b. Physics Department
- c. Operations and Maintenance Department
- d. Engineering Department

This structure omits the business services, shops, laboratories, and supply activities that are provided by other elements of LLNL. These provisions are expected to be satisfactory and need not be integrated into the project organization. Estimates of the costs and manpower levied by the project on other LLNL elements are given in Section D, Staffing Levels and Skills.

Figure B-1. MTF-B Project Organization

3. PROJECT PLANNING AND CONTROL

We recommend that a Project Planning and Control function be formalized in the organization. It will perform many of the Project Manager's staff responsibilities, enabling him to give more attention to line responsibilities. No executive authority is implied, though the manager may delegate signature, limited expenditure approval, or other authority as he sees fit.

This office will prepare the budget and track expenditures against it, prepare or assemble progress reports, and investigate and recommend solutions to problems as assigned by the Project Manager. It will follow up and close out his decisions and provide the process for intra- and interproject coordination. It will be represented on the change control, accident, configuration control, and other boards (see figure B-2).

These functions can be performed by the Project Manager himself or by as many as three or four professionals. They are largely nontechnical in nature, though familiarity with and comprehension of the project are assumed. The full-time attention to detail, process, and coordination that can be provided by a group such as this will contribute enormously to a smooth-running and successful project.

4. PHYSICS

The Physics Department has two major missions, the conduct of experiments and advanced studies of future configurations, instrumentation, and equipment. The structure must provide unity of control for these missions, as well as for planning and adherence to schedules, acceptance of a discipline regarding procedures and routines, and observance of formal communications and coordination where required. See figure B-3.

4.1 FUNCTIONS

Except for device availability and engineering support, the functions of the physics department are the functions of the project. Attainment of project

Figure B-2. Project Planning and Control

Figure B-3. Physics Department

objectives and success in laying a foundation for fusion power will be in their hands. These functions are the performance of experiments and the analysis of data therefrom. Two other general responsibilities that clearly require physics expertise are:

- o Advanced Concepts, which is intended to include theoretical investigations and new MFTF-B configurations
- o Advanced Development, including beams and diagnostics

The department will also provide consultation and technical support to the O&M Department and to offline maintenance groups.

4.2 STRUCTURE

Assignment of certain line responsibilities is imperative in an operations plan; figure B-3 shows these relationships. We accept and endorse the present project plan that calls for three experiment teams, each of which will spend 2 weeks on the device followed by 4 weeks of data analysis, throughout a period of several months of work with a given device configuration. Each team will be divided into two shifts, with the expectation that 16 hours of runs can be supported per day.

The physics department will be headed by an Associate Project Manager. Deputy Associate Managers will be appointed for experiments and for advanced studies, and team leaders will be appointed for the working levels. Each experiment team leader should have a deputy who will act as team leader on the other of the two shifts shared by the team. These experiment team leaders will, with the O&M Chief Operator, follow the test plan during routine experiment runs. The team leader will verify test conditions and keep test logs for later analysis, and will make "quick look" evaluations to determine validity of data. He may request changes in the test plan, within the current configuration, and has the authority to suspend testing if conditions are not satisfactory.

5. OPERATIONS AND MAINTENANCE (O&M)

This department will be completely responsible for and have complete authority over all hardware involved in the project. (This includes the dedicated computer system and its associated software.) The major organizational breakdown is by working shifts, of which there will be two for experiments and three for maintenance. (On some days, two maintenance shifts will be working together.) Each shift will be headed by a chief operator or a maintenance chief, reporting to the Associate Project Manager for O&M (see figure B-4). There will be five sections within each shift, corresponding to divisions of technical specialties. See figure B-5.

5.1 DIAGNOSTICS AS PART OF O&M

Diagnostics is one of the five sections included in O&M. While this assignment is a departure from present practice, it is recommended because it will preserve unity of control over all instrumentation and because it shares the same interfaces with supporting organizations as do other subsystems on the vessel.

O&M of installed diagnostics will not infringe upon the development of new diagnostic concepts and instruments by the Physics Department and it can be compatible with repair or modification by physics personnel at the shop level. It does follow that the O&M Department will employ a number of highly qualified instrument personnel, some of whom may now be classified as physics technicians.

It is recognized that both diagnostics and beam heating technologies are pressing their states-of-the-art at present. However, if anything approaching the run time schedules planned for MFTF-B is to be realized, both must be characterized and reduced to practice in the next 3 years.

5.2 SECTION/SHIFT MATRIX

This plan provides for the presence of a lead technician and a number of technicians for each of the five sections on each of five shifts. (A proposed schedule of operations and maintenance shifts is discussed in Section C, Device

Figure B-4. Operations and Maintenance Department

Figure B-5. O&M Technical Specialties

Availability vs Maintenance and Support Efforts.) Twenty-five crews, of different sizes and skill compositions, will thus comprise the working level of the O&M effort. The sections represent technical specialties (cryogenics, for example), while the shifts will include two operations run teams and three maintenance and repair teams. See figure B-6.

Operations run teams are expected to be rather small, under the truism that if experiments are in progress there is little maintenance to be performed. The daily maintenance team will be relatively large, correcting discrepancies, preparing for the following run shifts, and working with supporting laboratories and shops.

Weekend maintenance shifts will have varying and unpredictable workloads. These shifts are the only ones who will have access to the vessel for any appreciable lengths of time. As a minimum, they will perform prescribed weekly/biweekly routines and carryover tasks from the daily maintenance team. Other weekend work may range from as little as surveillance up to major replacements, demanding close managerial attention and flexibility in staffing and scheduling.

To the extent possible, overload and nonroutine maintenance and maintenance requiring special skills or equipment should be performed by support personnel. Overtime work (on weekends) by nonassigned personnel will prove to be more economical than staffing for overloads.

6. ENGINEERING

An Engineering Department, under an Associate Project Manager for Engineering, will handle all engineering functions in support of the project. Deputy Associate Managers will be appointed for:

- o Design
- o System Engineering
- o Documentation

Representatives from each section shall be permanent members of design review, change control, configuration control, and similar boards. See figure B-7.

Figure B-6. Operations and Maintenance Shift Matrix

Figure B-7. Engineering Department

6.1 DESIGN

The Design Section will, in the post-construction period, be primarily responsible for new vessel configurations and modifications to an existing configuration, including design studies resulting from analyses by the System Engineering Section. They will prepare bid packages for contracted construction or fabrication and monitor performance and acceptance. The Design Section will include drafting as required.

6.2 SYSTEM ENGINEERING

This section will conduct analyses of equipment and procedures to improve the effective utilization of the MFTF-B device. These specifically include reliability and maintainability studies. The highly restricted access to the vessel creates a requirement for failure prediction; System Engineering must prepare failure models, analyze performance trends, and arrive at replacement-before-failure schedules of all critical parts in and on the vessel. Their responsibilities also include change impact assessments, safety systems and interlocks, and product improvement studies. Assigned engineers representing the several MFTF-B disciplines will also act as consultants to the O&M and Physics Departments.

6.3 DOCUMENTATION

The Engineering Department will act as control and repository for specifications, drawings, manuals, and other technical records of the project. The Documentation Section will maintain logs of status and changes, to include tracking released engineering vs open changes. It will maintain the originals of all documents and will reproduce copies as required for project needs.

7.0 SUMMARY

Figure B-8 shows the foregoing departmental structures combined for the entire project. Since the individuals who will occupy their positions cannot now be identified, positions can only be defined in terms of functions. Some variations may be anticipated in response to the availability of specific sets of capabilities. This is particularly true in the Physics Department where relatively more and smaller groups are planned.

Figure B-9 shows a head count for the project. These estimates are based on the task counts given in section D and, in all probability, represent minimum numbers of personnel. The column headed engineers, in the line for Project Planning and Control, means degreed professionals, all of whom need not be engineers. The 30 technicians at offline support include 6 full-time equivalents not dedicated to MFTF-B. These include specialists whose skills will be needed only occasionally and who will be called on for overloads to the assigned crews.

Figure B-8. MFTF-B Organizational Structure

	MANAGERS	PHYSICISTS	ENGINEERS	TECHNICIANS	CLERICAL
Project Manager	1			1	
PP&C		4		2	
APM Physics	1				
Dep, Adv Studies	1			1	
Concepts		6	1	1	
Development		4			
Dep, Experiments	1			4	
Shot Leaders		24	7		
APM Oprns & Maint	1			1	
Chief Operators	2		26		
Maintenance Chiefs	3		27	1	
Off-Line Support	1		30	3	
APM Engineering	1			1	
Dep, Design	1	7	5	1	
Dep, Systems	1	5	2	1	
Dep, Documentation	1		2	3	
	<u>15</u>	<u>34</u>	<u>17</u>	<u>100</u>	<u>25</u>
				<u>191</u>	

Figure B-9. Staffing Summary

SECTION C

DEVICE AVAILABILITY VS MAINTENANCE AND SUPPORT EFFORTS

1. ALLOCATION AND EFFECTIVE USE OF MAINTENANCE HOURS

The primary objective of the O&M Department and, indeed, of the whole project is to maximize the availability of the device to the Physics Department in an acceptable configuration and operable condition, within reasonable cost. This will require a balance of time and effectiveness in which the greater burden is on the latter.

2. ACCESS TIME

The expressed desire of MFTF-B planners is to achieve 16 hours per weekday of productive physics runs, which leaves 8 hours per weekday and 48 hours on week-ends for maintenance. Access time is limiting for daily maintenance inside the vault. Maintenance personnel may not enter until radioactivity resulting from the preceding experimental runs has diminished to an acceptable level and must depart prior to the start of beam conditioning for the following experimental shift. Maintenance activity outside the vault in building 431 and in adjacent buildings is assumed to be free of radiation hazard. Our study has revealed no situations of any significance in which components outside the vault cannot be maintained satisfactorily within the scheduled effort. It is assumed that all available maintenance access time should be fully utilized and a schedule has been devised to meet this objective.

The following illustration shows the tradeoff situation graphically. The diagonal line of slope -1 is the envelope of total hours and the dashed horizontal line shows the desired 80 hours of run time. The lines from the origin represent increasing levels of maintenance effectiveness. Better maintenance effectiveness will result in both greater run time availability and decreased maintenance cost.

Figure C-1 shows a recommended schedule of two experiment shifts and three maintenance shifts that will fit the desired allocation. This weekly cycle will normally continue for 3 to 6 months, the life of a given device configuration.

The following criteria for scheduling have been observed:

- o 8 hours per shift
- o 40 hours per week
- o 16 hours between shifts
- o 2 consecutive days off per week

The schedule shows the daily maintenance shift to be the day shift (weekdays, 0800 to 1600). This is done to facilitate interaction with supporting shops, facilities, and personnel throughout the laboratory. Note, however, that the essence of the schedule is sequence, rather than start time, and that the day and hour column headings can be shifted either way.

The assignment of double crews on the weekday maintenance shifts and single shifts on other days is predicated on the following:

- o If a breakdown occurs during the experiment runs, there is an urgency to effect repair or replacement before the next following experiment shift.
- o The more extensive system operational checks and preventive maintenance can be performed more thoroughly and deliberately on the weekend shifts.

	MON			TUES			WED			THU			FRI			SAT			SUN		
	8	16		8	16		8	16		8	16		8	16		8	16		8	16	
PHYSICS RUN TEAM A THIRD SHIFT FIRST SHIFT																					
OPERATIONS RUN TEAMS THIRD SHIFT FIRST SHIFT																					
MAINTENANCE AND REPAIR TEAMS A B C																					
PHYSICS RUN TEAMS B AND C MANAGEMENT ENGINEERING																					

Figure C-1. Scheduling for Physics Runs and O&M Shifts

- o Much of the lighter preventive or routine maintenance (pertaining to diagnostics, instrumentation, computer systems, and some electrical/electronic equipment) will be performed by the double crews.

3. EFFECTIVENESS

Two other areas of investment in more effective maintenance should be thoroughly investigated, under the assumption that the flow of experimental data will be limited primarily by maintenance capability. These are design for maintainability and a preplanned maintenance program.

Much of the design is, of course, now complete and construction or fabrication is underway. It is recommended that designs be reviewed and, where practical, modified to incorporate:

- o Redundancy
- o Ease of replacement
- o Ease of handling
- o Handling equipment

The following components of MFTF-B should be investigated for preplanned maintenance programs:

- o Diagnostic sensors
- o Neutral beam injectors
- o Ion pump beams
- o Neutral beam lines
- o Local control and instrumentation system

These items are located within the vault, where access will be limited. They are more subject to failure than other components (magnets, cryogenics, mechanical systems, water cooling, for example), and they are critical to device operation.

Preplanned maintenance includes a repair/replace rationale, a schedule of part replacement in anticipation of failure, and failure prediction techniques such as failure analysis, automated fault isolation, and trend analysis.

SECTION D

STAFFING LEVELS AND SKILLS

1. INTRODUCTION

This section describes our approach to providing the following analyses required by the scope of work:

- o Staffing levels
- o Mix of specialties

Figure D-1 (entitled Staffing Levels Methodology) illustrates the steps required to produce these analyses.

The first step is to identify all tasks that will result in labor charges to MFTF-8 during the operations phase (starting in 1985). Tasks are then expanded into labor matrices that include the following data:

- a. Manpower required for each task
- b. Skill levels for the manpower
- c. Estimated durations
- d. Equipment and systems utilized by the task
- e. Support services required

Toward determining labor costs, labor matrices are combined (as appropriate) into a more refined set of data that we call a schedule of manpower loading. This type of chart indicates the following:

- a. Sequence and duration of component tasks (shown graphically)
- b. Manpower and skill mix for each task
- c. Combined instantaneous manpower levels for the entire set of tasks included on the chart

Figure D-1. Staffing Levels Methodology

The schedule of manpower loading also provides an opportunity to add manpower for transition between component tasks and for shift managers. The final bottom line of this type of chart is an estimate of the number of people (by skill) required to be present during each shift throughout the duration of the set of tasks included on the chart.

The next step is to convert schedules of manpower loading into staffing levels and specialty mixes. This is done simply by adding up the number of man-shifts (by skill) shown on the schedules of manpower loading (or combined sets of schedules) in 7-day increments and then dividing 7-day man-shift totals by 5. The result is the number of employees (by skill) required to work five shifts per 7-day week. This number of employees corresponds to the number of paychecks that will be paid by MFTF-B funds (not to be confused with the number of employees present on a particular shift).

The final steps in determining labor costs require combining the schedules of manpower loading into a typical annual cycle. Then the corresponding staffing levels and mixes are proportioned and added to calculate total man-year requirements by skill.

2. ONLINE O&M

A great deal of emphasis was placed on determining staffing levels associated with online operations and maintenance (O&M) because it represents the essential manpower core for MFTF-B after 1985. Staffing levels for support or development (designs, diagnostic development, etc.) might vary significantly depending on budget cuts or system failures, whereas online O&M staffing levels represent the absolute minimum to run experiments.

2.1 LABOR MATRICES

All tasks required for direct operations and maintenance of the MFTF-B facility were categorized into the following matrices (tables D-1 through D-5):

- a. Pumpdown/Cooldown
- b. Experiment Runs

	UTILITIES STATUS CHECK AND CRYOS START-UP	CRYOPUMP PD/CD ROUGH PUMP VESSEL, AND CALIBRATE DIAGNOSTICS (10 TORR)	AT 10^{-2} TORR, LN ₂ COOL- DOWN OF CRYOPANELS & MAGNET LINER	BRING CRYOPUMPS ON LINE	AT 10^{-6} TORR, FLOWGAS IN CRYOPANELS, MAGNET COIL & GUARD VACUUM	FLOW L: PANELS
APPROX TIME: INCREMENTAL	4 HOURS	30 HOURS	< 12 HOURS	< 2 HOURS	6 DAYS	1
ACCUMULATIVE	4 HOURS	34 HOURS	46 HOURS	48 HOURS	168 HOURS	1
SKILLS	4.0 MECH TECHS 1.0 ELEC TECH	2.0 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH 2 PHY ASSOC	2.0 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	2.0 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	2.0 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	2 1.0 1.0
PRIMARY SYS/EQUIP	16 GAUGES 42 SWITCHES 452 VALVES 10 BOTTLES 3 LEVEL IND	CRYOPUMPS ROUGH VAC PUMPS VESSEL N ₂ BAFFLE	CRYOPANELS MAGNETIC SHIELDS	CRYOPUMPS - CPP 500'S - CPR 800'S	CRYOPANELS MAGNET COIL GUARD VAC SPACE	CR M
SUPPORT SYS/EQUIP	SCDS/LCIS INTERCOM LHe SYS LN ₂ SYS	ROUGH VAC SYS LHe SYS RGA NO. 4 (OPTIONAL) LN ₂ SYS LCW SYS SCDS/LCIS INTERCOM POD BOIL-OFF RET SYS ARGON SYS	LN ₂ SYS SCDS/LCIS VESSEL INTERCOM	LN ₂ SYS LHe SYS SCDS/LCIS VESSEL INTERCOM	LN ₂ SYS LHe SYS LN ₂ /GHe HEAT EXCH SCDS/LCIS VESSEL INTERCOM	1 1 1 1
SERVICE	AIR WATER POWER GN ₂ GHe ARGON	POWER WATER AIR	POWER WATER AIR	POWER WATER AIR	POWER GHe AIR WATER	
NOTES:						LHe S: THRC- VACU

GENERAL NOTE: BUILDING AND SUPPORT PERSONNEL ARE NOT SHOWN.

Table D-1. Matrix: Pumpdown/Cooldown

LOW GHe MAGNET VACUUM	FLOW LHe IN CRYO- PANELS & MAGNET COIL	EVACUATE GHe FROM GUARD VACUUM	ENERGIZE MAGNET SYS- TEM	PREEXPERIMENT BEAM CONDITIONING	OPERATIONS READINESS CHECKOUT
	1 DAY 192 HOURS	< 2 HOURS 194 HOURS	< 4 HOURS 198 HOURS	10 HOURS 208 HOURS	< 2 HOURS 210 HOURS (8.3 DAYS)
NG TECH ECH	2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	1.0 ELEC TECH 1.0 MECH TECH	4.0 ELEC TECH 1.0 PHYSICS ASSOC .1 COMP TECH	2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH
L SPACE	CRYOPANELS MAGNET COIL	GUARD VAC SPACE GUARD VAC SYS PUMPS	MAGNET SYSTEM MAGNET POWER SUPPLY	SOURCES AND POWER SUP - 20 kV, 10 MS - 80 kV, 5 SEC - 80 kV, 30 SEC - 2 kV, 30 SEC	ALL
EXCH	LN ₂ SYS LHe SYS SCDS/LCIS VESSEL INTERCOM	SCDS/LCIS INTERCOM	LHe SYS LN ₂ SYS QUENCH PROTECTION SCDS/LCIS VESSEL INTERCOM	ELEC INSTRUMENTATION DEUTERIUM SYS BEAM DUMPS INJECTOR ACCESS CRYOPUMPS LOW SYS SCDS/LCIS DIAGNOSTICS VESSEL INTERCOM	ALL
	POWER WATER AIR	POWER WATER	POWER WATER	POWER DEUTERIUM WATER	ALL
	LHe SHOULD NOT FLOW THROUGH GUARD VACUUM				MAY OCCUR DURING BEAM CONDITIONING

Table D-2. Matrix: Experiment Runs

TIME	8 HOURS	NOTES
<div>SKILLS</div> <div>BLDG 439</div> <div>CHIEF OPERATOR 1.0 O&M ENG COMPUTERS 1.0 COMP TECH</div> <div>SCDS CONSOLES 3.0 ELEC TECH 4.0 PHY ASSOC</div> <div>PHYSICS ANALYSIS 4.0 PHYSICISTS 1.0 PHY ASSOC</div> <div>BLDG 431</div> <div>2.0 MECH TECHS 2.0 ELEC TECHS</div>	<div>THE CHIEF OPERATOR IS MANAGER OF ALL PERSONNEL INVOLVED IN CURRENT EXPERIMENT</div> <div>THE PHYSICS ANALYSIS PERSONNEL SHOWN REPRESENT 1/2 OF A RUN TEAM.</div>	
PRIMARY SYS/EQUIP	DIAGNOSTICS/DDP SYS HEATING: SOURCES AND PS ECRH AND PS BEAMLINE SYS	
SUPPORT SYS/EQUIP	LHe SYS LN ₂ SYS CRYOPUMPS CRYOPANELS ROUGH VAC SYS MAGNET SYS ARGON SYS VESSEL DEUTERIUM SYS GETTERS ELEC POWER LCW DBM SYS SCDS COMPUTERS SCDS CONSOLES SOFTWARE	
SERVICE	POWER WATER AIR DEUTERIUM	

Table D-3. Matrix: Maintenance Between Daily Experiments

	MAINTENANCE OUTSIDE VAULT		MAINTENANCE INSIDE VAULT		PREEXPERIMENT BEAM CONDITIONING AND DIAGNOSTICS PREPARATION	
TIME 8 HOURS	CONTINUOUS	START: 0:00 COMPLETE: 8:00	4 HOURS	START: 3:00 COMPLETE: 7:00	1 HOUR	START: 7:00 COMPLETE: 8:00
SKILLS	CHIEFS 2.0 O&M ENGS CRYOGENICS/VACUUM 2.0 MECH TECHS 2.0 ELEC TECHS VAULT 2.0 MECH TECHS 2.0 ELEC TECHS HEATING 2.0 ELEC TECHS 2.0 MECH TECHS COMPUTERS 2.0 COMP TECHS DIAGNOSTICS 2.0 PHY ASSOC		2.0 ELEC TECHS 2.0 MECH TECHS 1.0 PHY ASSOC NOTES: PEOPLE TAKEN FROM CREW USED FOR TESTING AND MAINTENANCE OUTSIDE THE VAULT (LEFT COLUMN). ACCESS TO VAULT IS NOT PER- MITTED DURING FIRST 3 HOURS AFTER EXPERIMENT SHIFT. MAINTENANCE INSIDE VAULT MUST BE COMPLETED PRIOR TO BEAM CONDITIONING		4.0 ELEC TECHS 1.0 PHY ASSOC NOTE: PEOPLE TAKEN FROM CREW USED FOR TESTING AND MAINTENANCE OUTSIDE THE VAULT (LEFT COLUMN).	
PRIMARY SYS/ EQUIP	CRYOGENICS/VACUUM: LHe SYS, LN ₂ SYS, CRYO- PUMPS, CRYOPANELS, MAG- NET SYS, ARGON SYS, ROUGH VAC SYS VAULT: VESSEL, DEUTERIUM, GETTERS, ELEC POWER, LCW HEATING: SOURCES AND PS, ECRH AND PS, HVTS, BEAMLINE SYS COMPUTERS: SCDS COMPUTERS, CONSOLES, SOFTWARE DIAGNOSTICS		GETTER SYS SOURCES (ALL) VESSEL SENSORS DIAGNOSTICS ECRH		SOURCES AND POWER SUPPLIES -20 kV, 10 MS -80 kV, .5 SEC -80 kV, 30 SEC -2 kV, 30 SEC	
SUPPORT SYS/ EQUIP			HOISTS		ELECT INSTRUMENTATION DEUTERIUM SYS BEAM DUMPS INJECTOR ACCESS CRYOPUMPS LCW SYS SCDS/LCIS DIAGNOSTICS	
MAINTENANCE ITEMS	<u>DESCRIPTION</u>	<u>FREQUENCY (ONCE PER)</u>	<u>DESCRIPTION</u>	<u>FREQUENCY (ONCE PER)</u>	NOTE: CONDITIONING MAY EXTEND INTO RUN SHIFT IF MAINT TASKS TAKE LONGER THAN 4 HOURS.	
	FILL 1 He IN CRYOPUMPS FILL LN ₂ DEWAR GHe RECOVERY (AUTO) CHANGE LHe IN ECRH MONITOR PERF TRENDS LN ₂ SUBCOOLER SEALS REGEN PURIFIERS CHANGE OUT D ₂ ENG TESTING REPAIRS REPLACE DOWN PS	SHIFT SHIFT SHIFT SHIFT SHIFT 20 DAYS 30 DAYS 7 DAYS AS NEEDED AS NEEDED SHIFT	CHANGE GETTER ASSY. CHANGE ONE 20 kV SOURCE CHANGE ONE 80 kV SOURCE REPAIRS NOTE: WHEN A GYROTRON NEEDS TO BE REPLACED (~ EVERY 6 WEEKS), ONE MAINT ENG, ONE ELEC TECH, AND ONE MECH TECH SHOULD BE CALLED ON FOR ASSISTANCE DURING THIS SHIFT.	3-14 DAYS 1 WEEK 1 WEEK AS NEEDED		

GENERAL NOTE: BUILDINGS AND SUPPORT PERSONNEL ARE NOT SHOWN.

Table D-4. Matrix: Short Term Standby (24 - 336 Hours)

	DEENERGIZE MAGNET & REGENERATE CRYOPANELS/MAGNET SURFACES	REGENERATE CRYOPUMPS	MAINTENANCE & REPAIR	ENERGIZE MAGNET	PREEXPERIMENT BEAM CONDITIONING AND DIAGNOSTIC PREPARATION
TIME 24 - 336 HOURS	FIRST 8 HOURS		CONTINUOUS	4 HOURS BEFORE BEAM RECONDITIONING	LAST 4 HOURS
SKILLS	1.0 ELEC TECH 1.0 MECH TECH	1.0 MECH TECH 1.0 ELEC TECH	1.0 O&M ENG 3.0 MECH TECHS 3.0 ELEC TECHS 1.0 PHYSICS ASSOC 1.0 COMPUTER TECH	1.0 ELEC TECH .5 MECH TECH	4.0 ELEC TECHS 1.0 PHYSICS ASSOC
PRIMARY SYS/ EQUIP	MAGNET SYS MAGNET SYS POWER SUP CRYOPANELS	CRYOPUMPS	ALL SYS/EQUIP OUT- SIDE OF THE VESSEL	MAGNET SYS MAGNET SYS POWER SUP	SOURCES & POWER SUP -20 kV, 10 MS -80 kV, .5 SEC -80 kV, 30 SEC -2 kV, 30 SEC
SUPPORT SYS/ EQUIP	SCDS/LCIS QUENCH PROTECTION LN ₂ SYS LH ₂ SYS VESSEL INTERCOM CRYOPUMPS GN ₂ SYS	SCDS/LCIS LH ₂ SYS LN ₂ SYS ARGON SYS GN ₂ SYS ROUGH VAC SYS POD BOIL-OFF/RET SYS LCW SYS VESSEL INTERCOM	NOTE: SEE MATRIX ENTITLED "MAINTENANCE BETWEEN DAILY EXPERIMENTS" FOR DETAILS OF MAINT TASKS	SCDS/LCIS QUENCH PROTECTION LN ₂ SYS LH ₂ SYS VESSEL INTERCOM	ELEC INSTRUMENTATION DEUTERIUM SYS BEAM DUMPS INJECTOR ACCESS CRYOPUMPS LCW SYS SCDS/LCIS DIAGNOSTICS VESSEL INTERCOM
SERVICE	POWER AIR	ARGON GN ₂ POWER AIR WATER		POWER	DEUTERIUM WATER POWER

GENERAL NOTE: BUILDING AND SUPPORT PERSONNEL ARE NOT SHOWN.

	DEENERGIZE MAGNET SYSTEM	DRAIN LH FROM MAGNET & CRYO-PANEL SYSTEMS	FLOW GHe IN MAGNET COIL & CRYOPANELS	DRAIN LN ₂ FROM MAGNET LINERS	DRAIN LN ₂ FROM CRYOPANELS	ALLOW He BOIL-OFF IN CRYOPUMPS	CLOSE LN ₂ SUPPLY VALVES TO CRYOPUMPS	WARM CRYOPUMP WITH GN ₂ PURGE PRESSURIZE 760 TORR
TIME	7 DAYS							
SKILLS	.2 O&M ENG 1.0 ELEC TECH 1.0 MECH TECH	.2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	.2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	.2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	.2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	.2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	.2 O&M ENG 1.0 MECH TECH 1.0 ELEC TECH	.2 O&M ENG 1.0 MECH TECH
PRIMARY SYS/ EQUIP	MAGNET SYS MAG SYS POWER SUP	MAGNET SYS CRYOPANELS	MAGNET SYS CRYOPANELS	MAGNET LINERS	CRYOPANELS	CRYOPUMPS	CRYOPUMPS	CRYOPUMP
SUPPORT SYS/ EQUIP	SCDS/LCIS QUENCH PROTECTION VESSEL INTERCOM	SCDS/LCIS LHe SYS VESSEL INTERCOM	SCDS/LCIS LHe SYS LN ₂ SYS VESSEL INTERCOM LN ₂ /GHe HEAT EXCH	SCDS/LCIS LN ₂ SYS VESSEL INTERCOM	SCDS/LCIS LN ₂ SYS VESSEL INTERCOM	SCDS/LCIS He RECOVERY SYS VESSEL INTERCOM	SCDS/LCIS LN ₂ SYS VESSEL INTERCOM	SCDS/LCIS GN ₂ PURGE VESSEL INTERCOM
SERVICE	POWER	POWER AIR	POWER AIR	POWER AIR	POWER AIR	POWER AIR	POWER AIR	POWER AIR GN ₂
NOTES								

Table D-5. Matrix: Long Term Shutdown

WARM CRYOPUMPS WITH GN ₂ PURGE & PRESSURIZE TO 760 TORR	GN ₂ BACKFILL OF VESSEL TO 10 TORR & DIAGNOSTIC CALIBRATION	GN ₂ OR AIR BACKFILL OF VESSEL TO 760 TORR	MAINTENANCE, REPAIR			
			OUTSIDE VAULT		INSIDE VAULT, OUTSIDE VESSEL	INSIDE VESSEL
1-1/2 DAYS			SECOND SHIFT 8 HR/DAY	FIRST & THIRD SHIFTS 16 HR/DAY	SECOND SHIFT 8 HR/DAY	SECOND SHIFT 8 HR/DAY
.2 O&M ENG 1.0 MECH TECH	.2 O&M ENG 1.0 MECH TECH .1 PHY ASSOC	.2 O&M ENG 1.0 MECH TECH	2.0 MECH TECHS 2.0 ELEC TECHS	2.0 MECH TECHS 2.0 ELEC TECHS	2.0 ELEC TECHS 2.0 MECH TECHS 1.0 PHY ASSOC	2.0 MECH TECHS 1.0 ELEC TECH
CRYOPUMPS	VESSEL	VESSEL	LN ₂ SYS LH ₂ SYS LCW SYS EXT VAC SYS POWER SUPPLIES SCDS/LCIS UTILITIES		VESSEL GETTERS SOURCES ECRH DIAGNOSTICS	VESSEL MAGNET SYS INJECTOR ACCESS CRYOPANELS GETTERS DIAGNOSTICS BEAM DUMPS
SCDS/LCIS GN ₂ PURGE SYS VESSEL INTERCOM	SCDS/LCIS N ₂ VAPORIZER INTERCOM	SCDS/LCIS N ₂ VAPORIZER (OPTION) FILTERED AIR SYS INTERCOM	INTERCOM		SCDS/LCIS INTERCOM	SCDS/LCIS INTERCOM
POWER AIR GN ₂	POWER AIR	POWER AIR	POWER AIR		POWER AIR	POWER AIR
		WITH GN ₂ BACK- FILL, VENTILA- TION AIR IS REQUIRED PRIOR TO VESSEL ACCESS			ACCESS NOT PERMITTED DURING FIRST 2 DAYS AFTER EXPERIMENT CYCLE LABOR REQUIRE- MENTS TO INSTALL AND TEST DIAGNOSTIC OR DESIGN CHANGES ARE NOT SHOWN IN THIS MATRIX	ACCESS NOT PERMITTED DURING FIRST 8 DAYS AFTER EXPERIMENT CYCLE TASKS INCLUDE PREVENTIVE MAINT ON DIAGNOSTICS, SENSORS, AND ECRH ITEMS

- c. Maintenance Between Daily Experiments
- d. Short Term Standby
- e. Long Term Shutdown

2.1.1 PUMPDOWN/COOLDOWN. This matrix (table D-1) covers the 7 to 10 days prior to experiment runs, beginning with pumpdown/cool-down of the cryopumps and ending with preexperiment beam conditioning and a readiness checkout.

2.1.2 EXPERIMENT RUNS. Tasks conducted in buildings 431 and 439 that directly affect physics experiment shots are shown in this matrix (table D-2), including online physics analyses by run teams.

2.1.3 MAINTENANCE BETWEEN DAILY EXPERIMENTS. Daily maintenance tasks such as filling Dewars and monitoring performance trends are covered in this matrix (table D-3). The conditions that will exist during experiment runs will also exist during the daily maintenance shift except that the radiation hazard will diminish sufficiently to allow access inside the vault, if necessary. A duration of 8 hours would allow approximately 4 hours inside the vault and 1 hour of preexperiment beam conditioning. This maintenance mode could apply up to durations of 24 hours.

2.1.4 SHORT TERM STANDBY. This matrix (table D-4) covers the following tasks:

- a. Maintenance inside the vault that could not be completed during a daily maintenance shift
- b. Regeneration of cryopanel, magnet surfaces, and cryopumps
- c. Normal maintenance outside the vault

Under standby conditions, the vacuum is maintained, but the magnet is deenergized and cryogenic surfaces will be raised to 10°K (part of regeneration).

2.1.5 LONG TERM SHUTDOWN. This mode will involve deenergizing the magnet system, warming cryogenic surfaces, and pressurizing the vessel to atmospheric

conditions. Bringing the vessel to a steady state shutdown will require approximately 8 days, after which access into the vessel will be permitted. Maintenance and repair tasks in the vault and in the vessel are covered by this matrix (table D-5).

2.2 SCHEDULES OF MANPOWER LOADING

The matrices described in the preceding paragraphs were combined into schedules of manpower loading for the proposed 19-week cycle (based on two experiment shifts each weekday separated by daily maintenance shifts).

The five matrices were combined in the following manner:

<u>Matrices</u>	<u>Schedules of Manpower Loading</u>
Pumpdown/Cooldown	Pumpdown/Cooldown
Experiment Runs	O&M Cycle
Maintenance Between Daily Experiments	
Short Term Standby	
Long Term Shutdown	Long Term Shutdown

2.2.1 PUMPDOWN/COOLDOWN. The basic information from the matrix remained essentially unchanged in converting to the schedule of manpower loading (figure D-2) except that a chief operator for each shift was added. As few as three people are required for certain shifts during helium cooldown and as many as 13 are necessary prior to experiment runs.

2.2.2 O&M CYCLE. Three matrices were combined to develop this schedule of manpower loading (figure D-3) because together they represent a 7-day O&M cycle:

- 10 experiment shifts (weekdays)
- 4 daily maintenance shifts (weekdays)
- 7 consecutive shifts of short term standby (weekends)

Each experiment run shift and each daily maintenance shift will require 18 people. Between 9 and 14 people must be on hand during short term standby shifts.

MONDAY TUESDAY WEDNESDAY THURSDAY FRIDAY

TASKS

NOTE: EACH TASK INCLUDES A CHIEF OPERATOR

EXPERIMENT OPERATIONS, THIRD SHIFT

FIRST SHIFT

MAINTENANCE BETWEEN DAILY EXPERIMENTS

MAINTENANCE OUTSIDE VAULT

MAINTENANCE INSIDE VAULT (OPTIONAL)

PRE-EXPERIMENTAL BEAM CONDITIONING

SHORT TERM STANDBY

GENERAL MAINTENANCE AND REPAIR

DEENERGIZE MAG/REGEN CRYOPANELS
AND MAG SURFACES

REGENERATE CRYOPUMPS

ENERGIZE MAGNET SYSTEM

PRE-EXPERIMENTAL BEAM CONDITIONING

SCDS MONITORING AND
CONTROL VERIFICATION

TIME (HOURS)	24	48	72	96
8	2 8	2 8	2 8	2 8
	2 8 2	2 8 2	2 8 2	2 8 2

8

2

3

8

2

3

8

2

3

8

2

3

LABOR TOTALS BY SHIFT

O&M ENG	1	1	2	1	1	2	1	1	2	1	1	2
MECH TECH	2	2	6	2	2	6	2	2	6	2	2	6
ELEC TECH	5	5	6	5	5	6	5	5	6	5	5	6
PHYSICIST	4	4	0	4	4	0	4	4	0	4	4	0
PHY ASSOC	5	5	2	5	5	2	5	5	2	5	5	2
COMP TECH	1	1	2	1	1	2	1	1	2	1	1	2

TOTAL	18	18	18	18	18	18	18	18	18	18	18	18
-------	----	----	----	----	----	----	----	----	----	----	----	----

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SKILL REQUIREMENTS BY TASK

O&M ENG	MECH TECH	ELEC TECH	PHYSICIST	PHY ASSOC	COMP TECH
1.0	2.0	5.0	4.0	5.0	1.0
1.0	2.0	5.0	4.0	5.0	1.0
2.0	6.0	6.0		2.0	2.0
INCL ABOVE					
INCL ABOVE					
1.0	3.0	3.0		1.0	1.0
	1.0	1.0			
	1.0	1.0			
	.5	1.0			
		4.0		1.0	
		1.0			1.0

NOTE:
 SHORT TERM STANDBY MODE CAN BE SCHEDULED AFTER ANY EXPERIMENT SHIFT ON ANY DAY FOR CHANGES (OUTSIDE VESSEL) REQUIRING BETWEEN 24 AND 336 HOURS.
 FOR CHANGES REQUIRING BETWEEN 8 AND 24 HOURS, 2 OR 3 CONSECUTIVE DAILY MAINTENANCE SHIFTS CAN BE SCHEDULED.

1	2	1	1	1	1	1	1	1	1	1
2	6	2	2	4	4	3	3	3	4	3
5	6	5	5	4	4	3	3	3	5	7
4	0	4	4	0	0	0	0	0	0	0
5	2	5	5	1	1	1	1	1	1	2
1	2	1	1	1	1	1	1	1	2	1
18	18	18	18	11	11	9	9	9	13	14

Figure D-3. Schedule of Manpower Loading: O&M Cycle

2.2.3 LONG TERM SHUTDOWN. The information on this schedule of manpower loading (figure D-4) is the same as the matrix data except for the addition of a chief operator each shift and some people for periodic verifications and checkouts. A typical day during shutdown (after warmup and pressurization) will require 13 people on the day shift and a minimal crew of five during each of the two night shifts.

2.3 STAFFING LEVELS/MIXES

Required staffing levels and specialty mixes were calculated for each phase of operations and maintenance represented on the schedules of manpower levels. Summaries of the calculations are given in tables D-6, D-7, and D-8.

A graphic representation of staffing levels over a 19-week example operations/maintenance/shutdown cycle is given in figure D-5 (online operations and maintenance only). The dip in staffing during long term shutdown would be filled partially by technicians for repairs or installation of design changes and by physicists conducting offline analyses. These tasks are addressed in paragraphs 4. and 5. of this section.

3. OFFLINE MAINTENANCE SUPPORT

Offline maintenance support staffing was analyzed on the basis of the following MFTF-B functions required to support the tasks and labor matrices identified in figure D-1:

- a. Offline shops and labs
- b. Spares/materials/consumables provisioning
- c. Supply, distribution, and storage
- d. ILS information/data management and work control

3.1 OFFLINE SHOP AND LAB FUNCTIONS

The primary shop and lab functions required are as follows:

- a. LRU/SRU/Spares detailed inspection and/or acceptance test
- b. Servicing, cleaning, disassembly, repair, and reassembly

KEY:

HOURS FOR PREPARATION, CHECKOUT, AND TRANSITION

HOURS TO COMPLETE TASK

CHIEF OPERATOR

SAT	SUN	MON	TUE	WED	THUR	FRI	SAT
TIME (HOURS)	24	48	72	96	120	144	168

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GH₂ TO MAG & CRYOPANELS

NOTE: LABOR SHOWN ON THIS CHART IS FOR MINIMAL ONLY. LABOR TO INSTALL AND TEST A RECONFIGURATION PRESENTED HERE BECAUSE IT IS SO VARIABLE, SUCH AS BE ADDITIVE TO THE LABOR FOR MINIMAL MAINTENANCE.

ALLOW He BOIL-OFF IN CRYOPUMPS

CLOSE LN, SUPPLY TO CRYOPUMPS

GN₂ PURGE TO CRYOPUMPS

GN₂ BACKFILL VESSEL TO 10 T

BACKFILL VESSEL TO 760 T

OUTSIDE VAULT, SECOND SHIFT

OUTSIDE VAULT, THIRD SHIFT

FIRST SHIFT

INSIDE VAULT

INSIDE VESSEL

PENETRATIONS CHECK

SCDS MONITORING & CONTROL VERIF.

FINAL MAINTENANCE TASK CHECK

LABOR TOTALS BY SHIFT

O&M ENG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
MECH TECH	4	3	3	3	3	3	5	3	3	5	3	3	5	3	3	5	3	3	5	3	7
ELEC TECH	3	3	3	3	3	3	5	3	3	5	3	3	5	3	3	5	3	3	5	3	5
PHYSICIST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
PHY ASSOC	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	1	0	0	1
COMP TECH	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TOTAL	9	7	7	7	7	7	12	7	7	12	7	7	12	7	7	12	7	7	12	7	15

Figure D-4. Schedule of Manpower Loading: Long Term Shutdown

Table D-6. Staffing Levels/Mix for Pumpdown/Cooldown

	PUMPDOWN/ COOLDOWN WEEK		LAST 24 HR DAY BEFORE EXPERIMENTS	
	MAN-SHIFTS PER WEEK	NUMBER OF EMPLOYEES	MAN-SHIFTS	NUMBER OF EMPLOYEES
O&M ENG.	21	4	3	3
MECH TECH	26	5	4	4
ELEC TECH	27	5	12	12
PHYSICIST	0	0	0	0
PHY ASSOC	0	0	2	2
COMP TECH	4	1	2	2
		15		23

Table D-7. Staffing Levels/Mix for O&M Cycles*

	TYPICAL 7 DAY, O & M WEEK		LAST 24 HOUR DAY BEFORE LONG TERM SHUTDOWN**	
	MAN-SHIFTS PER WEEK	NUMBER OF EMPLOYEES	MAN-SHIFTS	NUMBER OF EMPLOYEES
O&M ENG	25	5	4	4
MECH TECH	68	14	10	10
ELEC TECH	103	21	16	16
PHYSICIST	40	8	8	8
PHY ASSOC	66	13	12	12
COMP TECH	26	5	4	4
		66		54

*INCLUDES 1. EXPERIMENT RUN SHIFTS
2. MAINTENANCE BETWEEN DAILY EXPERIMENTS
3. SHORT TERM STANDBY (WEEKEND FOR EXAMPLE)

**INCLUDES TWO EXPERIMENT SHIFTS AND ONE MAINTENANCE SHIFT,
BUT NOT SHORT TERM STANDBY. THERE MAY BE SEVERAL (~5)
OF THESE DAYS BEFORE LONG TERM SHUTDOWN.

Table D-8. Staffing Levels/Mix for Long Term Shutdown*

	FIRST WEEK		SUBSEQUENT WEEKS		LAST WEEK BEFORE PUMPDOWN/ COOLDOWN	
	MAN-SHIFTS PER WEEK	NUMBER OF EMPLOYEES	MAN-SHIFTS PER WEEK	NUMBER OF EMPLOYEES	MAN-SHIFTS PER WEEK	NUMBER OF EMPLOYEES
O&M ENG	21	4	21	4	21	4
MECH TECH	74	15	70	14	62	12
ELEC TECH	73	15	63	13	55	11
PHYSICIST	0	0	0	0	0	0
PHY ASSOC	5	1	7	<2	5	1
COMP TECH	1	<1	0	0	0	0
TOTAL		36		33		28

*INCLUDES WARMUP AND PRESSURIZATION

Figure D-5. Staffing level for Online O&M

- c. Item adjustment, tuning, retest, and/or calibration
- d. Troubleshooting, fault isolation, and/or failure analyses investigation
- e. New equipment/configuration mockup and fabrication
- f. New equipment/configuration test and evaluation

3.2 OFFLINE SHOPS AND LABS STAFFING CALCULATIONS

MFTF-B hardware processing through the shops and labs was then estimated for the group 1 and 2 systems shown in the Integrated Logistic Plan, figures 2-3 and 2-4.

The currently available, limited MTBF/MTTR data was evaluated in the analyses as well as known experience factors from integrated systems of similar complexity. Straight line averaging for each system and maintenance function was utilized. The manpower calculations for offline staffing were then totaled from the group 1 and 2 offline maintenance work load charts shown in tables D-9 and D-10.

The staffing required to support the spares provisioning function, the supply function, and the information management function was then added to the shop and lab total resulting in the following total offline staffing level and skill mix.

- 1 Offline MFTF-B Maintenance Chief
- 22 Electrical Technicians
- 8 Mechanical Technicians
- 8 Clerical

Six of the mechanical technicians are full-time equivalent LLNL, resulting in a total head count of 33 MFTF-B dedicated offline personnel.

3.3 OFFLINE CONTRACT REWORK

The following items are planned for offsite contract rework and as such are not reflected in the MFTF-B/LLNL offline staffing level:

- a. ECRH gyrotron rework
- b. Arc chamber rework
- c. DDP and LSI disc/tape drive rework

Table D-9. Offline Maintenance Workload - Group 1 Systems

	LRU/SRU INSPECTION AND ACCEPTANCE TEST		FAULT ISOLATION AND FAILURE INVESTIGATION		DISASSEMBLY, REPAIR, REASSEMBLY		ASSEMBLY ADJUSTMENTS AND RETEST/ CALIBRATION		NEW EQUIPMENT MOCKUP AND FABRICATION		TOTAL HR/WK
	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	
MECHANICAL COMPONENTS	TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		
CRYO SYSTEM*	3	10	1	24	3	20	4	12			
	30		24		60		48		—		162
VESSEL AND VACUUM SYS	1.5	10	0.5	16	2	20	2	12			
	15		8		40		24		—		87
STRUCTURAL, GAS, WATER, AIR	0.5	8	0.5	12	1	20	1	10			
	4		6		20		10		—		40
HANDLING & ACCESS, FIXTURES, ETC.*			0.25	12	0.5	8	1	4	1	24	
	—		3		4		4		24		35

* — 1 MECH MFTF-B DEDICATED

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INCLUDES INFORMATION RESEARCH, TEST EQUIPMENT HOOK UP, DATA ENTRY,
HANDLING & PACKAGING, OBTAINING SRU'S, R&QA RECORDS, ETC.

Table D-10. Offline Maintenance Workload - Group 2 Systems

	LRU/SRU INSPECTION AND ACCEPTANCE TEST		FAULT ISOLATION AND FAILURE INVESTIGATION		DISASSEMBLY, REPAIR, REASSEMBLY		ASSEMBLY ADJUSTMENTS AND RETEST/ CALIBRATION		NEW EQUIPMENT CONFIGURATION EVALUATION		
ELECTRICAL COMPONENTS	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	ITEM QTY PER WK	HOURS PER ITEM	
	TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		TOTAL HR/WK
BEAM SYS	4	8	0.5	24	8	16	8	12	0.25	100	
	32		12		128		96		25		293
ECRH SYS	2	10	0.5	24	1	24	2	20	0.07	200	
	20		12		24		40		14		110
MAGNET (PS)	1	10	0.3	28	0.5	24	1	20	0.04	200	
	10		9		12		20		8		59
INSTRUMENTATION AND DIAGNOSTICS	3	12	2	28	2	32	4	24	0.25	100	
	36		56		64		96		25		277
CONTROL & COMPUTER SYSTEMS	2	16	0.25	24	0.25	24	1	24	0.03	200	
	32		6		6		24		6		74

TEST EQUIPMENT CALIBRATION, TOOLING MAINTENANCE, LLNL SHOP/LAB COORD., S&DC INTERFACE

80

INCLUDES INFORMATION RESEARCH, TEST EQUIPMENT HOOKUP, DATA ENTRY,
HANDLING & PACKAGING, OBTAINING SRU'S, R&QA RECORDS, ETC.

893

4. EXPERIMENTS AND ANALYSES

Physics run teams will spend most of their time conducting offline analyses. The run team labor required for experiment runs is covered in section 2.

The following manpower and skills are proposed for a single physics run team:

- 1 Physicist - Experimentation Leader
- 1 Physicist - Deputy Leader
- 2 Physicists - Beams Specialists
- 2 Physicists - Diagnostics Specialists
- 2 Physicists - Plasma Specialists
- 2 Physics Associates - Assistants

A total of 24 physicists and 6 physics associates will be required to staff three run teams.

Additional manpower will be required for offline, quasi real time applications program development. One full-time programmer, a part-time software engineer, and a part-time computer technician are proposed for this task.

5. DEVELOPMENT

Development includes the following group of tasks:

- o Design cycles
- o Diagnostic development
- o Software development
- o Change Request processing
- o Contract support for changes
- o Filing of baseline and change documents
- o Engineering support requests
- o Papers, publications, and reports
- o Physics concept studies

For development tasks, it was convenient to eliminate labor matrices and directly plot a single schedule of manpower loading (figure D-6). This was possible because the tasks involved little of the experiment hardware and could be accomplished during the day shift on weekdays.

Many of the development tasks listed in figure D-6 required estimates of average manpower, durations, and frequencies based on the past experience of interviewed engineers. For example, the average design cycle from concept design to installation and testing was assumed to take approximately 21 weeks. Another example is change request processing, in which initial reviews were assumed to occur weekly, yet only one out of three requests were assumed to result in an impact assessment.

Over the 26 weeks covered by figure D-6, the manpower and skill requirements remain relatively level, with the exception of mechanical and electrical technicians. The primary development tasks for technicians is in the fabrication, installation, and testing of new designs and diagnostics. Since many of these tasks would occur during a shutdown period (no experiment runs), at least six technicians (three mechanical and three electrical) from the experiment runs and daily maintenance shifts could be utilized to smooth out the reduced O&M staffing requirement at the end of a 19-week cycle (see figure D-5).

The following is the recommended staffing level and mix of specialties for development tasks based on the schedule of manpower loading:

Engineering

Design Engineering

6 Design Engineers

1 Software Engineer

1 Programmer

4 Draftsmen

} Could assist in Physics Department
part time

Systems Engineering

3 Systems Engineers

2 Reliability, Quality Assurance, and Safety (R,QA,S) Engineers

2 Logisticians

Figure D-6. Schedule of Manpower Loading: Development

SKILLS BY TASK AND ORGANIZATION

[illegible]

D-37/D-38

8

Documentation

- 1 Computer Documentation Specialist
- 1 Technical Writer
- 3 Clerical

Physics

Advanced Studies Concepts

- 6 Design Engineers
 - 1 Software Engineer
 - 1 Programmer
- } Could assist in Physics Department
part time

Development

- 4 Physicists

The mechanical and electrical technicians required only a portion of the time for design cycles and diagnostic development and are not shown in the preceding staffing list.

6. MANAGEMENT

Staffing recommendations for management and administration were based on the organization study in annex B. The following is a summary of proposed manpower and skills:

- 1 Project Manager (PM)
 - 1 Systems Engineer
 - 1 Procedures Specialist (Planner)
 - 1 Costs Specialist (Planner)
 - 1 Scheduling Specialist (Planner)

} PP&C
- 1 Associate PM - Physics
 - 1 Deputy Associate PM - Advanced Studies
 - 1 Deputy Associate PM - Experiments

- 1 Associate PM - O&M
- 2 Chief Operators
- 4 Maintenance Chiefs

- 1 Associate PM - Engineering
 - 1 Deputy Associate PM - Design
 - 1 Deputy Associate PM - Systems Engineering
 - 1 Deputy Associate PM - Documentation

7. SUMMARY

In this section, the staffing and skill requirements for tasks (given in preceding sections) are rearranged into personnel assignments by organization. Table D-11 summarizes each organization's requirements including additional personnel for clerical tasks.

In summary, the following personnel will be required during the MFTF-B operations phase:

MFTF-B Dedicated Personnel

- 1 Project Manager
- 3 Planners
- 37 Physicists
- 25 Engineers
- 94 Technical
- 25 Clerical
- 185

LLNL Personnel

- 6 Technical

Total: 191

Table D-11. Personnel by Organization

	MANAGERIAL			PROFESSIONAL					TECHNICAL										CLERICAL	SUMMARY BY ORGANIZATION					
	PROJECT MANAGER	ASSOCIATE PM	DEPUTY ASSOC PM	CHIEF OPERATORS	MAINTENANCE CHIEFS	PHYSICIST	DESIGN ENG	SYSTEMS ENG	R, QA, S ENG	SOFTWARE ENG	CONTRACT ADMINISTRATOR	PLANNER	LOGISTICIAN	PROGRAMMER	COMP TECH	PHY ASSOC	MECH TECH	ELECTECH			DRAFTSMAN	COMP DOC SPEC	DOC SPEC	TECH WRITER	
ORGANIZATION																									
PROJECT MANAGEMENT PROJECT MANAGER PPAC	1							1				3											1 1 2	1 PROJECT MANAGER 1 ENGINEER 3 PLANNERS 3 CLERICAL 8	
PHYSICS ADVANCED STUDIES CONCEPTS DEVELOPMENT EXPERIMENTS		1	1			0 4 24			1				1			6							1 1 4	37 PHYSICISTS 1 ENGINEER 8 TECHNICAL 6 CLERICAL 52	
OPERATIONS AND MAINTENANCE ONLINE OPERATIONS SHIFTS ONLINE MAINTENANCE SHIFTS OFFLINE MFT-B MAINT SUP		1		2*	3*	1									2 10 3	4 10 11	2 22						1 1 8	7 ENGINEERS 77 TECHNICAL 10 CLERICAL 34	
ENGINEERING DESIGN SYSTEMS ENGINEERING DOCUMENTATION		1	1 1 1				6		3	2	1			1					4		1	0	1	1 1 1 3	16 ENGINEERS 9 TECHNICAL 6 CLERICAL 31
LLNL SUPPORT OFFLINE LLNL MAINT SUP HAZARDS CONTROL CONTRACT ADMINISTRATION									1		1												8	6 TECHNICAL	
* THESE PEOPLE WOULD LIKELY BE O&M ENGINEERS																							181 TOTAL		

SECTION E

MAINTENANCE BY LLNL STAFF VS SUBCONTRACTOR STAFF

1. INTRODUCTION

A trade study on the subject of subcontracted versus in-house maintenance must acknowledge the conflicts between laboratory and project values. This particular study, which seeks to optimize MFTF-B operations, is necessarily biased in favor of the project's interests. LLNL objectives of maintaining a stable, highly competent work force and the capability for performing advanced research and development programs of national importance must be considered. Methods and practices for achieving such objectives are neither competitive nor compatible with a commercial or project-oriented approach. On the other hand, the merits of the MFTF-B project dictate a highly efficient, cost-effective management to meet the prospects of reduced budgets and program stretch-out.

Effective use of personnel is a value shared by both LLNL and MFTF-B. If this operations plan is adopted, the online operations and maintenance function will approach a routine of surveillance, component replacement, and minor adjustment and repair. The present laboratory staff is markedly overqualified for this kind of work and their assignment will lead inevitably to job dissatisfaction, boredom, inattention, poor performance, and eventual separation.

The skill levels of present LLNL employees will be essential in the plan for offline maintenance. Major repairs will be conducted in shops operated by other divisions of LLNL, with the dividing line between major and minor to be defined in detail in the Logistics Plan.

The true compromise to be worked out within the laboratory is not whether online O&M should be subcontracted, but rather the degree to which offline maintenance should be performed by laboratory employees dedicated full time to the project or part-time, responsive only to demand.

2. LLNL STAFF

The laboratory has a very well-qualified staff of engineers and technicians who have gathered a great deal of experience in research and development work. They are particularly competent in the areas required for fusion technology. Total manpower costs chargeable to the MFTF-B project are quite high, due primarily to the laboratory policy of retaining this pool over peaks and valleys of workload. LLNL direct pay scales are believed to be competitive in the Bay area for given skill levels.

3. SUBCONTRACTOR STAFF

An independent subcontractor would be free to select personnel whose qualifications match job requirements and whose wages would be in proportion thereto. Since a major element of this plan is the reduction of operations and maintenance effort to the minimum necessary routine, it follows that skill levels and base wages would be low. A subcontract structure tailored to the specific conditions and needs of the project could further reduce overall costs.

Additionally, there is a presumed benefit to be derived from experienced, professional management, per se. This can lead to simplified procedures, consolidation and cross-utilization of resources, and minimal unproductive activities. A commercial contractor also has somewhat more freedom in adjusting staffing levels to current needs.

4. CONCLUSIONS

It is recommended that online operations and maintenance be performed by subcontract to a competitively selected company. Offline maintenance requiring advanced skills and judgment should be performed by LLNL.

Two approaches to project organization for O&M are shown on the attached charts. Figure E-1 is identical with figure B-4 and shows a high degree of subcontractor integration into the project, such that the subcontractor Site Manager is, or

Figure E-1. Operations and Maintenance Department

closely approaches being, the Associate Project Manager for O&M. Since this minimizes the project-subcontract interface, it will be the least cost arrangement. Figure E-2 shows a staff of project employees detailed to oversee the subcontractor's work. This will provide greater technical expertise within the O&M Department and may lead to better coordination with LLNL shops and offline maintenance. Care must be taken, however, to assure that oversight does not become direction; the benefits of subcontracted O&M management will be lost if it merely provides bodies to work with or under project personnel.

Figure E-2. Operations and Maintenance Department

SECTION F

TRANSITION TO OPERATIONS

SECTION F

TRANSITION TO OPERATIONS

The current construction program will phase down during calendar year 1984 and facility shakedown will occur during the first half of 1985. Three sets of actions in addition to construction should be accomplished in the next 3 years:

- o Documentation
- o Subcontract support structure
- o Training

1. DOCUMENTATION

The following outline of titles represents the documentation felt to be necessary or highly desirable for effective planning, operations, records, and control.

PLANS:

- Operations
- Logistics
- Reliability, Quality Assurance, and Safety
- Configuration Management
- Training
- Documentation
- Project Management
- Experimentation
- Automation
- Manuals (for each major subsystem)
- Operator's
- Maintenance

DESCRIPTIVE MATERIAL:

Necessary

System Documentation List
 (Drawing Tree)
System Specification*
Electrical Schematic*
Panel Schedules
System Mechanical Schematic*
Electro-Mechanical Schematic*
Instrumentation Measurement List
Component Fabrication Drawing
Final Assembly Drawing
 Cable
 Equipment
 Panel
Parts List
Spares List*
Sensor Location/Mounting
Procedures
 Acceptance Test
 Qual/Calibration/Validation
 Troubleshooting
 Maintenance and Repair
Component Maintenance Drawing
O&M Requirements and Specifications

Desirable

Interface Control Drawing
 (System Interface)
Component Specification
 (Source Control)
Piping Diagram
One-line Power Diagram
Logic Diagram (Flow Chart)
Wiring Diagram
 Wire/Cable/Conduit
As-Built Drawings

* Mandatory for Configuration Control

2. SUBCONTRACT SUPPORT STRUCTURE

Decisions should be made whether or not to subcontract for certain items in support of MFTF-B. Implementation of affirmative decisions should include subcontractor selection. Negotiated terms and procedures should be in place by late 1984.

Supply of spare/replacement parts
Repair/rework of critical items
Operations and maintenance

3. TRAINING

The background for skill requirements is developed elsewhere in this plan. In summary, the following points are relevant to the training program:

- o The existing LLNL Hazards Control Education Program is adequate.
- o Required O&M skills closely parallel available engineer and technician backgrounds. Formal classroom training will not be required; on-the-job training will be adequate.
- o TMX operations will be phased down in time to release experienced personnel for MFTF-B.
- o Further training for engineers and physicists is not required.

3.1 O&M CREW TRAINING

The online operations crews should have the same skills and receive the same training as the maintenance crews. A total of about 70 O&M personnel needs to be indoctrinated into the details of the MFTF-B facility. To keep crew sizes at a minimum, each crew member must have a general knowledge of all systems and be able to recognize irregularities outside his own area of expertise while the problems are still small. Each crew member's knowledge of whom to contact and his ability to assist experts in other fields will minimize overall operating costs.

Crew on-the-job training can be a productive period while the learning process is underway.

- a. An audit of documentation to hardware enforces familiarization with the systems and identifies deficiencies.

- b. Participation in hardware installation supplies a base for understanding maintenance activities.
- c. Being part of checkout and acceptance teaches operational needs, procedures, and a background in troubleshooting.

The times indicated in figure F-1 will allow the operations trainee to replace site activation personnel as competence is gained. The last months of the buildup should see the majority of the trainees performing as full-fledged workers. Note that the full complement of trainees is for 24 hours per day operation, which may be more than can be managed on one shift. If this proves true, a rotation system can be devised to reduce the number on site at any given time.

3.2 ESTIMATED TRAINING COSTS

Personnel on LLNL rolls prior to initiation of training for MFTF-B will have had personnel indoctrination and Hazards Control Education courses; therefore, there is no cost to MFTF-B. As the trainees will be productive workers most of the time and performing useful audits some of the other time, only a fraction of the \$2.3 million for salaries should be chargeable to training. About 25 percent or \$575,000 should be a fair training cost above activation requirements.

4. OPERATIONAL BASELINE INTEGRATION

MFTF-B project managers must assure themselves that the operations documentation is complete and accurate. Even though several subsystem contracts call for complete documentation, including both technical descriptions and manuals, full system and integrated operations instructions will still be missing. Not only will existing and scheduled documentation need to be reviewed but additional documents representing composite systems and detailed planning must be prepared.

4.1 PERCEIVED NEEDS

The individual plans, manuals, and hardware descriptions listed on the previous pages must be prepared or reviewed to assure that:

Figure F-1. Operational Team Buildup

Design drawings and specifications are complete and accurate and reflect revisions due to fabrication, installation, and testing activities.

The design-furnished O&M documentation is complete and accurate and design has specified all O&M actions engineering deems necessary.

Hazard analyses have been performed on all systems and equipment and failure modes and effects analyses (FMEA) have been prepared on all critical systems. These results should be combined into one data base.

Spares information is codified as to level of repair, failure rates, quantities on hand, maintenance instructions, and standardization, using the information gained during the acceptance, activation, and integration testing of the facility systems, subsystems, and equipment.

Integrated O&M instructions (as opposed to detailed manuals) are developed.

Levels of required control for each subsystem are selected.

4.2 IMPLEMENTATION

These actions may be accomplished within the MFTF-B project (by early activation of the dedicated engineering group) by the LLNL Engineering Division or by a subcontract for engineering services (which could be managed by a cadre for the PP&C office) (see figure F-2).

Figure F-2. Baseline Integration Effort

SECTION G

SCHEDULES AND COSTS

SECTION G

SCHEDULES AND COSTS

This section presents order-of-magnitude estimates of costs and times for events and tasks described in this report for the transition years 1984 and 1985. All costs are calculated in 1981 dollars, with salaries at average LLNL rates.

1. INSTALLATION AND CHECKOUT

Three managers and 11 technicians will be assigned to the project in the first quarter of 1984, growing to 7 managers (including 5 shift O&M chiefs) and 52 technicians by the end of the year. These personnel will participate in installation, acceptance testing, and service of equipment scheduled for delivery in 1984. Salary costs will be \$2,300,000 for the year. Most of this effort is properly allocable to the installation and test and facility preparation accounts, with 25 percent, or \$575,000, as the estimated cost for training.

2. PHYSICISTS

No estimate is made of the number of physicists to be assigned to MFTF-B in 1984. Effort will include experiment planning and possibly work in advanced concepts and development; however, the magnitude of these tasks and, in particular, the rate of transfer from TMX or other projects are unknown. Thirty-four physicists will be required for MFTF-B operation and the summary below shows only this step function in January 1985.

3. BASELINE INTEGRATION

The documentation tasks discussed in Section F, Transition to Operations, will require approximately 12 man-years of technical effort in 1984. Assuming that 75 percent of the cost will be engineers' salaries and 25 percent at technician/technical writer rates, the cost will be \$850,000.

4. PERSONNEL COSTS

It is assumed that the shakedown period (the first 6 months of CY 1985) will require a 25 percent overload of engineer and technician costs (overtime plus additional offline support) in the first quarter and 10 percent in the second quarter. The remainder of CY 1985 and ensuing years will be at a steady state mode. The table below summarizes the planned personnel buildup and related costs by calendar quarter.

	1984					1985				
	J F M	A M J	J A S	O N D	J F M	A M J	J A S	O N D		
Personnel (Numbers)										
Managers	3	3	5	7	15	15	15	15		
Physicists					34	34	34	34		
Engineers	8	10	10	12	21	19	17	17		
Technicians	13	25	37	54	135	119	108	108		
Clerical	3	3	4	6	22	22	22	22		
Personnel Costs (\$1,000)	425	640	870	1,220	3,550	3,280	3,080	3,080		

5. POWER AND CONSUMABLES

Electricity is by far the largest cost in this category, at an estimated 52 million kilowatthours or \$2.013 million per year. Refrigeration of cryogenics accounts for 59 percent of this expense. In addition, resupply of nitrogen, helium, and deuterium will cost \$680,000 per year during sustained operations.

6. SPARES

The following table summarizes the results of our analysis of replacement parts. Initial costs are extracted from the MFTF-B Work Breakdown Structure estimates; sparing factors are judgmental applications of experience on comparable systems.

HARDWARE SUBJECT TO REPLACEMENT

SYSTEM	INITIAL	INITIAL SPARES		ANNUAL SPARES	
	COST, \$M	%	\$M	%	\$M
Magnet, Power Supply	2.3	60	1.36	10	0.23
Magnet, Other	5.5	15	0.83	3	0.17
Vessel	6.2	40	2.47	3	0.19
Control & Diagnostics	7.0	60	4.20	20	1.40
SSNBPS	44.2	30	13.25	5	2.21
ECRH	5.5	50	2.73	40	2.18
External Vacuum	1.0	40	0.40	10	0.10
Cryogenics	7.5	50	3.75	5	0.38
LCIS	<u>3.5</u>	<u>25</u>	<u>0.87</u>	<u>5</u>	<u>0.17</u>
Totals	82.6	(36)	29.86	(8.5)	7.03

7. COST SUMMARY

The table below summarizes the dollar costs (in thousands) of the items discussed in this section.

<u>Calendar Years:</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>
Personnel			
Training	575		
Documentation	850		
Other Buildup	1,725		
Operations		12,990	12,320
Power		2,010	2,010
Consumables		680	680
Spare Parts	29,860	7,030	7,030