

INTERN EXPERIENCE
NASA AMES RESEARCH CENTER

AN INTERNSHIP REPORT

by

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of Texas A&M University
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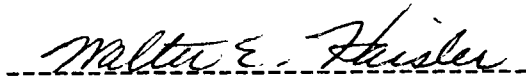
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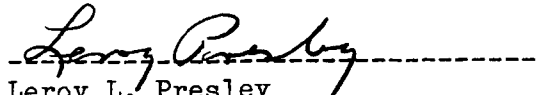
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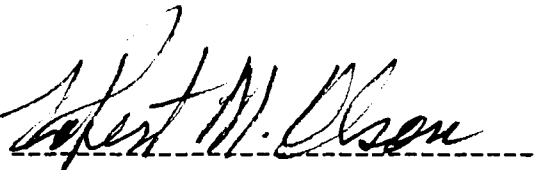
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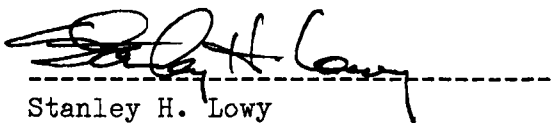
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December 1984

ABSTRACT

INTERNSHIP EXPERIENCE , NASA AMES RESEARCH CENTER

AN INTERNSHIP REPORT (Dec. 1984)

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This report is an account of my Doctor of Engineering Internship at the NASA Ames Research Center, Moffett Field, Ca., 94035. The Internship covered the period, September, 1983, through August, 1984. The report highlights the human relations and organizational interaction aspects of the Internship. Several lessons were learned, particularly in dealing with architectural and engineering firms, their cost estimates, and with matrix organizations that, except for existing on paper, functionally are vaporous. These lessons are discussed herein in some detail.

The Internship assignment was to serve as the Project Manager for the Fiscal Year (FY) 1984 Construction of Facilities Project: CONSTRUCTION OF FLUID MECHANICS LABORATORY (\$3.9 million). The assignment began with the start of the design phase of the project and will continue through the final design stage. At the end of the Internship, the design was 95% complete and all long-lead items had been procured.

DEDICATION

This report is dedicated to my family: My wife, Pamela; my daughters, Rebecca and Wendy; and my sons, Preston and James. I wish to acknowledge the sacrifice they all made while I was absent from them for the better part of a year. Special credit goes to Pamela who was unfailing in her prayers, encouragement, and extra effort in carrying the full load.

Frank W. Steinle, Jr.

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* Preliminary Engineering Report

CHAPTER I

ORGANIZATION OF INTERNSHIP REPORT

The body of this report is organized into six topics (CHAPTER II through CHAPTER VII). The goal of the discussion for each topic is:

CHAPTER II - INTRODUCTION

In this chapter, the background of the Internship project, Internship objectives, organizational structure, expectations, assignment details, and planned approach are introduced.

CHAPTER III - INTERNSHIP EXPERIENCE

Herein, the Internship experience, with emphasis on the human element is discussed. Featured are perspectives, interactions with individuals and the organizations they represent, and how they affected the progress of the Internship.

CHAPTER IV - WORK PERFORMED

The nature of managerial and technical work performed is discussed in this chapter. Many of the managerial functions and experiences are highlighted in the preceding two chapters. The discussion of management work here is more of a summary nature. In the case of technical work performed, most of the information is first introduced in this chapter.

The Journal used as model for style and format for this report is the "Journal of Aircraft"

CHAPTER V - CHRONOLOGY

The chronological data provided herein covers the project from the start of the Internship to the present. It is provided as an aid to an orderly view of the Internship.

CHAPTER VI - LESSONS LEARNED

This chapter discusses the major lessons learned. These lessons will have lasting effect on my approach to engineering management.

CHAPTER VII - ACCOMPLISHMENT OF OBJECTIVES

The purpose of this chapter is described in the title. The Internship objectives are recalled and the degree to which they were accomplished is discussed.

CHAPTER II

INTRODUCTION

INTERNSHIP OBJECTIVES

The primary objective of the Internship assignment, Project Manager for the "FY 84 Construction of Facilities Project - CONSTRUCTION OF FLUID MECHANICS LABORATORY", was "to develop the engineering and managerial skill necessary to function effectively as the manager of a complex facility design and construction project". The full text of the Internship Objectives is contained in Appendix I.

The assignment location was the NASA Ames Research Center, Moffett Field, California. I have been at the Ames Research Center since being assigned here by the US Air Force as part of the staff to augment the wind tunnel testing in support of the F-111 aircraft development program. I was assigned as a wind-tunnel test engineer in the Aeronautics Division, now renamed the Aerodynamics Division. I have remained in this Division (in a civilian capacity since 1965) and since 1975, have been the Assistant Chief of the Aerodynamic Facilities Branch (formerly, the Experimental Investigations Branch).

The birth of the Internship project began in the Aerodynamics Division (User) prior to my tour of educational leave in 1982 at Texas A & M University to work toward the degree of Doctor of Engineering. Although the project did not originate in my Branch, I was aware of the project and was involved to a limited degree. The

was aware of the project and was involved to a limited degree. The Fluid Mechanics Laboratory project, when completed, will provide a 1900-square-foot main laboratory building and a large-volume compressor system housed in a separate building. The compressor will provide the necessary suction capability to power in-draft wind tunnels housed within the laboratory. The tunnels will be used in conducting basic research in the field of fluid mechanics. Included in the main building will be an area dedicated to the development of non-intrusive (laser) instrumentation for the measurement of fluid flows in the tunnels. The building also will include space for offices, a control/computer room, a conference room, a dark room, and wash rooms. A discussion of the project history will be presented later in this chapter.

It was understood that a new and different assignment would be required if the Internship were to be at NASA Ames. Consequently, it was my goal to obtain this particular assignment. The selection of courses at Texas A&M were structured to augment my experience and appropriate opportunities were used to informally negotiate this assignment. Further, the Internship Objectives were proposed in view of both the known problems with Construction of Facilities (C of F) projects and my expectations for what was accomplishable.

The Objectives are broken down into three categories: Technical, Managerial, and Leadership. A listing of the text from the Internship Objectives along with a discussion of my expectations at

the onset are presented as follows:

Technical Objectives

The first objective is, "Assure that the prioritized technical objectives of the project are met. This will require close coordination between User requirements and analysis efforts performed by engineering support personnel assigned to the project manager.". Both the evolution and existence of a negotiated set of "User Requirements"¹ and a "Preliminary Engineering Report" ² (PER) were known. These will be discussed later in this chapter. Among these, what the User wanted and what NASA promised Congress were supposed to be well defined. Based on past exposure, insufficient effort was expected to have been put into either document to preclude both the need for changes and the usefulness of changes in scope and concept. It was also known that engineering personnel would be matrix-assigned to the project. Further, because of the small budget (\$3.9 million) in comparison with the scope of the problems associated with the \$30 million repair effort for the 40x80/80x120-foot wind tunnel, the other projects which totaled more than \$35 million, and the general understaffing, The project staff were not expected to be either co-located or assigned on a full-time basis. Consequently, considerable coordination effort was expected to be required to develop the project's technical requirements and optimize the design.

The second objective is "Be sensitive to the desire of the User to add innovative technology to the project as new ideas are generated.

Plan dates to afford maximum opportunity to add new or change concepts." The assignment as Project Manager would be in the Systems Engineering Division (different line-management organization). This Division expected a firm set of requirements from which to evolve an optimum design within the cost and budget constraints. The need for and/or desirability of making some changes in the requirements was anticipated. I was sensitive to my organizational origin, the possibility of having to manage the laboratory some day, and the need to "freeze" the design. Consequently, particular effort on not freezing an element of the design until necessary was planned. It was expected that some reluctance to this approach would be encountered.

Managerial Objectives

The first objective is "Assure that the project costs are determinable at any given time. This will require the establishment of cost accounting and control procedures for the project." A systematically-generated estimate for the cost of the project was expected to exist. It was expected that a means of cataloging the costs would be devised (e.g., computer-based) and that expenditures would be charged against these. Control was expected to be simple since the Project Manager would be in the approval chain for expenditures.

The second objective is "Assure that schedules are met. This will

require constant review of plans, objectives and progress. When shortages are projected, negotiations for additional or redistributed resources will be required." The principal resource available was people (and very few of those). By virtue of unwritten policy, any additional funds required would have to come from a reduction in the project itself. Of course, some funds from non C of F budgets could be used under appropriate circumstances. Most of the negotiations required to maintain schedules were expected to center around the availability of people.

The third objective is, "Maintain an up-to-date awareness of project problems, progress, and anticipated needs." Due to the anticipated scattering of personnel, a combination of team meetings as well as one-on-one interaction with both NASA and contractor (A&E) personnel would be required. The initial design stage, up to the concept definition (15% design) milestone, was expected to be the most critical.

The fourth objective is, "Prepare and present managerial summary reports to top level NASA management to keep them informed of the project's status." Routine monthly briefings to the Director of the Systems Engineering and Computer Systems Directorate and monthly reports to NASA Headquarters were expected. Weekly briefings of an informal nature to the next lower level (Division) and an occasional briefing to NASA Headquarters personnel would be required.

The fifth objective is "Negotiate engineering change orders promptly." In the course of the design and procurement of any long-lead items, changes are inevitable. "Horror stories" wherein the concept was to make the change and quote the price later were common knowledge. I resolved to stay ahead of any such problems.

Leadership Objectives

The first objective is "Provide positive direction to the project so that no time is lost and expenses are kept to a minimum." Both the fragmented staff and the relationship with the User organization were expected to be a possible source of delay. For example, it took two years to evolve the User's requirements. Consequently, the need for extra effort in communicating with the User was expected.

The second objective is "Promote team identity among the various personnel matrixed to the project through communications." Accomplishing this objective was expected to require team meetings, personal interaction, active member participation in the decision process, and member involvement in the generation of a project newsletter.

The third objective is "Maintain close monitoring and communications with contractors to assure accurate accounting of progress, costs, and quality of work." The need for both frequent and thorough inspection of progress and quality was expected.

The fourth objective is "Assure that team members have positive feedback of work effectiveness." The accomplishment of this objective was expected to require the taking of time to focus on the efforts of each person and provide feed back accordingly.

INTERNSHIP ASSIGNMENT

The Internship assignment was to be the Project Manager for the C of F Project CONSTRUCTION OF FLUID MECHANICS LABORATORY. In this section, Job Description, Organizational Relationships, C of F Project Process, Assignment Objectives, and Nature and Duties of Job will be discussed.

Job Description

In the Introduction to the Internship Objectives, it was stated, "One of the first objectives will be to negotiate a job description for this internship position." Due to management choice, this negotiation did not take place. While attending Texas A&M, my position as Assistant Chief of the (then) Experimental Investigations Branch was filled by an individual who was designated as Acting Assistant Chief. This was done by administrative choice and did not require a formal competition for the position. The principal reason behind this was two fold: A reorganization of the Aerodynamics Division was in

progress and it placed no additional administrative burden to leave me listed as having the job description of Assistant Chief.

Functionally, full freedom to carry out the assignment within whatever guidelines that would go with an official assignment as Project Manager was given. Had an official job description been negotiated, the job description in Appendix II would have been submitted. This description can be distilled to

Be experienced in facility engineering project management

Negotiate successfully for resources

Get the job done on time and within budget

Be prepared to defend the project status and direction

Be firm, if necessary, but keep everyone happy.

Organizational Relationships

The full scope of project responsibilities and organization is defined in the "Project Management Plan"³. Organizational relationships for the project from the project level to the NASA Administrator, NASA Headquarters are shown in Fig. 1 (taken from the Management Plan). Correspondingly, the relationship for the project from the team member level to the NASA Ames Research Center's Directorate level is shown in Fig. 2.

With reference to Fig. 1, the lines of communication and funding to the Ames Center for institutional and programmatic (research) matters

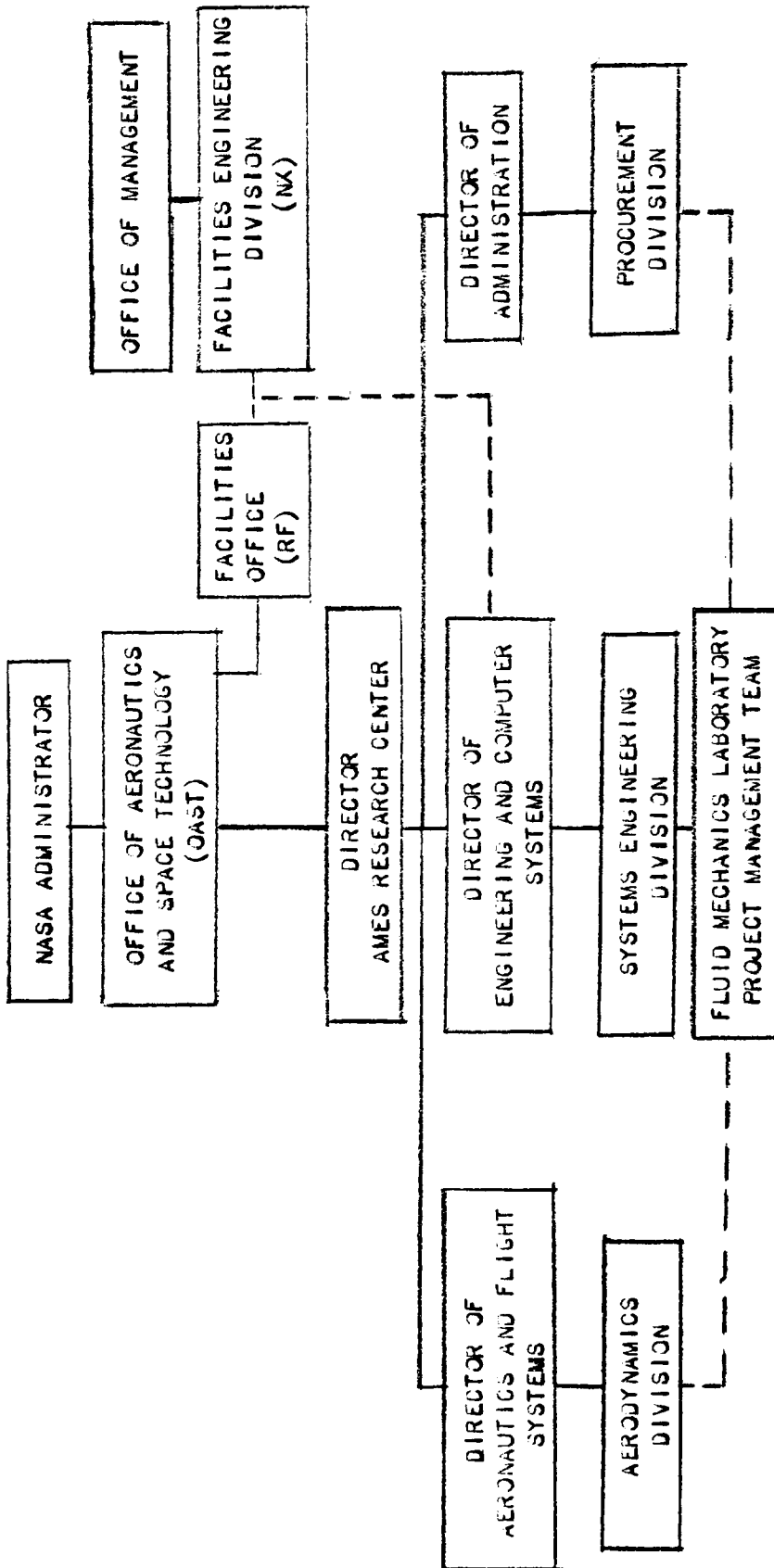


Fig. 1 ORGANIZATIONAL RELATIONSHIP - NASA HQ TO PROJECT LEVEL

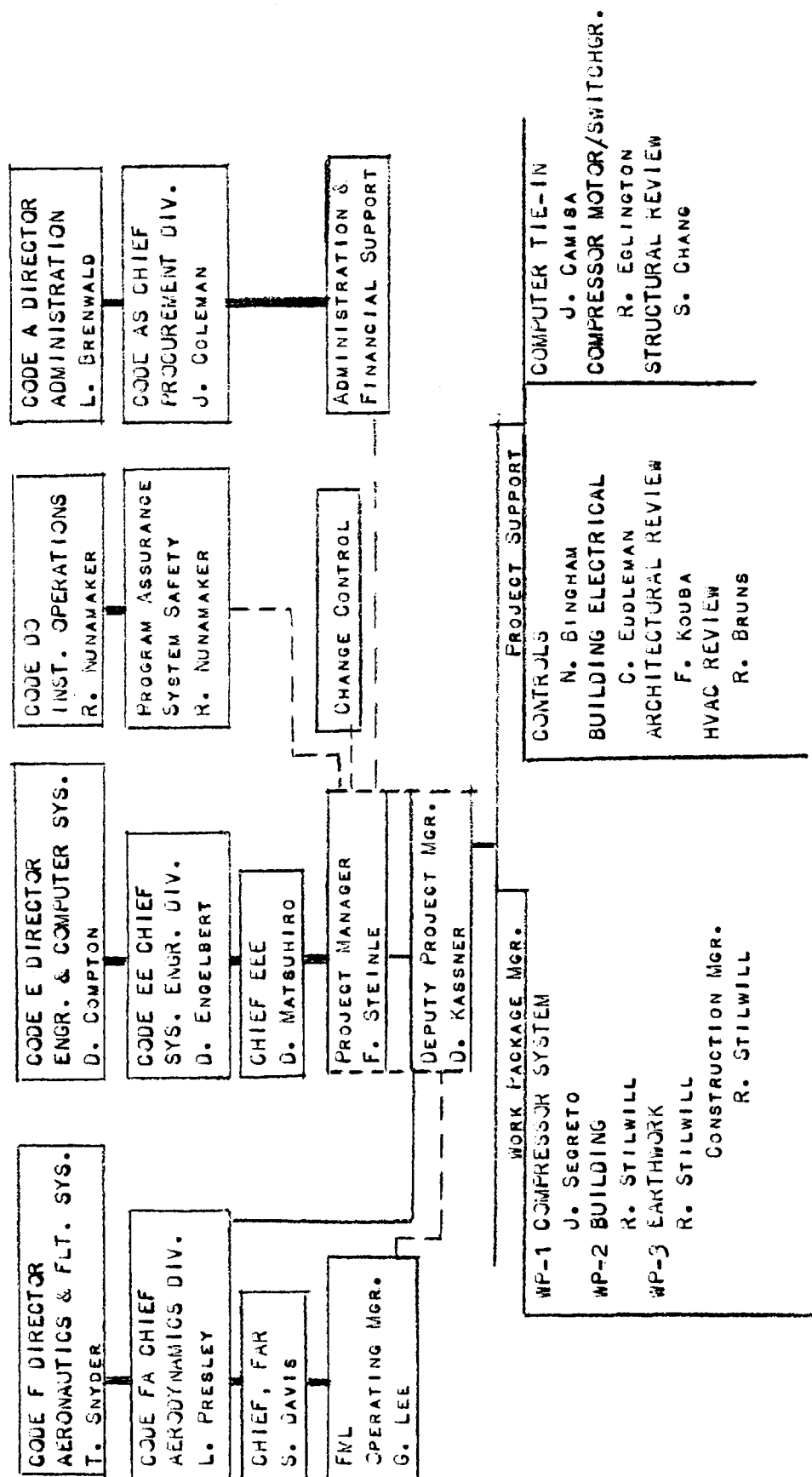


Fig. 2 ORGANIZATIONAL RELATIONSHIP - AMES DIRECTORATE TO PROJECT TEAM

flow from the NASA Administrator through the Office of Aeronautics and Space Technology (OAST) to the Director, Ames Research Center. The Ames Director communicates to the staff through the Directors of the various Directorates. Three of the Directorates are depicted in Fig. 1.

The User side of the project is reflected in the line management from the Director of Aeronautics and Flight Systems (Code F) through the Aerodynamics Division (Code FA). The Chief of FA, Mr. L.L. Presley, was my Industry Advisor. For purpose of merit-pay performance evaluation, Mr. Presley was also my supervisor during the Internship. The project management portion of the project is in the line management from the Director of Engineering and Computer Systems (Code E) through the Systems Engineering Division (Code EE). Funding and contract administrative support for the project is provided from the Director of Administration (Code A) through the Procurement Division (Code AS).

Headquarters responsibility for Construction of Facilities Projects originates with the Office of Management. The Facilities Engineering Division (Code NX) has Headquarters responsibility for budgeting and management of C of F projects. Code NX is responsible for verifying facility requirements with OAST and the coordination of other facility aspects with appropriate Headquarters organizations.

Coordination with OAST is accomplished through OAST's Facilities

Office (Code RF). In particular, RF's mission is to assure that OAST's programmatic requirements are properly addressed and that necessary manpower and support resources are made available for adequate implementation of the project.

Communication to Ames Code E from Headquarters Code NX is with the cognizance of Code RF. Code E, through Code EE, has oversight of the management of the project including planning, budgeting, reliability and quality assurance (R&QA) plan, safety plan, documentation, and reporting. Code EE will assign and provide the necessary personnel and resources for the project team to accomplish its assignment.

The organization of the Fluid Mechanics Laboratory Project Management Team is depicted in Fig. 2. Referring to this figure, the highest level is at the Directorate level. Line management for this project is assigned to the Mechanical Systems Branch (Code EEE). Typically, C of F projects are assigned to Code E's Facilities Engineering Branch (Code EEF). In this particular case, construction management for the project will be carried out within Code EEF. This project was assigned to Code EEE instead as a means of both broadening EEE's experience and reducing the workload of EEF. Further, the project required early design and bidding of the compressor system for the project which is the type of work normally done by EEE. The Chief of EEE, Mr. D. Matsuhira, supervises me in the performance of the C of F project.

In a philosophy similar to that of Headquarters RF/NX, the User (Code FA) supplied the Deputy Project Manager. The Project Manager is required to maintain close ties with the User through the Deputy. The approval of specifications and drawings requires the joint signature of both the Project Manager and the Deputy.

The laboratory will ultimately be the responsibility of the Aerodynamic Research Branch (Code FAR). The Assistant Chief of FAR has been designated as Operating Manager for the laboratory. The Project Manager is responsible for assuring that the Operating Manager has copies of all project documentation.

The Institutional Operations Office (Code DO), although not a Directorate, functions at that level and has NASA Ames Center responsibility for institutional safety. This includes personnel safety & health, fire safety, and R&QA. Support to the project is provided by DO through the Safety, Reliability and Quality Assurance Office (Code DOD), the Systems Safety, Health and Medical Services Office (Code DOH), and the Reliability and Quality Assurance Office (Code DOR).

Administrative and Financial Support provided by the Procurement Division (Code AS) includes contract administration, funding control, and accounting. A Contract Administrator is assigned to the project to administer the various Work Packages.

The Project Manager determines the work package structure and negotiates for the assignment of Work Package Managers and project support. Also, the Project Manager is Chairman of the Change Control Board. The Change Control Board's function is to approve changes in approved documentation and changes in design or scope. At this writing, the laboratory is still in the design-definition stage and it has not been necessary to enact change control procedures. Enacting change control will occur after the design is complete, the design is filed, and an engineering change-order is contemplated.

C of F Project Process

The C of F process, from idea to project completion, is delineated in NASA Headquarters document, "NHB 8820.2, Facility Project Implementation Handbook"⁴. The handbook is intended to cover all aspects from the standpoint of a Facility Project Manager (FPM)--in this case, the writer. The document is supplemented by "NHB 7320.1B, Facilities Engineering Handbook"⁵ (FEH). This latter document "contains policies, standards, criteria and guidance that the designer needs for the design of NASA facilities".

The C of F process covers land acquisitions, facility rehabilitation and repair, minor and major modifications to facilities, and new construction. Classification of work, funding levels, and sources are shown in Fig. 3 (from ref. 4). In this case, the project is categorized as new construction. Figure 4 (extracted from ref. 4)

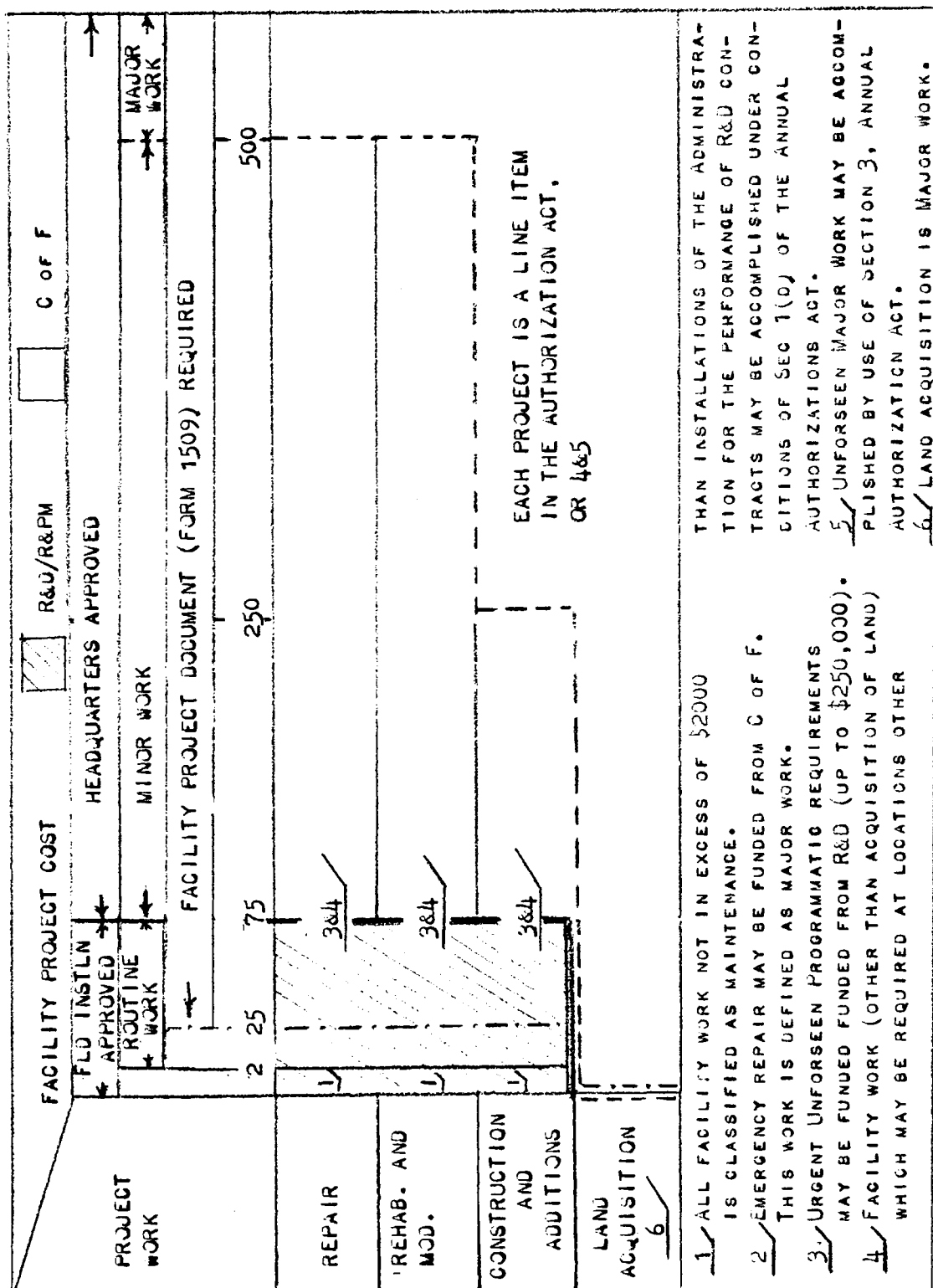


Fig. 3 CLASSIFICATION OF C OF F WORK

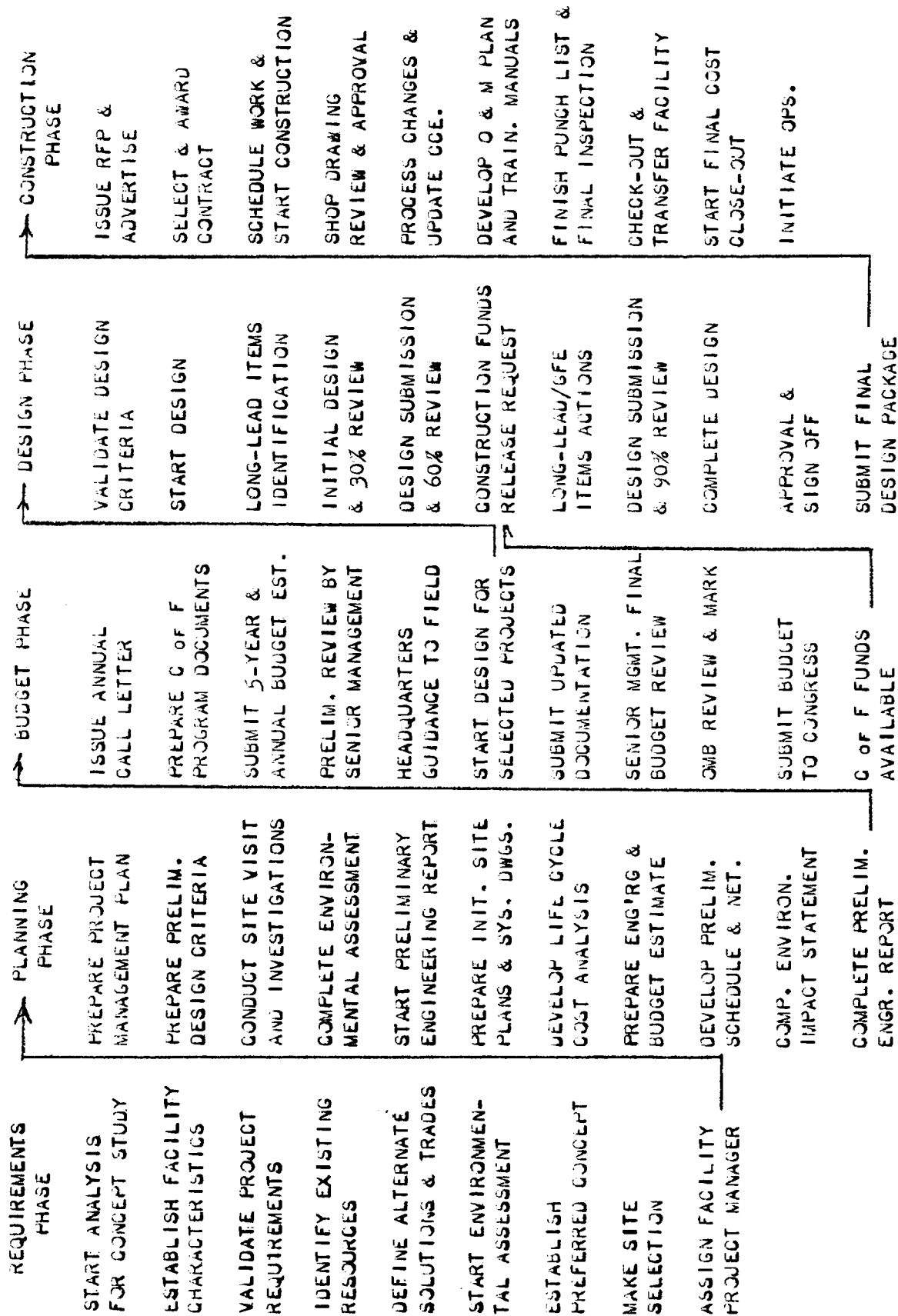


Fig. 4 C of F PROCESS, MILESTONES

shows the phases and milestones in the process. The process starts with an idea or identifiable need. Out of this, preliminary work (funded out of budgets other than C of F) is done and the project is carried and assigned a priority on the NASA Center's five-year C of F plan. The project may start at either the Center or the Headquarters level. An advocacy package is ultimately prepared. The package documents the required capability, defines functional requirements, and establishes concepts and criteria. The resolution of unanticipated problems starts toward the end of the advocacy cycle. Funding from the Headquarters C of F budget starts after the advocacy has been approved. This C of F funded process covers the remainder of the project. This process includes facility studies, a preliminary engineering report (PER), design, and construction. Prior to the allocation of design funding, the project must pass Headquarters, Office of Management and Budget, and Congressional review and approval. The design and construction funds are budgeted separately. Headquarters limits design funds to six percent of the construction budget.

All through the C of F process, NASA Headquarters monitors the situation closely. Monthly reports, informal meetings at either Headquarters or the Ames Center as well as formal reviews are required. NASA Headquarters does not customarily release at once all of a project's construction funds for a given fiscal year. In the case of this project, the release of all construction funds before the end of the first quarter of the fiscal year (begins October 1)

was sought and obtained.

Assignment Objectives

The "Project Management Plan"³ is intended to cover the project through its life cycle. This cycle is divided into five project phases: Preliminary Engineering, Design, Construction and Installation, Check-out, and Activation. Assignment to the position of Project Manager occurred just before the start of the Design phase.

The overall assignment (including the relationship with the Deputy Project Manager) is defined in the "Project Management Plan"³. The text of this portion of the plan is listed in Appendix III. The basic assignment is to be responsible "for the execution of the project under the direction of Ames and NASA Headquarters Management". This means keeping the project on schedule, under budget, and within scope. Functions and responsibilities within this framework include:

Planning, organizing, directing, and controlling the project

"Reporting to and interacting with Ames Management and NASA Headquarters Management", including notification of problems having "material impact on schedule, cost, basic function, or safety"

Determining type and number of team members and making the final selection of team members

Being responsible for costs, scheduling, reporting, and safety and reliability

Coordinating with the Deputy Project Manager and including the Deputy in the "management approval loop".

Nature and Duties of Job

The principal workload associated with the project was centered around directing, planning, coordinating, and administrating. Technical requirements of the job evolved mainly out of directing and coordinating. The Project Manager was required to interact at the technical level with all disciplines involved in the project (mechanical, electrical, structural, civil, architectural, and safety). A broad understanding of the technology involved was required to function most effectively with User, Project Team Members, and Contractors. This was particularly true in matters of systems engineering, User requirements, R&QA, and safety. Occasionally, the assignment called for the Project Manager to take the lead in design/analysis.

Managerial duties involved planning, directing, personnel evaluation,

development of required plans, funding and cost control, documentation, Work Package definition and preparation support, and reporting. The "Facility Project Implementation Handbook"⁴ lists the following activities that are considered to be principally managerial in nature.

Organization, Internal Office Procedures,
Work Package (Contract) Definition,
Project Budget and Schedule,
Project Evaluation and Control,
Management and User Reporting,
Procurement of Government Furnished Equipment (GFE),
Procurement of Long Lead Items,
Project Records Control,
Procurement and Liaison Policies,
Configuration Management,
Spare Parts Funding and Purchase,
Transportation and Logistics,
Facility Acceptance and Activation Procedures, and
Management Plan

With the exception of Configuration Management and Activation Procedures, the Internship substantially included the activities of this list.

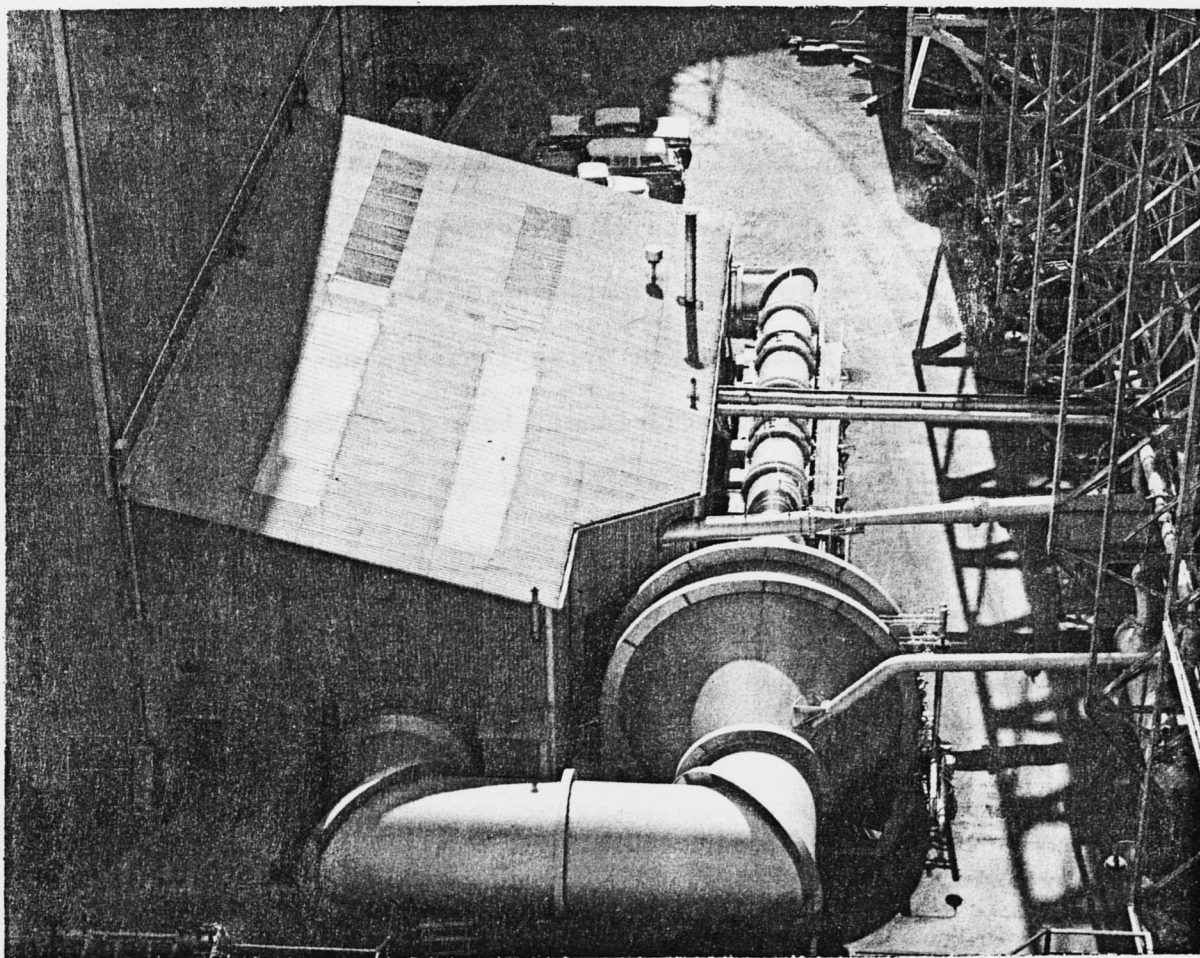
PROJECT DESCRIPTION

A description of both the Origin/Evolution and the Status at Assignment of the project is useful to a proper appreciation of the Internship project.

Origin/Evolution

The origin of this project started around 1975. At that time, the Ames FAR Branch was conducting research into the acoustics associated with trailing-edge vortex shedding of oscillating airfoils at low speeds, the development of laser velocimetry for non-intrusive measurement of flow within the boundary layer, and advanced transonic airfoil development. The first two of these activities were highly successful. However, the production of data was limited by availability of vacuum capability to operate the small sized in-draft research tunnels used to generate data. This led to a proposal for a line item in the Ames five-year C of F Plan for a facility with which to do basic fluid mechanics research.

Internal studies of a cursory nature supporting this idea were done from time to time and various alternatives were considered. Meanwhile, the Ames 2-by-2-Foot Transonic Wind Tunnel (Fig. 5) was not performing up to rated capability owing to trouble with its drive motors. The motors, located within the tunnel, were subject to overheating and leakage of oil from the bearings. This tunnel was



The 2-by 2-Foot Transonic Wind Tunnel is a closed-return, variable-density tunnel equipped with an adjustable, flexible wall nozzle and a slotted test section. Airflow is produced by a two-stage, axial-flow compressor powered by four, variable-speed induction motors mounted in tandem, which deliver a total of 2.98 MW (4000 hp). Steady-state testing models are generally supported on a sting. Internal strain-gage balances are used to measure forces and moments. This facility was modified for occasional two-dimensional research tests by adding motorized, rotating, thick-glass, model-supporting side windows mounted in unventilated, plane side walls. Mach number is continuously variable over the Mach number 0.2 to 1.4 range. Stagnation pressure is variable over the range of pressures from 162 to 3040 psia. Stagnation temperature is nominally 580 degrees Rankine. The facility has been operational since 1951. The tunnel is located within the courtyard of the 40 x 80-Foot Wind Tunnel.

Fig. 5 2-by 2-Foot Transonic Wind Tunnel

used extensively in the above mentioned advanced transonic airfoil research. Attempts to purchase new motors (the old motors were modified water-cooled model motors for testing propeller driven models) failed. An engineering study showed that a drive system with the motors being external to the tunnel was preferable. However, the space occupied by an external drive system would interfere with the utility of the 40x80-Foot Wind Tunnel (The 2x2-Foot tunnel is located in the courtyard formed by the 40x80-Foot tunnel circuit). As a result, the Chief of EEF proposed moving the tunnel so as to be an adjunct of what will now be the Fluid Mechanics Laboratory. The cost estimate for this new project (including moving the tunnel) was \$10-million.

Changes within NASA Headquarters nearly four years ago resulted in a shift in emphasis to basic research. This was a major factor in moving the project to number one in priority (after the move of the 2-by-2-Foot tunnel was deleted from the project). The project was finally approved in 1982 for FY 1984. It was "shoe-horned" to fit within a \$4-million budget. NASA Headquarters ultimately authorized \$3.9-million for the project.

Status at Assignment

By the time my assignment as Project Manager began, two previous managers had been in charge. The managers had accomplished the completion of a documented set of User requirements¹, the

"Preliminary Engineering Report"², the "Project Management Plan"³, and the contract for Architectural & Engineering (A&E) services. The assignment as Project Manager began during the final negotiations for the A&E contract. The A&E contract was awarded to Sverdrup & Parcel and Associates, Inc., San Francisco, California.

The "User Requirements"¹ listed all of the technical & functional requirements that were envisioned prior to start of the design. As the design unfolded, it became obvious that considerable augmentation of the technical design requirements was needed. The initial document took two years to complete. Evolution of the augmented version required numerous interactions with the User over the first 10 months of the project. It is too extensive to list. Appendix IV contains for reference the index to the current version along with an excerpt from the current version in the area of Safety Systems.

The "Preliminary Engineering Report"² (PER) is also too extensive to list. Reproduced here is the project description contained in the REQUIREMENTS section of the PER.

"This project will provide a 20,000 sq. ft. building to house the Fluid Mechanics Laboratory (FML) for support of research in basic fluid mechanics, adaptive tunnel wall concepts, helicopter rotor aerodynamics, and non-intrusive flow measurement technology. It will include a large area for experiment research (four (4) indraft tunnel bays and a central experimental bay) and space for related support facilities and personnel. The facility will permit research into the basic flow mechanisms governing the performance of modern aircraft and rotorcraft. The project will include an Instrumentation Development Laboratory to accommodate development of laser velocimeter (LV) and laser holography systems for non-intrusive measurements....A new compressor will be included for powering the small scale indraft tunnels. The compressor will be capable of pumping a

minimum of 170,000 SCFM to accommodate the existing indraft tunnels as well as future larger indrafts, including 3-dimensional adaptive wall tunnels. The compressor will be separated from the main FML building on its own slab within a separate enclosure. The compressor will be connected to a manifold running outside the main FML building along the indraft tunnel bays. Piping from this manifold will penetrate into each tunnel bay and terminate with flanges for connection to the indraft tunnels...."

In the above description of the compressor capacity, the term SCFM (meaning standard cubic feet per minute) should have read ACFM (meaning actual cubic feet per minute). The difference between the two is an error in magnitude of the order 1.8 (the compression ratio specified for this compressor). No such machine could be bought. The User Requirements¹ contains the correct terminology. Although embarrassing, the conflict did not cause a problem.

The purpose of the Management Plan is to cover all aspects of the management of the project. At the start of the Internship, the "Management Plan"³ had interim approval by NASA Headquarters, pursuant to making required changes in text. A review of the plan showed that additional changes were required. These additional changes were required to bring the plan in line with the recent reorganization in Code FA (abolishment of the Experimental Investigations Branch and the creation of the Aerodynamic Facilities Branch) and the re-definition of the project Work Package structure. Figure 2 reflects the re-defined structure.

When the Internship started, the A&E contract was ready to be signed by both the A&E and the Government's Contract Administrator. I was

present when the contract was signed. Negotiations for the signing of the contract had been protracted. The issue was the amount of funds available for the A&E's services. The Government had sought to exclude the compressor system from the A&E's responsibility. For economic reasons, the A&E was not willing to undertake the project for six percent of the budget, not including the compressor system. When faced with the prospect of re-competing for A&E services with attendant delays, the Government elected to make the A&E responsible for the entire project.

The project was under several constraints and directives. The most pressing constraint was one of meeting the schedule for beneficial occupancy (first quarter of fiscal year 1986) and bringing the project in within budget. When contact was made with NASA Headquarters to inquire about early release of funds, the first response was a question as to why the project was five months behind schedule.

A constraint, on the part of the User, was to be sure the design would accommodate the move of the 2-by-2-foot tunnel. Beyond that, there was internal disagreement in the User organization as to priority regarding the size of the compressor system (future research capability) versus laboratory floor space.

Directives having principal effect on the project are found in "AHB 1700-1, Health and Safety Manual"⁶. These directives require a

Hazards Analysis and a Design-Safety Review Committee. The Hazards Analysis was to have been done prior to the PER² and then updated as the design progressed. It hadn't been started at the beginning of the Internship (post PER).

INFORMATION SOURCES

Information sources include manuals & texts, corporate knowledge, and industry contacts.

Manuals & Texts

The previously discussed "User Requirements"¹, "Preliminary Engineering Report"², "NHB 8820.2 - Facility Project Implementation Handbook"⁴ and the "NHB 7320.1B - Facilities Engineering Handbook"⁵ and the Ames "AHB 1700-1 Health and Safety Manual"⁶ are manual-type sources of information. Other sources include industry standards (ASME, AGMA, NEMA, etc.), reports, and textbooks. Reports and textbooks used will be introduced in CHAPTER IV, WORK PERFORMED, of this report in the section, TECHNICAL CONTRIBUTIONS.

Corporate Knowledge

There is a wealth of experience within the staff of the Ames Research Center. A feature of the resources within the Center is the

availability of and accessibility to consultation. Knowledge as to what previous projects experienced proved to be invaluable, particularly in the area of cost-assessment.

Industry Contacts

Considerable use was made of industry contacts in the verification of design approaches. The Work Package Manager for the Compressor System proved to be particularly adept in this matter. I participated in many such consultations. Examples included contacts for purpose of discussing control valves, centrifugal compressor design philosophy, and the design of speed-increasing gearboxes.

METHODOLOGY

Very early in the project, it became obvious that anticipating sources of delays and maintaining communications was the key to the project's progress. Further, the project's past history of uncertainty and the changes in project leadership led to the conclusion that a positive sense of direction was very important. With this in mind, the methodology adopted was to be specific, keep everyone informed as to progress and plans, and "fast-track" the design and review as much as possible. Time for review at each stage was to be controlled to be at the minimum. In view of the danger of suppressing valuable input, a personal resolution to encourage input was made.

CHAPTER III

INTERNSHIP EXPERIENCE

HUMAN RELATIONS

As part of the Doctor of Engineering Program, I studied arbitration, labor-relations, and human relations. Additionally, the required course in Industrial Communications was particularly helpful. As an outgrowth of this course, Ouchi's "Theory Z"⁷ was read. The composite of this experience convinced me that all people, and their viewpoints, are valuable and that the organization should take advantage of them.

Individual Viewpoints and Goals

Taking advantage of individual viewpoints and goals requires identifying what they are. The following represents my assessment of individual viewpoints and goals that had principal impact on the Internship.

The Chief of the EE Division was particularly concerned with the need to successfully complete this project. Since I was from the User organization, he was concerned that the User would be allowed to make late changes that would adversely affect the project. This viewpoint was shared to varying

degrees by the various Branch Chiefs within EE.

There was a general uneasiness within FA regarding EE's commitment to meeting FA's needs.

The Chief of FA was concerned with the project being out-of-balance. In particular, the size of the compressor system promised was nearly three times that of what was needed to support existing experimental apparatus.

The Assistant Chief of FA was facility capability oriented and was in favor of growth capability which could not again be purchased. This is not to say that he favored an inordinate sacrifice of research space.

The Chief of FAR wanted a "showcase" of offices, complete with lots of space for research experiments. He saw very little need for the large compressor system and had a strong preference for one much smaller, with any savings to be invested in interior items to support research and more office space.

The Chief of EEF foresaw that the 2-by-2-foot tunnel would never be moved. He wanted the project to be sited with this viewpoint in mind. Interestingly, he was the one who first proposed that the tunnel be moved.

The Deputy Project Manager has been the only one associated with the project since its inception. He shared the viewpoint that it should be sited to accommodate the move of the tunnel.

I believed that the laboratory should be sited to accommodate the move of the tunnel. Furthermore, by virtue of my background in facility operations, my view was that the compressor system should be as promised.

Working within this framework proved to be interesting, challenging, and, at times, frustrating.

Organizational Perspectives

Organizational perspectives reflect the viewpoint of the individual leaders of the organization. These viewpoints at the onset of the Internship have either been mentioned or alluded to previously. In summary, at the onset, FA and EE were uncomfortable working with the other. Each seemed to feel that the other needed watching; however, both were committed to improving relations.

These negative attitudes diminished substantially as the Internship progressed. The resolution of major points of disagreement about the project, communications in other areas of interface (different

projects), and the general attitude of management toward resolution of conflicts are factors in the improvement.

Strategies for Reaching a Conclusion

Both the FA and EE organizations are managed by highly-motivated and intelligent managers with the courage of their convictions. The problem of gaining approval for the course of action desired and of establishing agreement between FA and EE was encountered, at times, in interactions with these managers.

The universally recognized first step employed in solving such problems was the application of the Boy Scout Motto, "Be Prepared". This required identifying the problem and the variables, consulting with project team members and other sources as necessary, and developing a preferred approach with alternatives to carry forward. The next step was to either "tell", "sell", or "meld".

A straight tell approach was to inform management of the situation, what was planned, and not ask for approval. If nothing surfaced, then silence was taken as approval. This works only with items of no strong significance, or of (sometimes) mild controversy. An example of this was the announced plan to include a 10-ton bridge crane in the compressor building to support future maintenance/repair needs. Reaction was either very favorable, mildly favorable, or ambivalent, depending on who was reacting.

Selling situations, presented the need to continue to provide the necessary information, negotiate, and, as necessary, compromise. Several instances of this situation arose during the course of the Internship. A good example was gaining the agreement of the Chief of EE that the project would use an all-metal building for housing the compressor system. The User agreed with the idea of employing an all-metal building as opposed to one built of concrete.

A major concern of the Chief of EE was that the noise from the compressor would be at too high a level at the research laboratory to the west of the FML. The management of the organization in charge of the laboratory, Manned Vehicle Systems Research Facility (MVS RF), had been promised a low noise level from the FML. This promise was one of the planning items in the orientation and layout of the FML. In fact, this was the key element in where the 2-by-2-Foot tunnel had to be located with respect to the FML (The siting indicated in the PER is shown in Fig. 6). A secondary concern was the attractiveness of a metal building.

Resolution of this issue required establishing confidence in the noise level figure predicted for outside the compressor building. I participated with the Compressor System Work Package Manager in gathering technical data and performing the analysis necessary to demonstrate that the noise level would not be a problem. This included:

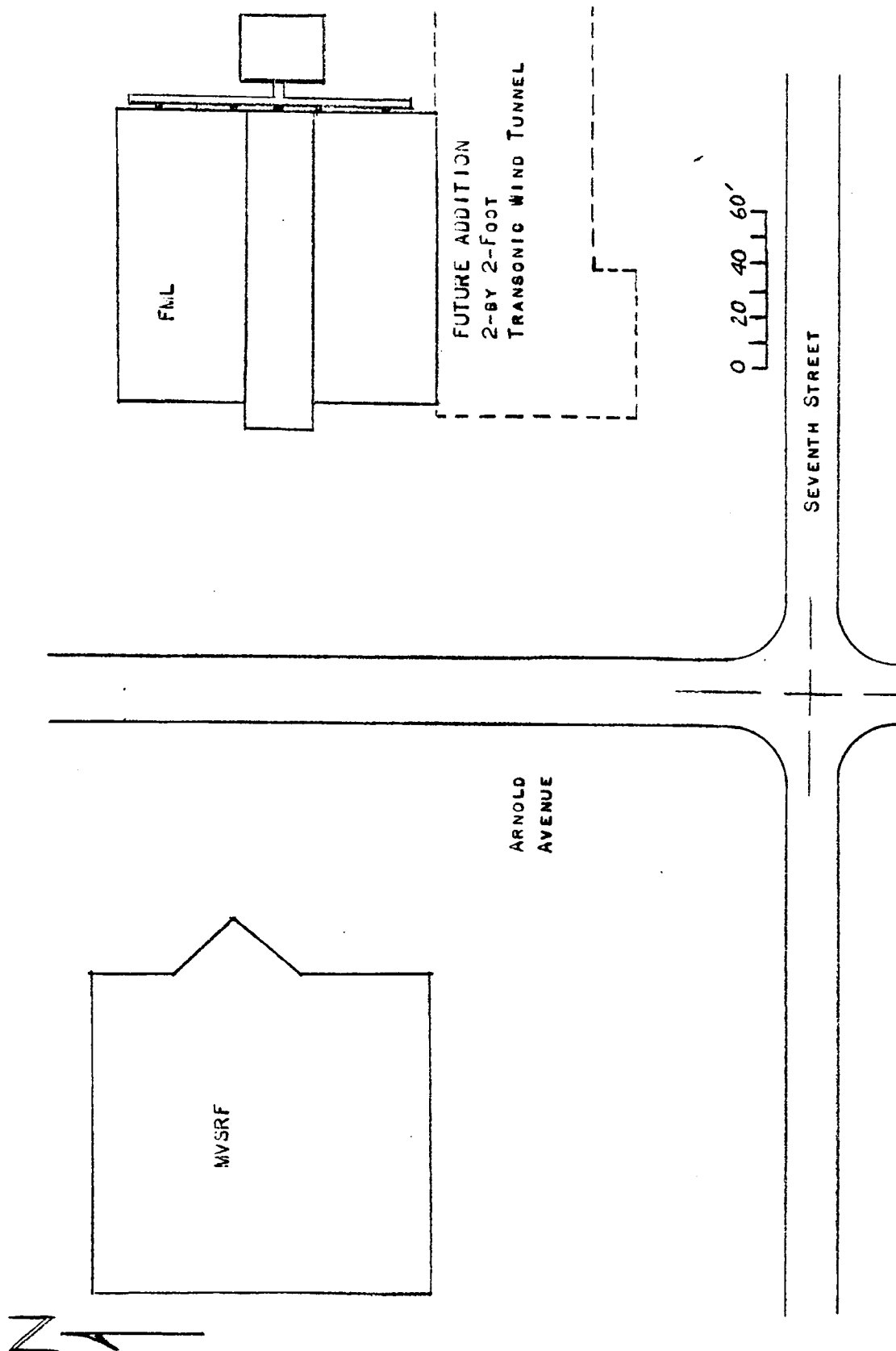


Fig. 6 SITE PLAN, PER PHASE

Visiting a plant with a compressor of the same generic design (1/12th power level) and obtaining noise power spectra

Using this information from above to validate predictive data

Scaling the predictive data for power level and impeller speed differences

Measuring the attenuation across an uninsulated metal building and using this to verify predictions for a metal compressor building

Applying theory predicting noise attenuation as a function of distance

Documenting the results in an internal report.

The Chief of EE sent the report to the management of the MVSRF for comment. Following agreement from MVSRF, the Chief of EE requested an opinion by the Center's architect as to the acceptability of a metal building. This point had already been discussed with the Architect. Approval was given.

The meld approach concerns melding the viewpoints of the participants. In the concept definition portion of the project (up

to the 15% design point), much effort was spent in resolving where the facility should be located and what it should contain. Resolution of this required a protracted effort to meld both FA and EE concerns, priorities, and views to a common point.

The focal point of the problem was whether the 2-by2-foot tunnel would ever be moved. The first problem was to elicit from the User a statement of intent to move, or not to move, the tunnel. It took some time, but the User responded and went on record as wanting the facility designed to accommodate a future move of the tunnel.

To accommodate the move would require moving the FML some 100 feet to the north of where it could otherwise be located (Fig. 6). The Chief of EEF was strongly against this, because he was (and still is) convinced that the tunnel would never be moved. Both history and the near-term C of F plans would support this conclusion.

The next step was to call a meeting of both EE and FA. The agenda was controlled by giving both sides the opportunity to provide items for discussion. The agenda was established prior to the meeting. My strategy was to moderate and not get caught in the middle. Moderation was accomplished setting the tone of the meeting through my opening remarks which included a statement of the problem and the goal of the meeting. The meeting was not adjourned until the next step in the process was agreed upon. The process was repeated again, at which time a combination of agreement and capitulation with

protest was reached.

A second situation that required considerable effort to meld opinions and priorities was the establishment of the detailed layout of the facility. Resolution of the above 2-by-2-foot tunnel question helped establish the general layout. However, it did not help in settling on the configuration and location for the entrance lobby, the laser laboratory, windows, mechanical room, and the rest room/locker room.

The PER² configuration (elevation and floor plan are shown in Fig. 7 and in Fig. 8, respectively. The final elevation and floor plan are reflected in Figures 9 and 10, respectively. A comparison of these shows that, aside from the reduction from two stories to one story, relatively few changes were made. The reduction from two stories to one story was not a point of controversy; everything else about the office area was. Eliminating the second story (Fig.8) did create a problem with the mechanical room since no one wanted it next to their office. The central issue was the location of the lobby, followed closely by the issue concerning location, size, and accouterments of the rest rooms. The establishment of the final configuration required me to spend some time at the drafting board preparing compromise solutions. I deleted the shower twice and the Deputy exercised his own quiet leadership and influence to keep it in. The shower is included in the design. The last issue to be settled was where the mechanical room was to be located. Code EE did not want any equipment on the roof and the User thought that it was a

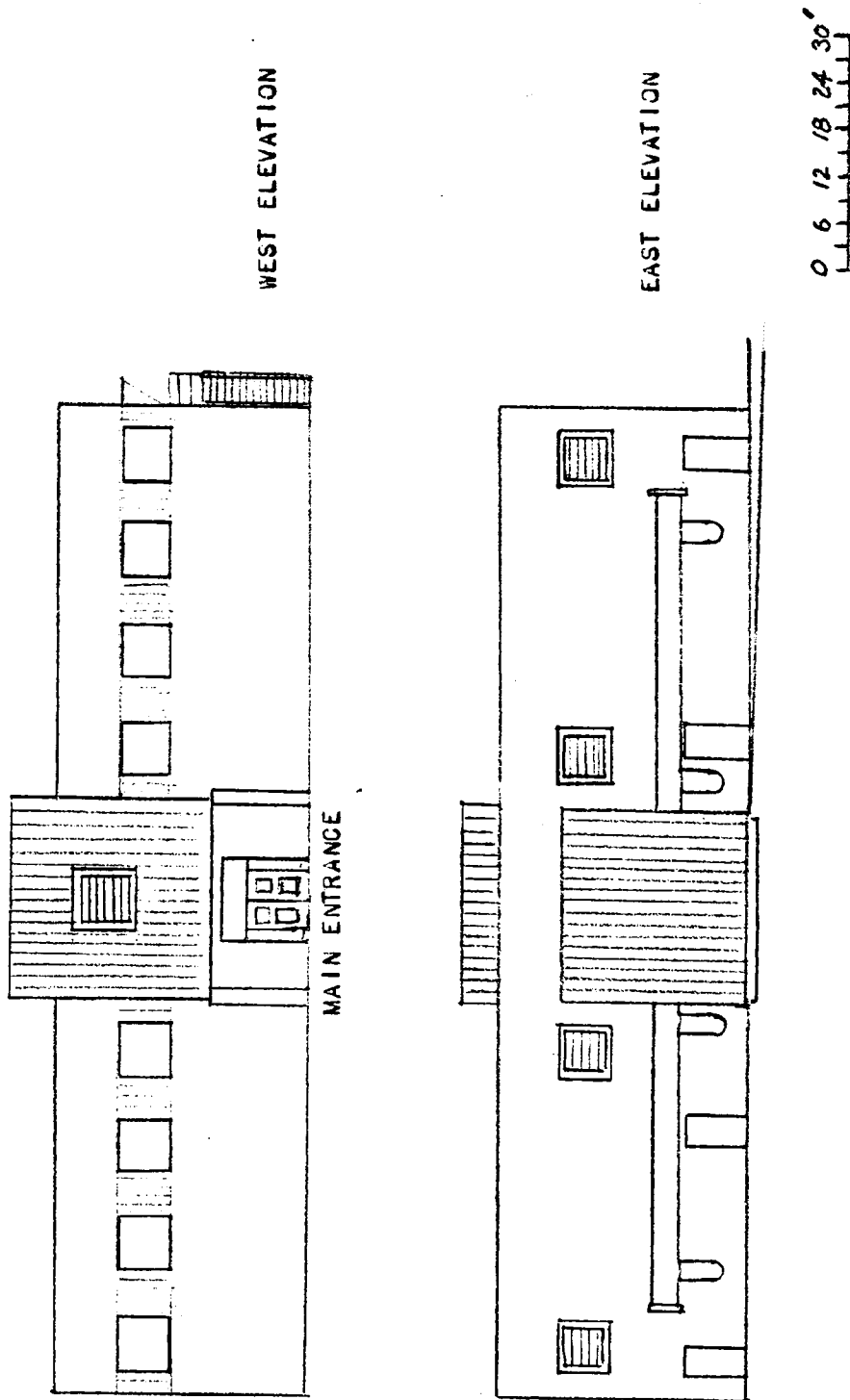


Fig. 7 FML ELEVATION, PER PHASE

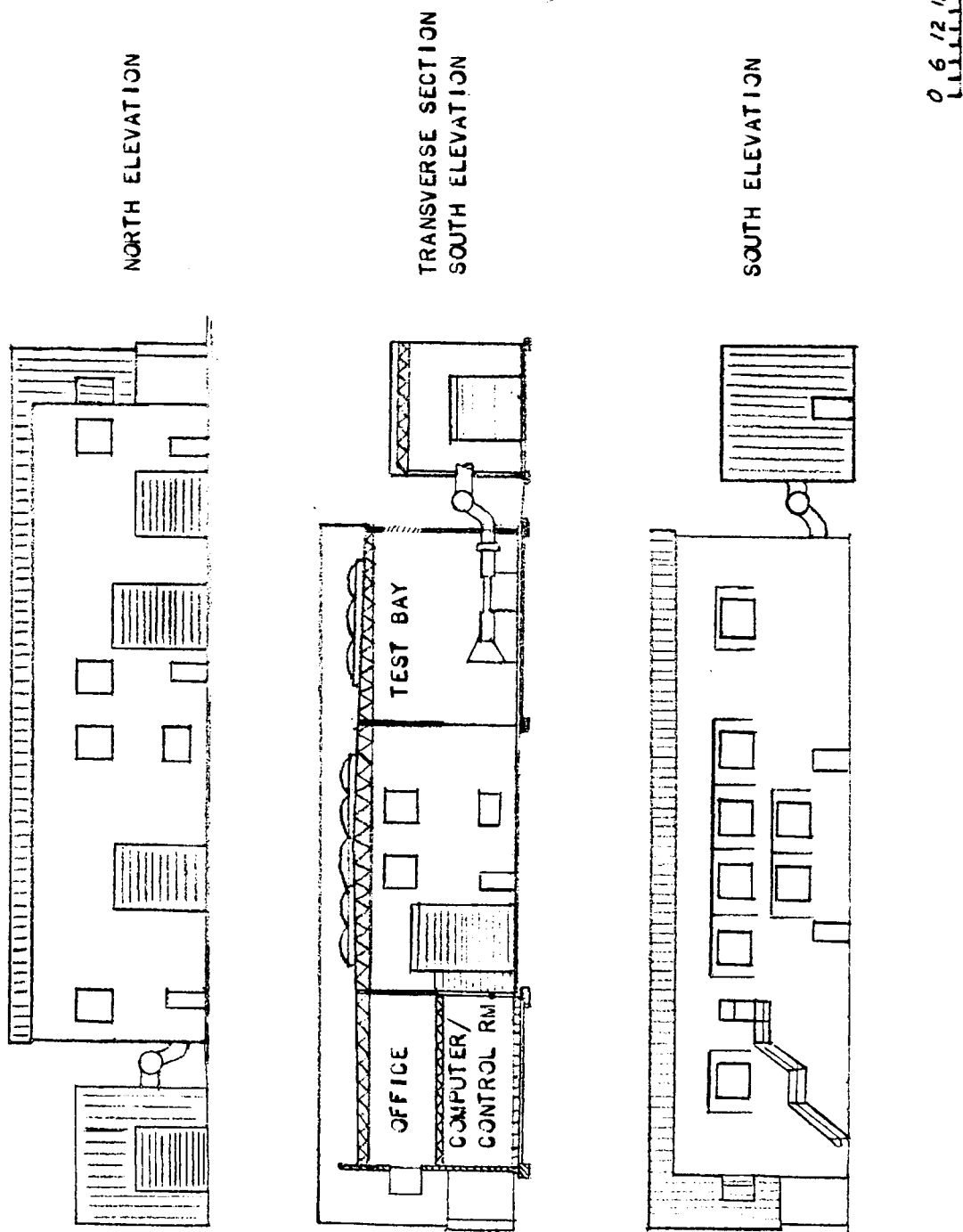


Fig. 7 - Concluded FML ELEVATION, PER PHASE

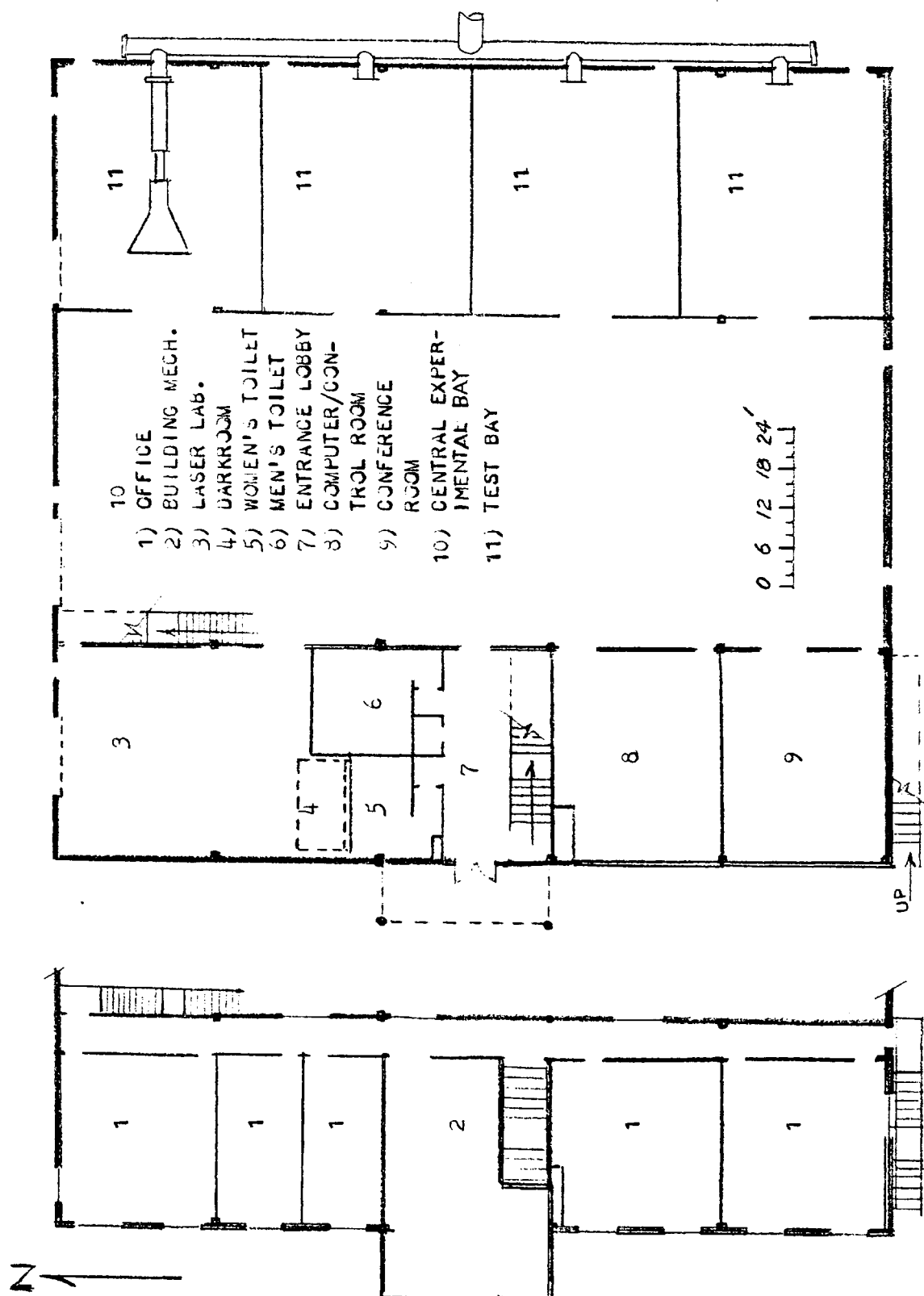


Fig. 8 FML FLOOR PLAN, PER PHASE

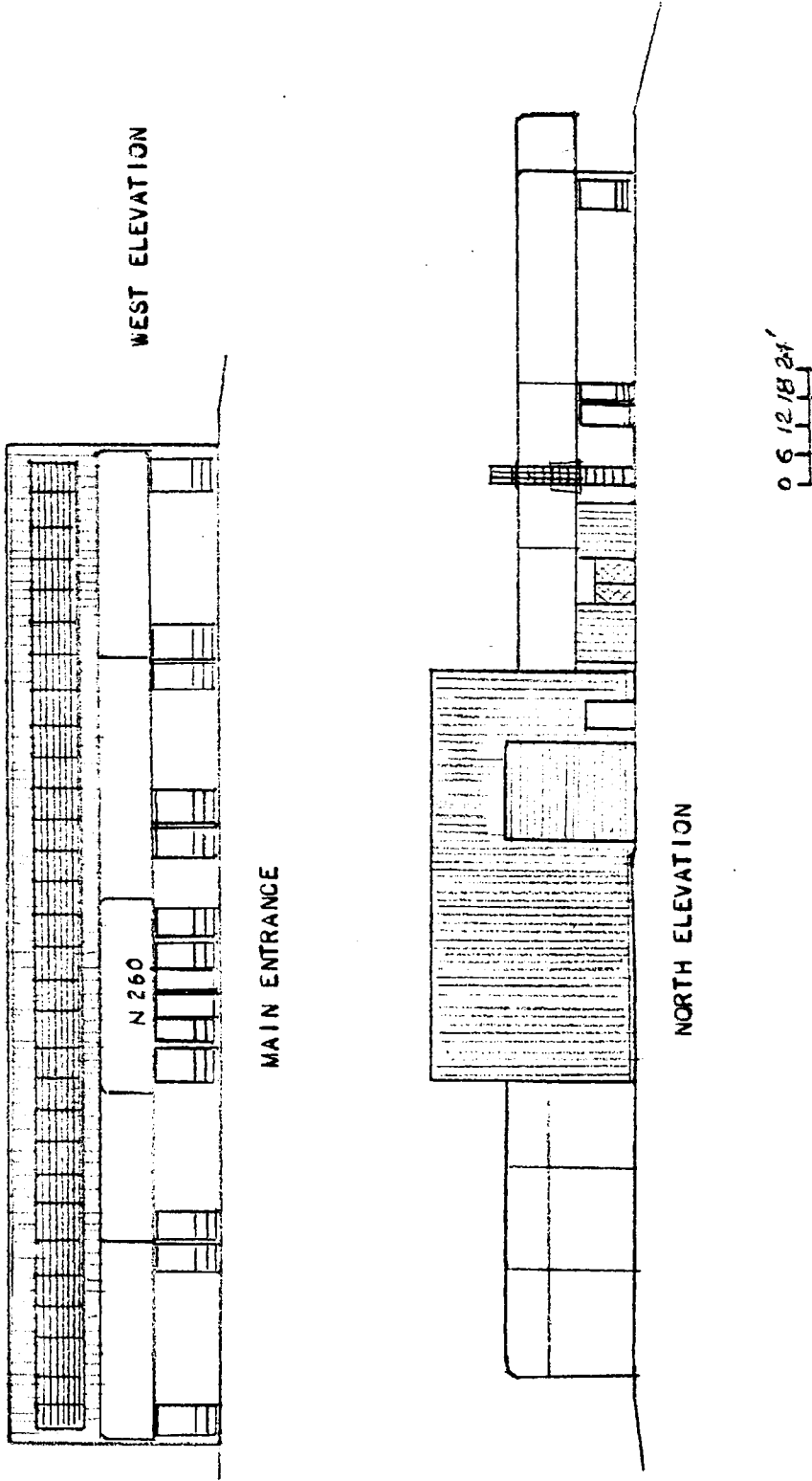


Fig. 9 FML ELEVATION, FINAL DESIGN

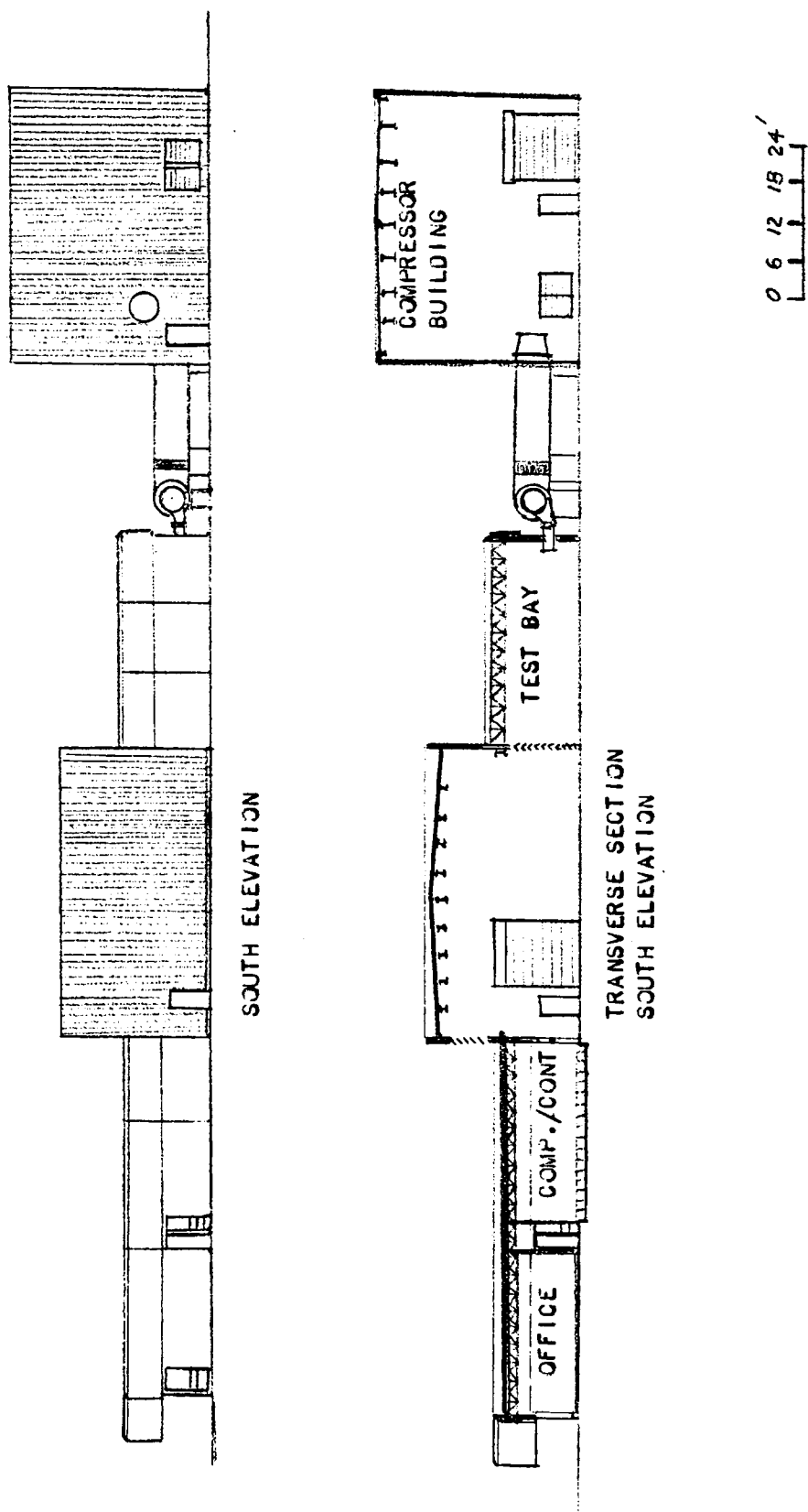


Fig. 9 - Concluded FML ELEVATION, FINAL DESIGN

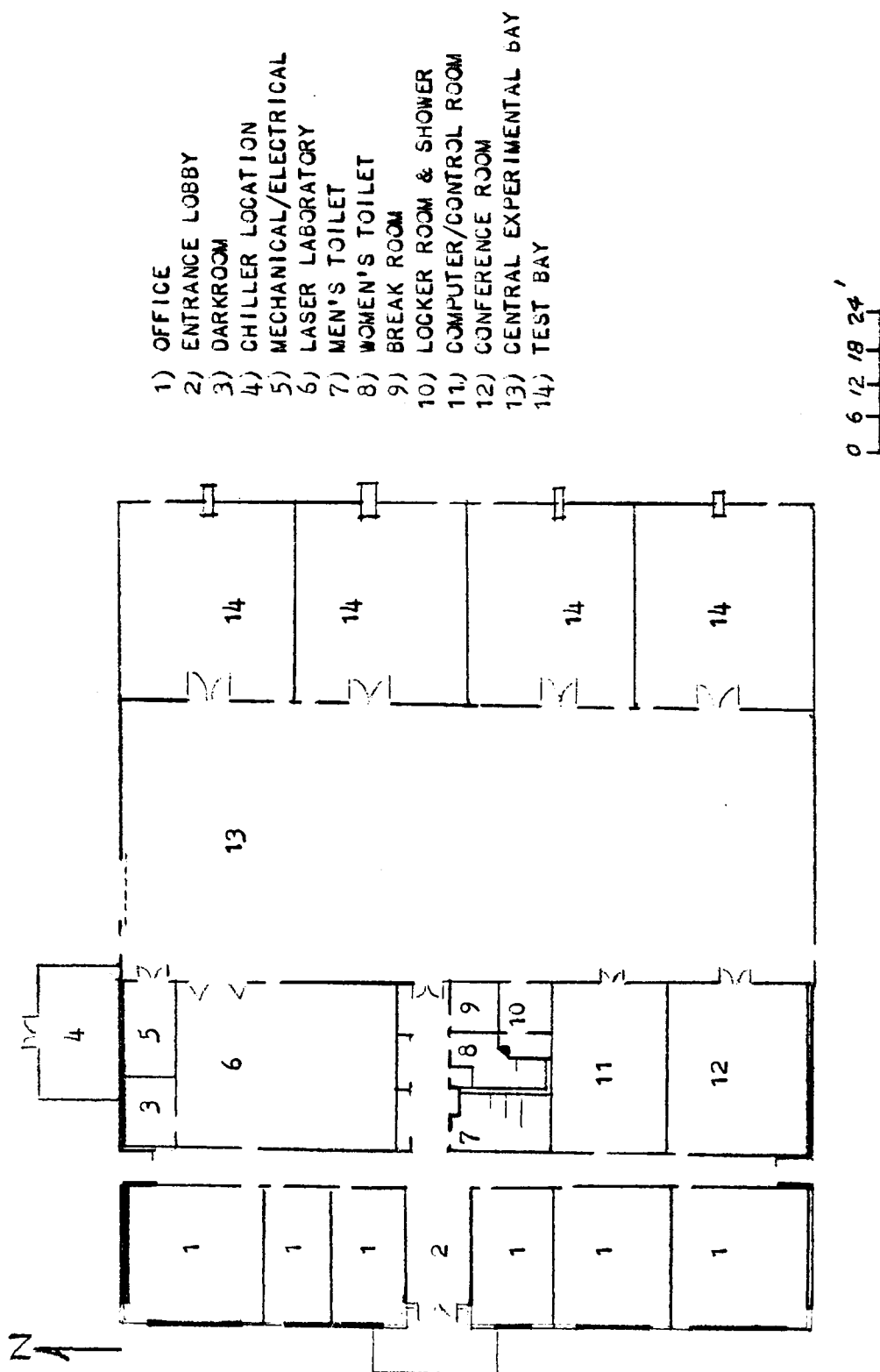


Fig. 10 FNL FLOOR PLAN, FINAL DESIGN

perfectly good place for mechanical equipment (chiller). The establishment of the final configuration did not require a joint meeting of FA and EE. The final configuration was established through a series of individual meetings wherein I served as a mediator, negotiating for both Code EE and the User. The issue was resolved by relocating the mechanical room to the north end of the building and reducing it in size by locating the chiller outside (see Fig. 10).

Interpersonal Relations

Human relations must, of necessity, include interpersonal relations. A personal relationship with management as well as team members and contractors was sought, while at the same time avoiding conflict of interest. Getting to know people was a most satisfying part of the Internship. In this regard, I have grown in ability to interact with people who prefer to start a professional contact with a social interaction (sometimes lengthy) before getting down to business. The hardest lesson to learn has been patience in the face of a need for extra socialization to promote functioning effectively.

INDUSTRIAL INTERACTIONS

The course of the Internship included numerous professional interactions with the A&E firm (Sverdrup & Parcel and Associates, Inc.), contractors, and Ames personnel.

A&E Interactions

Interactions with the A&E concerning the development of the design have been professional. The experience was quite educational. The A&E was clearly in a marginal profit situation, as evidenced by the delay in signing the contract with the A&E. Despite the marginal profit situation, a lack of professionalism on the part of the A&E was not experienced. However, the amount of concepts considered was an absolute minimum. It became obvious that the A&E would much rather translate a design performed by the customer into final form.

Interactions concerning cost estimates were particularly involved. The re-design clause of the contract required the A&E to re-design to cost should the basic design bid price be greater than the budget. This clause guaranteed that the A&E would estimate the cost conservatively. Since the project was sized by the Government on the basis of their cost estimate, differences in estimating costs could cause real problems. This happened and was a real threat to the procurement of the compressor system, which will be discussed later in this Chapter. Numerous visits to the A&E were made in an attempt to bring their cost estimate and those resulting from local experience into agreement. Some improvement in agreement was accomplished. However, it was not sufficient to eliminate the high concern on the part of both Code EE and the User.

As could be expected, the A&E desired to obtain payment for any work considered to be outside the contract. Care in requesting changes was taken to avoid this type of work. One point of contention did arise. In this particular case, drawings were submitted during the period when changes in concept should be paid by the Government (post 30% design). However, the concept presented (building fascia) did not match what the Government expected. The A&E had prepared a series of concept sketches. The Government selected one. Subsequently, the A&E proposed a constant thickness concrete panel with a one-inch notch (reveal) for decoration. The Center's architect maintained that the reveal proposed would not give the effect shown in the concept sketch selected. The A&E's architect said it would. The A&E was directed to change to what the Center's architect said was required (increase in thickness starting at the location of the proposed reveal). Initially, the A&E sought to bill the Government for the entire cost incurred in redrawing the details showing the fascia. I rebutted this idea and held out for a sharing of cost on the basis of faulty communication between their architect and the Center's architect. On review, the A&E agreed that cost sharing was proper.

Contractor Interactions

Contractor interactions included both support-service contractors and supply contractors. Code DOH supplied a support-service contractor,

Mercury Engineering, Inc., to perform the hazards analysis. Code DOQ supplied a support-service contractor, Syscom Company for system safety and R&QA support. Code EEF supplied support-service contractor, Ishimaru Design Group, Inc., for R&QA review of the design drawings for adherence to codes and for self-consistency. During the construction phase, the Ishimaru Design Group will also provide inspectors. Training in what to inspect and documentation support will be supplied by Syscom Company.

Interaction with support-service contractors was similar in nature to interaction with team members. On a person-to-person basis, it was the same. The difference was in the interface. Coordination with both the support-service Technical Monitor and the contract employee's supervisor was required. Direct tasking to the contract employee was not permitted.

Interactions with supply contractors (vendors) were conducted on a professional level. Most interactions were with the contractor for the compressor system, Allis-Chalmers, Inc. Interactions with the contractor for the earthwork work package (bring the site up to elevation and soil quality) involved only bid-opening. The principal point of contact with the contractors has been through the Work Package managers. During the vacation of the Compressor System Work Package Manager, I served as the prime point of contact.

Negotiations with the compressor system vendor after the contract was

signed were extensive. This was brought about by the decision to change the drive motor (9000 horse power) from synchronous to induction and the main lube-oil pump from gear-driven to electric motor-driven. During the preparation of the technical specifications, the Compressor System Work Package Manager and I selected a synchronous motor (with the approval of the Deputy and upper management) as opposed to an induction motor because domestic prices listed the synchronous motor as costing the least and power factor correction equipment would not be needed. The gear driven main lube oil pump was selected to provide a measure of protection against electrical failure during compressor operation. A pump with bronze drive gear and internal pressure relief was specified. Manufacturers were checked to see if such a pump was routinely available. Pumps in the anticipated capacity were available.

In the bid response to the statement of work the two bidders accepted the terms of the contract. Only after the contract was signed were concerns voiced. It was learned that dynamics in the synchronizing process during starting of the synchronous motor would couple with natural modes in the compressor drive train and produce high stresses in the drive shaft. These stresses, coupled with the expected high duty cycle, could result in the need for replacing the driveshaft between the gearbox and the drive motor and the rotor shaft of the drive motor in ten years or less. Also, it was learned that the type of gear-driven lube pump specified was not made in the capacity required (higher than anticipated). Response to these concerns led

to the change in drive motor and lube oil pump and also delays in submittal schedule that led to slippage in the A&E's design schedule. This experience taught me that the bidder never takes exception to the terms of the solicitation for a fixed-price contract.

Some delay (of the order of two weeks) in the submittal of interface type information to the A&E was anticipated as a result of these changes. Actual delays extended well beyond two weeks. The extended delays resulted from the compressor system vendor's effort to improve his profit situation through protracted negotiations for the drive motor, gear box, and switch gear. Attempts to induce the vendor to provide the needed information on schedule were not successful. The absence of a defensible liquidated damages clause in the contract meant that, aside from an appeal on a professional basis, the only recourse to late submittals was to withhold progress payments until the required submittals were delivered. This withholding had to be done. It did get the attention of the vendor and was a factor in getting the delivery of other submittals back on schedule.

Internal Interactions

Internal interactions, as used here, are intended to refer to those with upper level management (excluding Code FA), project team members, support organizations, and the User (Code FA).

Upper level management interactions have been uncomplicated. Within

the Code EE organization, interactions have been of a peer nature. At the Branch level, interactions have been for purpose of consultation, and for task support. At the Division level (Chief of EE) negotiations have concerned matters of policy and budget. Examples of these two types of interactions concerned how many work packages should the project contain and how much reserve funds should the design have at the time of release of the bid package. Resolution of these two examples required a sell approach.

Above the Division level (Director and Headquarters), relations have been primarily of a reporting nature. For example, prior discussions within Code EE were necessary to be sure that the desired approach, or format for reporting was satisfactory.

Project team member interactions were more personal and were conducted at the peer level. Owing to the nature and level of the work within EE, most team members were heavily involved with numerous other projects within EE. Consequently, it was necessary to coordinate and negotiate for their time. The exception was the Compressor System Work Package Manager who was assigned full time to the project. In this case, I served as the manager's first level supervisor.

Support organizations are considered to be those outside Code EE and FA. These interactions were minimal--limited to the interface necessary to arrange for the support-service contractors for Safety

and R&QA (Mercury Engineering, Inc. and Syscon Company). All that was required was a brief conversation and an internal request for help (Service Request) to be filled out.

Some of the interactions with the User have been indicated in prior sections of this report. The most challenging interaction with the User will now be discussed. Conflicts in User priority and the unexpectedly high predicted cost for the building by the A&E was the source of much uncertainty at a time when it was imperative to define and solicit the compressor system. Resolution of this uncertainty was the high point of all my interactions with the User.

This situation presented the task of resolving priorities of building versus capability and with developing the strategy that would afford the maximum flexibility. To aid the situation, an independent cost estimate from a professional cost estimating firm, Lee Saylor, Inc. was secured. This firm has their own published approach. The A&E used the cost estimating guide by Means⁸. The fundamental source of the problem was that the A&E used a multiplier of 1.3 to represent San Francisco area rates and Lee Saylor's experience said it should be more like 1.15 (typical of Sacramento) for the Moffett Field area.

Aside from the problem of high predicted cost, the other issue was the size of the contemplated compressor. The Chief of FA was uncomfortable with the size of the compressor. The machine's large size was established almost by a process of "levitation". In

studying the marginal cost of increasing the size of the machine versus capability, it was obvious that there was a tremendous benefit from economy of scale. A 10% increase in system cost was worth a 30% increase in capability. The increase in capability gave the option of either increasing the number of small facilities that could be supported simultaneously, or increasing the size of an individual facility. Because of attractiveness of this feature, the team preparing the PER² quickly arrived at a capacity consistent with the largest centrifugal compressor that could be obtained from domestic sources.

The 0.15 difference between multipliers in the A&E's and Lee Saylor's estimates meant the difference between the machine promised and one 60% smaller. Both resolution of the differences in estimates and development of a smaller machine option were sought. The option was not allowed by the Contract Administrator for fear that the bidders for the smaller machine might not be the same as for the larger machine. This could result in the Government having to pay bid preparation costs should the low bidder not be the same for both machines.

Finally, the strategy of going for the larger machine first and if the price came in below \$1.33 million, staying with the larger machine was sold. The Government estimate (in concert with the A&E) for the system was \$1.27 million with the low at \$1.1 million and the high at \$1.5 million. Selling this approach required lengthy

discussions concerning the reliability of the cost estimate. Only two bids were received. The low bid (Allis-Chalmers, Inc.) was \$1,267,855) The other bid was \$255,936 higher. The team was counting on the need for business in the market to bring in a low bid, even though there might only be two bidders. The low bidder believed that they were not low enough. Fortunately for the project, they misread their competition.

The subjects of the Compressor System and the previously discussed orientation and layout of the laboratory were the major interactions with the User. Others have been minor by comparison. Aside from resolving issues concerning the scope of the facility, the other interactions have been routine business (planning groundbreaking, ordering of architectural model of the facility, and reporting).

THE VAPOROUS MATRIX ORGANIZATION

In principle, the structure of a matrix organization should lend itself to maximum flexibility. The manager has the ability to draw dedicated resources from appropriate organizations for the time needed to complete a particular task. This implies that the manager has control of the individual's work assignment and priorities. On paper, the Fluid Mechanics Laboratory Project appears to be such a project. Early in the project, I called a team meeting and no one came. This led to the term, Vaporous Matrix Organization. My translation: A vaporous matrix organization means the personnel

identified are the ones to do the work. The manager must find them and negotiate for their services, in spite of their already 100% workload.

Controlling and Directing

When the structure was viewed and treated as being characteristic of an individual profit center, response to needs was excellent. Control and direction was accomplished through one-on-one negotiations. Some adjustment in schedule was necessary to avoid conflicting priorities.

Maintaining Communications

Frequent personal briefings and a bi-weekly newsletter were used to maintain effective communications. A sample of one of the newsletters is contained in Appendix V. The newsletter, "FML Bi-Weekly" was particularly successful with promoting relations between the project and both upper level Ames and Headquarters management. I believe that it was a factor in the early release of all of the construction funds. Further, personal contact at the working level was the most effective communication technique used.

COSTING

This section might as well be termed "Cost Estimates I Have Seen". The Center has a history of underfunded C of F projects. Owing to this, I resolved to review the basis for the project's cost estimate as soon as possible. My findings served to heighten the concern for the possibility that the project, as promised in the PER, was underfunded. This raised the possibility that the compressor system specified could not be procured. It was imperative that this be resolved as quickly as possible since the compressor system was the long-lead item that needed to be both identified and procured quickly.

Internal Estimate

The estimates for the compressor system were found to have a sound basis in fact since they were based on quoted prices for components which had been identified as necessary for the system. Tracking down the basis for the building estimate proved to be successful--there was a guess as to what the building would cost on a per square-foot basis. The guess was somewhat educated, since a building had just been completed and its cost per square foot was "known". The per square foot basis cost, plus a twenty percent allowance for uncertainty, plus escalation seemed to be the source of the internal cost estimate. The fact that the contractor for the completed building went bankrupt was disturbing and destroyed any confidence in

the building cost estimate.

A&E Estimate

The A&E used a cost estimating procedure based on the Means⁸ guide. As mentioned earlier, the key point of contention was the 1.3 multiplier in cost for the San Francisco area. I arranged for project support within EE to verify costs. The findings showed concrete costs to be high by a few percent, steel construction to be about right, earthwork to be high by 33%, building mechanical systems costs to be high by around 85%, and electrical costs to be high by at least 15%. Historical local cost data and sources of quoted costs were provided to the A&E in an attempt to obtain an estimate more in line with expectations. Subsequently, the A&E modified some of their estimates, reducing the disparity between their estimate and that of the independent cost estimating firm, Lee Saylor, Inc., to around seven percent.

Independent Firm Estimate

The independent cost estimate was crucial to the major decision point in the project (sizing and procuring the compressor). The firm of Lee Saylor, Inc. was recommended by the A&E. The Government would have selected this firm regardless of other recommendations since they were already engaged in costing a major C of F project at the

Center (the National Aerodynamic Simulator Building) and would be able to respond with the most up-to-date analysis. The rapid engagement of Lee Saylor, Inc. was accomplished by directing the A&E to provide an independent cost estimate. The cost, including fee and profit for the A&E, was less than \$6,000. The analysis and adjustment of the estimate by Lee Saylor, Inc. (done in the same manner that the A&E's estimate was examined) showed that there was sufficient reserve to procure the promised compressor if the price came in at, or below, \$1.33 million.

INTRODUCING INNOVATION

Being innovative when the expectations are for being conservative can be difficult to sell. It was learned that both timing and persistence are key elements in selling innovation. The goal of doing earthwork for the project early as a hedge against wet-weather construction came under the framework of introducing innovation.

Selling

Delay in getting started with the project which would result in having to compact engineered fill in wet weather conditions was a major concern of mine. Doing the work early, under optimum conditions, was expected to provide insurance against lost time due to wet weather, guarantee getting the current low price for fill,

reduce the possibility of unanticipated settlement after the project was completed, and not constitute a significant risk to the accountability of the building contractor. To me, this seemed to be obvious, and no trouble in selling was anticipated. Selling the User was easy. Selling Code EE was not. Code EE was divided on the idea. At best, only lukewarm support was obtained, with others being in opposition.

Timing

I decided to wait for a better opportunity and try again to sell the idea. During the initial attempt at selling, the Chief of EE was away at advanced management training and the Assistant Chief was in charge. When the Chief returned, the idea was resurfaced. The support was better.

The next presentation to the Director of Code E occurred while these negotiations were in progress. The presentation called for a statement of problems and concerns. With the consent of the Chief of EE, concern for wet weather compaction of the required engineered fill was indicated. Before the concern could be discussed further, the suggestion of doing the earthwork early was made. With the Director's nodding approval of the idea, I went ahead with all haste.

The competition for the subsequent contract for the earthwork was good. The ratio of high to low bidders was 1.8:1 (the Contract

Administrator had predicted a 2:1 ratio). The low bidder was 30% below the Government's estimate. The contract was awarded to the low bidder and a groundbreaking ceremony was planned for June 29, 1984. The ceremony was held as scheduled, without the presence of the earthwork contractor. The contractor was delayed some two weeks owing to problems in securing a construction bond. Once under way and after initial problems with the compacted material not meeting specifications was resolved, the work went well. The earthwork was completed on August 15, 1984.

Persistence

The adage, "Persistence Pays Off" applied to the case of the earthwork. The risk of persistence is that one can lose credibility as well as become unpopular. The success of this application was that all parties involved have been left with the feeling that they were involved in a success.

PRODUCT SAFETY DEVELOPMENT

The Center's safety policy is: If an error is made, make sure that it is on the side of safety. It is to this effect that the Center requires hazards analyses prior to the PER² and during the design process as well as concurrent design safety reviews to assure that hazards are addressed.

Hazards Analysis

As indicated earlier, the project was supposed to have had a hazards analysis completed prior to the PER². One was not done. The regulation post-dated the PER activity in this case. Arranging for the hazards analysis was done through Code DOH by service request. The first analysis was done after the 15% point, it was updated after the 30% point, and updated again after the 90% design submittal.

Points of discussion centered on what is a hazard and what should be the recommended remedies. These points were negotiated with the contractor performing the analysis. The last point negotiated was a statement of what would the assessment be if the safety recommendations were adopted. Some difficulty was encountered, but was resolved by exploring the packaging of the assessment. The contractor was concerned about misinterpretation of the assessment. The difficulty was resolved by agreeing to show, in the recommendations column, what the revised assessment would be. An example of the assessment from the "Hazards Analysis"⁹ is presented in Appendix VI.

Safety Reviews

The Center calls for a Design Safety Review Committee to be convened

for the purpose of reviewing the safety of the design. I was responsible for negotiating for members of the committee. Members with sound engineering (including facility operations), human factors, and safety backgrounds were sought. Individual members were asked if they would serve on the committee. Subsequently, appointment to the committee was negotiated with their respective supervisors.

Contractual Impacts

Safety recommendations that were acted upon did not incur additional design costs since the A&E was contractually obligated to design to satisfy Center safety requirements. However, implementation of the safety recommendations did cost resources. Therefore, it was in the interest of the Center to be sure that the hazard assessment and recommendations were correct and reasonable. Problems stemming from questionable assessments and/or recommendations were avoided by discussing and commenting on the proposed assessments and recommendations before they appeared in print. In some cases, the Project Team and the User made recommendations as to hazards and recommended solutions that had not been previously identified. In my opinion, this process has resulted in the development of the low contractual-cost design safety features that were desired for the Laboratory.

REPORTING

I reported to all levels of the project (staff, User, Organizational Directors, and NASA Headquarters). This particular subject has been addressed in prior discussion. The following is a synopsis:

NASA Headquarters

Both formal and informal reports were presented to Headquarters staff. A copy of the FML Bi-Weekly newsletter was routinely sent to Headquarters for their information. The newsletter was beneficial in establishing credibility with Headquarters.

Organizational Directors

Reporting to Organizational Directors was formal. A stand-up presentation to the Code E Director was made every six weeks. In accordance with an established format, significant events, schedule, problems and concerns, and reserve fund status were presented. Presentations to the Center Director are now required every three months.

User Organization

Close contact was maintained with the Deputy who is from the User organization. Additionally, the weekly FA staff meeting was attended

wherein progress of the project was informally reported.

Staff

Staff must be kept informed to maintain project cohesiveness. The FML Bi-Weekly newsletter and frequent personal contacts accomplished this. Feed back was positive. If I did not say anything for a while, I was asked. The newsletter was secondary to the personal contact. On several occasions during the course of the Internship it was observed that the newsletter had not been consulted for news. The personal contact never failed to get the message across.

CHAPTER IV

WORK PERFORMED

The work performed during the Internship will be discussed in terms of management functions and technical contributions.

MANAGEMENT FUNCTIONS

An attempt to give the reader a good overview of the managerial problems and work performed during the Internship has been made. The following discussion concerning the management functions of planning, organizing, budgeting, directing, controlling, and personnel is intended to be of a summary nature.

Planning

Planning is thought of in terms of short term and long term. The long range milestones for this project were inherited. They were changed to accommodate slippage in dates and changes in work package structure. The philosophy that governed the short term planning was to try to make up as much lost time as possible. Project status and planned near term activities were in constant focus. The identification of long lead purchase items and Government furnished equipment (GFE) was planned early. Despite my best efforts to work around potential delays, some still occurred. For example, in the development of the specifications for the compressor system a

critical issue was the availability of the individual who was responsible for providing the specifications for the control system. The individual was in the process of changing jobs (promotion) and was in a use, or lose, annual leave situation. The issue was anticipated and some success in negotiating for the individual's time was experienced. However, it was not enough to prevent about two weeks slippage in the release of the specifications.

Organizing

The principal task in organizing was the optimization of the work package structure. This task included the selling of the three work package concept and the identification of who would be responsible for them. Once done, there was no appreciable need to change the organization.

Budgeting

Budgeting was a continual problem. Constant attention to the current cost estimate was required. The budget to go with each of the work packages was defined. Should the cost estimates that evolved show a change of greater than 10% from the stated budget, I would had to resubmit the budget estimates to Headquarters. This in itself would not have been a big problem. However, from the standpoint of credibility, it would have been best to not have to resubmit them. This did not happen during the Internship.

Directing

Directing of the project personnel was accomplished through negotiating work priorities with the staff. This was not autonomous directing and perhaps should be titled negotiating. Directing the A&E was accomplished by working through the Contract Administrator who had the contractual authority to direct. In this case, it was necessary to discuss with the Contract Administrator what was desired and either have the Administrator call the A&E, or send a note drafted by myself.

Controlling

Controlling involves keeping the project moving and keeping the expenditures as planned. The course of the project was controlled through negotiations with EE and FA management and through frequent visits to the A&E. Almost always, the visits were with the Deputy. About half of the time, members of the Project Team were included in the visits. At these meetings, concerns and problems as well as comments on the design drawings were discussed. The content of the design reviews given by the A&E was controlled by establishing the agenda with the A&E well in advance of the review. Controlling the budget was not a problem since I was the one who initiated purchasing and service request actions.

Reporting

Daily reporting to someone has been required. Most reporting was to staff to keep them informed. Reporting to management and

Headquarters was done periodically. Reporting was kept on an informal basis as much as possible. Formal reporting required the preparation of visual aids to support the presentation.

Personnel

Personnel work consisted of negotiating and evaluating performance objectives for the Compressor System Work Package Manager and personnel administrative matters. Two administrative tasks were performed. One was to write a recommendation for promotion for the Work Package Manager. The other was to write recommendations for cash awards to two Team members. One award was for a cost-saving suggestion. The other award was for compensation for lost vacation time as a result of volunteer work on the project. The decision to recommend these latter two awards was at my discretion.

TECHNICAL CONTRIBUTIONS

At the technical level, I was involved in all phases of the project. Direct technical contributions included the addition of variable inlet guide vanes for the compressor system, analysis of losses in and design of the compressor system piping, prediction and analysis of acoustic emission from the compressor system, review of the compressor system, and review of soil mechanics and building foundation design.

Variable Inlet Guide Vanes

The original concept for the compressor system called for the

compressor to be a single performance-line machine with a control system designed to operate the machine at a single design point (200,000 ACFM). The above machine would have to pass through a strong surge condition on starting and would always operate at a high energy consumption level. As a result, I proposed the addition of a set of inlet guide vanes and a control system that would permit operating the compressor over a performance map at minimum power (Fig. 11). With reference to Fig. 11, the zero degree inlet guide vane (IGV) curve would have been the operating line for the compressor without the IGV's. The control system would have limited the machine to operating at, or above the 200,000 ACFM design point. I was able to sell the concept and subsequently worked with the Compressor System Work Package Manager and the other team members responsible for electrical controls to develop the specifications for the controls.

Compressor System

The design of the piping (manifold, headers, surge-control, flow meter, and discharge piping) involved extensive collaboration with the Compressor System Work Package Manager. I performed the piping loss and fluid flow computations necessary for evaluation of the performance of the manifold design. Compressible flow analysis was based on the equations and tables contained in "NACA Report No. 1135"¹⁰. Screen losses were estimated on the basis of Horner¹¹ and of Dadone and Napolitano¹². Pipe flow losses for expansions, contractions, "tees", and friction were estimated using tables and

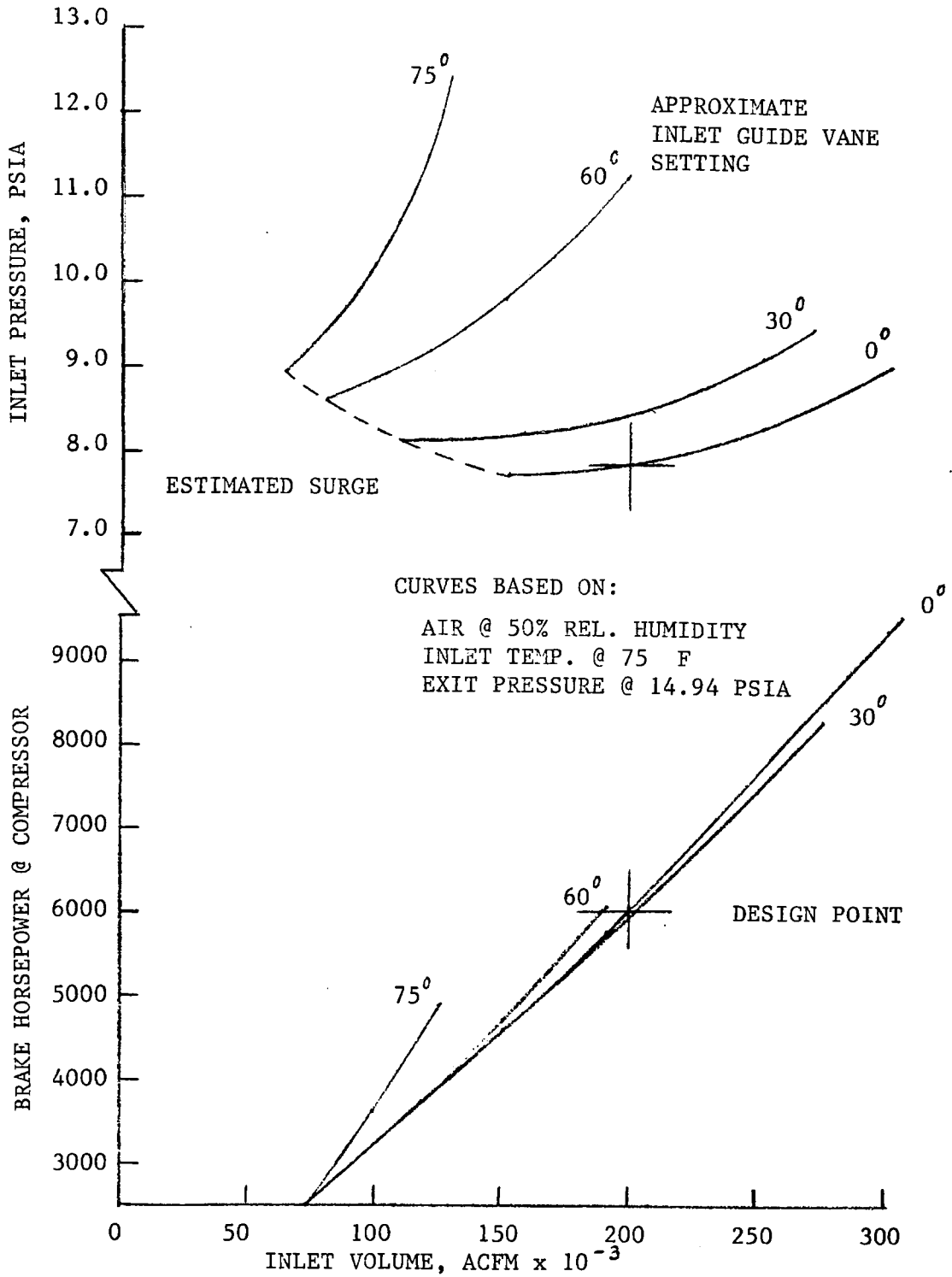


Fig. 11 Compressor System Performance

charts in Schaum's Outline Series by R.V. Giles¹³.

Acoustic Emission

As previously mentioned, work was done jointly with the Compressor System Work Package Manager to predict the noise level for the compressor system. The text edited by Beranek¹⁴ and tables from notes provided by private communication with a colleague at the Ames Center, M. Ospring, were used in developing the predicted noise levels of the system.

Compressor System Review

The design of the Compressor system was heavily influenced by a review committee chaired by myself. Particular attention was given to the lubrication system. I drew on experience gained as Branch Operating Manager of Code FA wind tunnel facilities in contributing to the design of the system.

Foundation Design Review

Test borings of the laboratory site were arranged for by the A&E. The firm of Peter Kaldveer and Associates performed the borings and both analyzed and reported the results (with recommendations as to soil treatment). The language of the draft version of the report showed a zone of loose sand under the site of the compressor. I consulted with Center personnel as to the need for additional borings to better define the soil profile, as well as studied the data from the standpoint of predicted settlement after construction was

completed. The text by D. F. McCarthy, PE,¹⁵ was used in estimating the amount of settlement. Subsequently, I met with the A&E and Peter Kaldveer to discuss the interpretation of results. Peter Kaldveer agreed that the report was somewhat ambiguous and agreed to reword the portion concerning loose sand to reflect more accurately a high gravel content and non-susceptibility to liquefaction. A comparison of results from past borings in the area and the above clarification were instrumental in the decision to not do additional borings. Subsequently, The earthwork design for the foundation was reviewed by myself. This included the above mentioned settlement analysis and computing the volume of engineered fill required for the project.

CHAPTER V

PROJECT CHRONOLOGY

As indicated previously, the beginnings of the FY 84 C of F Project: CONSTRUCTION OF FLUID MECHANICS LABORATORY started around 1978. A chronology for the project, dating from the start of the Internship (Sept. 1983) to the present follows.

STATUS AT START OF INTERNSHIP

Sept. 1, 1983 The "Preliminary Engineering Report"² and the "User Requirements"¹ had been released. Contract negotiations with Sverdrup & Parcel and Associates, Inc. for Architect and Engineering services were in progress. The draft "Management Plan"³ had been sent to Headquarters, comments had been received, and the plan needed to be updated. The preliminary Hazards Analysis had not been performed.

INTERNSHIP HISTORY

Sept. 12, 1983 This was the start of the Internship. I was briefed on the status of the project. The former Project Manager was charged with making corrections to the "Management Plan".

Sept. 15 The Project Team completed the review of the proposed contract for A&E services with Sverdrup & Parcel and Associates, Inc.

Sept. 27 The contract for A&E services was signed. The schematic design phase presentation (15% design) was scheduled for October 27, 1983.

Oct. 4 Topographical site data and Center utilities drawings were provided to the A&E.

Oct. 7 Mercury Engineering, Inc. started preparation of the Preliminary Hazards Analysis.

Oct. 12 Design constraints affecting the design of the compressor control system were formalized.

Oct. 13 Three soil borings were taken at the building site. The Center was required to compensate the tenant farmer for damage to his bell pepper crop at the site caused by the boring equipment. Damages were agreed to be equivalent to the value of three rows of produce. Thirty days notice was given to the farmer so this will not happen again.

Oct. 28 The schematic design review was held. The cost estimate by the A&E showed that the project is underfunded by \$1,075,676. Preliminary examination of the projected costs showed that the amount of concrete required is grossly over-estimated.

Nov. 1 The preliminary soils report showed a zone of expansive clay next to the topsoil layer. Internal review of this report was started.

Nov. 9 The Preliminary Hazards Analysis was presented by Mercury Engineering, Inc. Some changes in design were needed.

Nov. 14 The Design Safety review panel was appointed. The high cost estimate by the A&E placed the size of the compressor system in jeopardy. A single test-cell isolation valve with a Kirk-key interlock to prevent drive start of the compressor system was selected in favor of a two-valve isolation.

Nov. 15 The program status was presented to the Code E Director. The A&E was requested to accelerate the design of the Compressor system.

Nov. 17 The Preliminary Hazards Analysis was completed.

Nov. 18 The Project Manager for the A&E resigned. The head of the Mechanical Section was appointed as interim Project Manager.

Nov. 28 NASA comments to the 15% design were transmitted to the A&E. Headquarters release of funds for the project was requested.

Nov. 29 The head of the A&E's mechanical section was appointed Project Manager for the A&E.

Dec. 9 The A&E presented the 90% design submittal for the Compressor System.

Dec. 27 Notice of the bid opportunity for the Compressor System was announced in "Commerce Business Daily". Location of the building lobby was established to be in the center of the building front, as shown in the PER. This left the location of the mechanical room in doubt. The constraint placed on the arrangement by the Chief of EE was that no mechanical equipment will be located on the roof (chiller or boiler).

Dec. 29 Headquarters released \$1.4 million for acquisition of the Compressor System.

Jan. 11, 1984 The Design Safety Review Committee issued its report.

Jan. 19 The team member responsible for design of the compressor control system was replaced (left due to promotion).

Jan. 23 The Code E Director's review was held.

Jan. 27 The A&E presented the 30% design review for the

rest of the project (building). The total cost was projected at \$4.8 million (\$.9 million over budget). An internal audit of the A&E's cost estimate was started.

Feb. 13 Analysis of the A&E's cost estimate showed that the cost of engineered fill was high by 33%, the cost of steel and concrete appeared realistic, the cost of the HVAC system was high by about 85%, and the cost of electrical work was high by about 15%. The mechanical room and the darkroom were relocated to the north end of the building. The chiller was located outside, across the wall from the mechanical room.

Feb. 14 The statement of work for the Compressor System was released.

Feb. 16 Comments to the 30% design were delivered to the A&E. The building floor plan was altered to add a locker room/break room combination with a shower. Negotiations with the A&E for revision of their cost estimate were started. The Government contended that the 1.3 San Francisco area weighting factor was too high (should be more like 15% for the Moffett Field area).

Feb. 23 A meeting with the A&E and the firm doing the soils work (Peter Kaldveer and Associates, Inc.) resulted in the firm agreeing to issue a letter that indicates no additional fill, beyond the three feet required to bring the site up to elevation, is

required.

Feb. 27 An estimate of the sound pressure level for the Compressor System showed that a metal compressor building would be sufficient for a sound enclosure. Supporting data to establish the validity of the estimate was required. The diameter of the small header pipes to the vacuum manifold was enlarged to 16 inches from the original concept of 14 inches.

Feb. 28 The A&E was asked to complete, by May 1, specifications for release of an Earthwork work package. The goal was to have a contractor identified in time for a groundbreaking ceremony before June 30.

Mar. 8 The base design package for contractual purposes (redesign clause) was identified for the project. The package did not include cranes in both the Central Bay and the Compressor building, Central Bay heaters, a shop air compressor, curbs, gutters, a sidewalk parallel to Arnold Avenue, tire-stops in the parking lot, or realignment of Arnold Avenue.

Mar. 13 The review for the Code E Director was held.

Mar. 22 The bids for the Compressor system were opened. The two bidders were Allis-Chalmers, Inc. (\$1,267,855) and Roots-Dresser, Inc. (\$1,523,791). The Government estimate was for

\$1,270,000.

Mar. 23 The price quote from the A&E for early release of the Earthwork specifications was approved. The added design cost was \$3,120.

Mar. 27 The base design package was approved.

April 2 The A&E was directed to obtain an independent cost estimate.

April 5 The text from SPECSINTACT was mailed to the A&E. This started the process of deletion, consolidation, and addition to the specifications for the Building work package.

April 6 The A&E selected the firm of Lee Saylor, Inc. for the independent cost estimate.

April 11 Review of the revised Hazards Analysis (post 30% design) was held.

April 12 Lee Saylor, Inc. presented the preliminary cost estimate. Several items were omitted and there were questions in some areas.

April 13 A meeting was held with the User to establish

strategy and options for award of the Compressor System contract.

April 18 The Earthwork 90% design review was held. The final version of Lee Saylor, Inc.'s cost estimate was presented. The estimate showed a reserve of \$300,000 (base design package, plus landscaping, shop air compressor, and heaters for the Central Bay). This cleared the way for award of the Compressor System contract. The front elevation for the laboratory was selected.

April 20 The contract for the Compressor System was awarded to Allis-Chalmers, Inc.

April 23 George Lee was appointed as Operating Manager for the Fluid Mechanics Laboratory. The review for the Code E Director was held.

May 1 The development of the R&QA plan was initiated. A joint review with the Director of Code F and the Director of Code E was held. Pursuant to this review, a parking strip in front of the laboratory was added to the project.

May 5 An architectural model of the Laboratory was ordered. The User paid for the model.

May 9 A technical coordination meeting was held with Allis-Chalmers personnel. Major items discussed were the

need/advisability to change from a synchronous to an induction motor and to replace the gear-driven main lubricating pump with an electric-driven pump.

May 14 Long-lead electrical items (high voltage cable and an oil-switch for building power) were ordered.

May 21 Gathering of supporting data and an analysis for noise level from the compressor building was completed. The Chief of Code EE was asked to approve the use of an all-metal compressor building.

May 24 An existing contract was modified so as to do ductwork at the substation in support of the project. The decision was made to use a fuse disconnect as opposed to a circuit breaker. The project savings from these two actions were estimated to exceed \$50,000.

June 4 Headquarters released the remainder of the project funds. The updated Hazards Analysis was approved.

June 5 The Code E Director's review was held. the A&E presented the 90% design for the building. The design was incomplete in the compressor building area owing to Allis-Chalmers being late with delivery of design drawings to the A&E. An existing contract was modified so as to complete the work at the substation (except for

pulling through the high-voltage cables and making the final connection).

June 15 Approval by the Chief of Code EE was given for a metal compressor building.

June 18 Work at the substation was completed.

June 20 A meeting was held with Allis-Chalmers and Hitachi, Ltd. to discuss the change to an induction motor and the change to an electric-driven main lube oil pump.

June 21 Bids were opened for the Earthwork. Covey Trucking Co. of San Mateo, Ca., was low bidder (\$62,977). High bid was \$118,000. The low bid was 30% less than what the Government expected.

June 28 The Earthwork contract was awarded.

June 29 The groundbreaking ceremony was held. Final signing of the Earthwork contract was delayed until the contractor could post a performance bond.

July 11 Approval to delete the requirement for a metal stairway over the vacuum manifold was given. This resulted in a project cost reduction of around \$6,000.

July 16 The Earthwork was started. The farmer lost the gamble to harvest an onion crop from the site of the project.

July 20 The change to an electric-driven main lube oil pump was made.

July 24 The Code E Director's review was held.

Aug. 15 The Earthwork was completed.

Sept. 10 The maximum diameter of the vacuum manifold was increased from 62 inches to 72 inches. The corresponding small diameter section of the manifold was increased from 42 inches to 48 inches.

Sept. 18 The A&E submitted 100% design drawings (except for the compressor building systems and manifold piping).

Sept. 20 A review of the 100% structural design showed that the A&E's design for a tilt up panel did not meet code. A meeting was held to establish what needed to be done to correct the design.

Sept. 21 Ishimaru Design Group, Inc. (Support Service Contractor) started quality control checking of the design drawings.

Sept. 28 A meeting was held with the A&E to discuss the numerous comments by Ishimaru Design Group, Inc.

Oct. 10 The Contract Administrator for the Compressor System contract was asked to negotiate a change to the contract for the contractor to supply the contraction section to be used for velocity sensing.

Oct. 11 A meeting was held with the A&E to discuss final comments regarding the design drawings.

Oct. 16 All vellums, except for the compressor system piping were picked up from the A&E. Late delivery by Allis-Chalmers was still holding up delivery of the final design.

Oct. 23 Compressor system piping vellums were delivered by the A&E.

Oct. 26 Specifications were completed and ready for final typing.

Oct. 29 All vellums were corrected as required and ready for final review and signature by the Chief of EEF.

Nov. 2 Sepias of drawings affecting the compressor system were sent to Allis-Chalmers, Inc.

Nov. 5 All 62 vellums were sent to Reproduction Services for copies (70 each).

Nov. 8 Specifications were sent to Reproduction Services for copies.

Nov. 15 Copies of vellums and specifications were ready.

Nov. 16 The Director's quarterly review was held. The early completion of the earthwork was acknowledged as being a good idea. Twenty-five copies of the building work package were mailed. Opening of bids will be held December 15, 1984.

CHAPTER VI

LESSONS LEARNED

Lessons were learned in the course of the Internship regarding human relations, cost estimating, contract changes, operation of A&E firms, and the procurement of long-lead items.

HUMAN RELATIONS

Hidden agendas, resistance to change, the difficulty of bringing about agreement between strong willed persons, the need for adaptability, and the importance of timing are known factors affecting human relations.

Hidden Agendas

Identifying hidden agendas was recognized as being an essential part in approaching any problem of selling. For example, understanding the attitudes certain persons had concerning the size of the compressor system was an important factor in structuring the approach to gaining approval to procure the system.

Resistance to Change

The resistance to doing the earthwork early was a surprise. To the best of my knowledge, the root cause of the resistance was that it was not normally done because of concern for workload on the part of both procurement and construction management and possible problems in

interfacing with the prime building contractor. I made the mistake of assuming that the benefit of doing the earthwork early in this case was universally obvious. This experience has taught me that resistance to change should always be anticipated.

Agreement Between Strong-Willed Persons

The Internship was my first experience at bringing managers of two different line-organizations to a common point. The experience gained was a good one. This experience was a reminder of the need for patience in working toward agreement between strong-willed persons.

Need for Adaptability

I was reminded of the need for adaptability in structuring the project organization and way of doing business to make best use of the staff available. This was brought to the fore when the initial attempt to treat the Project Team as a true matrix structure failed. It was learned that the staff function very well when they are kept informed of the overall picture and tasks are individually negotiated to the effect that the staff is allowed to impact the project schedule.

Timing

The importance of timing in surfacing an issue was highlighted in the circumstances that led to approval to do the earthwork early. Other circumstances have taught me that it is poor timing to surface an

issue in the hope of approval for action when there is insufficient data to satisfy the approving individual. Data include those required for defining the problem and identifying possible solutions. In such circumstances, the trait of risk-aversion will prevail and more homework will be required.

PERIL OF COST ESTIMATING

Happy is the Project Manager who has two separate cost estimates that both indicate the project has adequate funds. Even if this is the case, the two estimates will not agree with each other. In the case of this project, one estimate showed adequate funds and the other did not. An analysis of the elements of each cost estimate will serve to point out some of the differences. However, the Project Manager should not expect to resolve the differences in cost estimates. The peril of cost estimating is that after two or more estimates are provided, the Project Manager is responsible for both determining and defending the choice of what estimate to most believe. The defense must be sound, or else the approval process for a proposed course of action is apt to come to a halt.

INEVITABILITY OF CONTRACT CHANGES

The Compressor System Work Package Manager and I worked with the idea in mind that a statement of work could be written wherein changes in design would not be needed or desired. More experienced colleagues said to the effect that this was a dream. The lesson that the bidder never takes exception to the statement of work was quickly followed by confirmation that changes are inevitable.

HOW A&E FIRMS OPERATE

The experience with the A&E has given me a good view of how A&E firms operate. It seems, in the pursuit of profit, the A&E's policy is to follow the minimum path to project completion. The limitation on the fee for A&E services (six percent of the construction budget) set by Congress is marginal for a project of the size of the FML (\$3.9 million). It may be, in a commercial situation with a different fee structure, the minimum path may not be followed.

A&E'S Approach

The A&E's approach to project completion seems to be:

Try to use the contractee as the designer and specification writer as much as possible.

Do no more than the minimum conceptual work.

Be as conservative as possible in engineering a system.

Copy a proven design whenever possible.

Bill the contractee for changes in scope as much as conscience will allow.

Meet design delivery schedules, ready or not.

The above is in no way intended to indicate a lack of professionalism. None was experienced.

A&E Contract Considerations

In view of the above mode of operation of an A&E, the following contract considerations are suggested:

Require a 15%, 30%, 60%, 90%, and 100% design review. The FML contract with the A&E did not contain provisions for a 60% review. Such a review would have been very helpful.

At the 60% review point, require a quality control check of all drawings for individual correctness and drawing to drawing consistency. Spell out in the contract what should constitute this quality control. The A&E did not do a quality check until the 100% point. Correcting deficiencies found by the Government cost several weeks of delay that could have been avoided by a check at the 60% point.

Negotiate the terms of the A&E contract to include what constitutes a design review.

Require the A&E to procure an independent cost estimate. Base any redesign clause on this estimate. The estimate should be provided at the concept design point (15%) and at the 60% design point.

MANAGEMENT OF PURCHASE OF LONG-LEAD ITEMS

Experience with the Internship has convinced me that procurement of long-lead items can not be started soon enough. Further, delays are

inevitable. The problem with delays is in estimating how much they might be. Planning should maintain as much flexibility as possible to allow for these delays.

It is a guess as to how much delay should be anticipated. In the case of the procurement of the compressor system and its expected delivery, the delays in both procurement and delivery items amounted to four months out of what optimally could have been a 15 month schedule. This same order of slippage was experienced in the design of the laboratory.

CHAPTER VII

ACCOMPLISHMENT OF OBJECTIVES

The foregoing chapters of this report were intended to introduce the background and objectives for the Internship, discuss the approach taken, illustrate the experience and lessons learned in carrying out the approach, and chronologically document the significant developments of the project. This final chapter is intended to discuss how the foregoing accomplishments and experience relate to the original Internship objectives presented in CHAPTER II.

TECHNICAL OBJECTIVES

The technical objective of "Assuring that the prioritized technical objectives of the project are met" has been exceeded. the original requirements by the User¹ and the commitment of the "Preliminary Engineering Report"² have been met in the design. The cost estimates for the project show that these features can be acquired within the budget. The design of the Compressor System manifold has permitted giving the User expanded test capability. Although not written, the User expected to have three manifold header pipes sized to accommodate indraft tunnels of up to 0.7 square feet in throat area. The design provided can accommodate tunnels of up to 0.95 square feet in throat area.

The internal features of the laboratory were included in the technical requirements. In developing the plan of the facility, I

provided an additional office and both a locker and a break room that was not in the original project. This was accomplished by locating a portion of the mechanical equipment outside the building and by negotiating for a small reduction in the size of both the control room and the laser development laboratory.

The objective of "Be sensitive to the desire of the User to add innovative technology to the project as new ideas are generated" was met. Identified at the early stage of the Internship was the need to add a set of variable inlet guide vanes to the compressor system which would both permit control of the vacuum in the manifold and simultaneously result in minimum power consumption. These features are now part of the Compressor System being procured. Additionally, at the 90% design point, I provided for the addition of extra power outlets and an additional window in the front of the laboratory building in response to a request by the User. The request resulted from the User's examining where personnel would be located in the various rooms.

MANAGERIAL OBJECTIVES

Assuring that project costs are always determinable was accomplished. A file for tracking expenditures was maintained. This was simple since the number of purchase actions was less than ten. the Center's internal accounting system provided a monthly status report of actions. The other aspect of determining costs is knowing the

expected cost. Knowing the cost was accomplished through auditing and updating the cost estimate by the A&E and the independent cost estimating firm, Lee Saylor, Inc. The current cost estimate was reflected in the reserve funding status which was reported to the Director of Code E (nominally, every six weeks).

The objective of assuring that schedules are met was not accomplished in the micro-sense. Those that could be controlled were met. In the overall sense, schedules have been met. The long-lead purchases (Compressor System, in particular) will be delivered early. The substation work and the earthwork have been completed early. The design of the facility is about six weeks behind schedule. However, owing to the early completion of the earthwork, the operational date for the facility is still on schedule for the first quarter of FY 86.

Despite the fragmented staff, the objective of maintaining "up-to-date awareness of project problems, progress, and anticipated needs" was met. The initial expectations were for the concept definition phase (15% design) to be most critical. Experience showed that getting past the design definition (30% design) point was most critical. In accomplishing this objective, many visits to the A&E were made and daily interactions were had with both the User and team members. Team meetings were not practical. Staff was briefed through the personal interactions and the project newsletter which I originated.

The objective of "Prepare and present managerial summary reports to top level NASA management to keep them informed of the project's status" was met. The newsletter was routinely sent to Headquarters. I prepared a formal briefing to the head of Headquarters, Code NX, gave two informal briefings to a representative of Code NX, gave a joint formal review to the Director of Code F and Code E, gave formal briefings to the Director of Code E, and gave weekly briefings to the Chief of FA (User).

Two items of an engineering change order nature have been negotiated promptly. The objective was to "Negotiate change orders promptly". these two items (change to synchronous drive motor for the Compressor System and change to electric-driven main lube-oil pump) were accomplished in minimum time. The process involved a design safety review as well as interaction with the Contract Administrator and the contractor. The principal source of difficulty was in securing the necessary supporting data to establish the justification for the contractor's price quotation. This was done within the span of two weeks.

LEADERSHIP OBJECTIVES

The objective of providing "positive direction to the project so that no time is lost and expenses are kept to a minimum" has been accomplished within what was controllable. Time lost due to establishing the basic design with the A&E (redesign-to-cost clause) and time lost due to delay with Allis-Chalmers in supplying design

data to the A&E was unavoidable. The rest of the project has gone without delay. Maximum use of surplus equipment and purchase of equipment to supply to the General contractor was made in order to hold costs to a minimum.

Success in promoting team identity was obtained through communications by the use of the newsletter. Team members were very responsive to project needs formalized in the newsletter. Team members consistently showed interest in the project in one-one-one interactions.

The objective of maintaining close monitoring and communications with contractors was accomplished. The project required constant communication with the A&E. At least one trip to the A&E was made every week to review, deliver, or retrieve work. Through this close monitoring, additional design expenses were held to a minimum.

The objective of assuring "that team members have positive feedback of work effectiveness" was met. Meeting this objective encompassed the exchange in one-on-one interactions with team members and in giving positive feedback to the supervisor of the team members. This assured both direct and indirect inputs. In two instances, the feedback was in the form of a formal recommendation for a cash award.

SUMMARY

My Internship experience as Project Manager of the FY 84 C of F Project: CONSTRUCTION OF FLUID MECHANICS LABORATORY at the NASA Ames Research Center, Moffett Field, California, has been presented. Considerable freedom to manage the project was given and an active role in many technical areas was taken. I was successful in selling and implementing the goal of doing earthwork early as a separate work package. The success of this venture is expected to bear fruit for other Project Managers in the conduct of their projects. Success in both influencing the design of the laboratory and in establishing good working relations, particularly between the Systems Engineering Division and the Aerodynamics Division (User) was experienced. This latter point is perhaps the most valuable Organizational contribution that I made. Several valuable lessons, particularly concerning dealing with A&E firms, were learned and considerable knowledge regarding the design of buildings and systems was acquired. In summary, it has been a most rewarding experience.

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APPENDIX I

DOCTOR OF ENGINEERING INTERNSHIP OBJECTIVES

INTRODUCTION

The internship will be fulfilled as Project Manager for the "Construction of Fluid Mechanics Laboratory" FY 84, Construction of Facilities Project at the NASA Ames Research Center, Moffett Field, California 94035. A representative job description for this type of position is shown in Attachment 1*. The precise details of the position description for the internship will, of necessity, be different due to the particulars of this project. One of the first objectives will be to negotiate a job description for this internship position. However, the responsibilities will remain essentially the same.

INTERNSHIP OBJECTIVES

The primary objective of this internship is to develop the engineering managerial skill necessary to function effectively as the manager of a complex facility design and construction project.

During the internship, Mr. Steinle is to demonstrate and apply technical and managerial and leadership abilities to the managing of the design and construction of the Fluid Mechanics Laboratory.

TECHNICAL OBJECTIVES

Some of the technical objectives to be accomplished are:

(a) Assure that the prioritized technical objectives of the project are met. This will require close coordination between User requirements and analysis efforts performed by engineering support personnel assigned to the project manager.

(b) Be sensitive to the desire of the User to add innovative technology to the project as new ideas are generated. Plan dates to afford maximum opportunity to add new or change concepts.

MANAGERIAL OBJECTIVES

(a) Assure that the project costs are determinable at any given time. This will require the establishment of cost accounting and control procedures for the project.

(b) Assure that schedules are met. This will require constant review of plans, objectives and progress. When shortages are projected, negotiations for additional or redistributed resources will be required.

(c) Maintain an up-to-date awareness of project problems, progress, and anticipated needs.

(d) Prepare and present managerial summary reports to top level NASA management to keep them informed of the project's status.

- (e) Negotiate engineering change orders promptly.

LEADERSHIP OBJECTIVES

- (a) Provide positive direction to the project so that no time is lost and expenses are kept to a minimum.
- (b) Promote team identity among the various personnel matrixed to the project through communications.
- (c) Maintain close monitoring and communications with contractors to assure accurate accounting of progress, costs, and quality of work.
- (d) Assure that team members have positive feedback of work effectiveness.

REPORT OF INTERNSHIP

The final objective of the internship is to prepare a Professional Internship Report which will summarize the experience and document the work performed and lessons learned. The report will establish that the objectives of the internship have been satisfactorily fulfilled and will satisfy the requirements of the College of Engineering.

* Attachment 1 is not presented. It is a job description, typical of the internship position. The job description that the writer would have negotiated embodies all of the features of the former and is presented as Appendix II.

APPENDIX II

JOB DESCRIPTION

TITLE

Project Manager, FY 84 Construction of Facilities Project,
CONSTRUCTION OF FLUID MECHANICS LABORATORY, AST, Experimental
Facilities and Equipment

NATURE AND PURPOSE OF POSITION

The Project Manager for the FY 84 Construction of Facilities Project,
CONSTRUCTION OF FLUID MECHANICS LABORATORY, manages, administers, and
provides the technical direction for the activities of the personnel
involved in all phases of the project from design-development through
construction and acceptance.

ASSIGNMENT

The incumbent is assigned as Project Manager for the FY 84 C of F
Project, CONSTRUCTION OF FLUID MECHANICS LABORATORY. The incumbent
is to use the "Preliminary Engineering Report" (PER) and the "User
Requirements" as a starting point and be responsible for the project
through design, construction, and acceptance. The project is

budgeted at \$3.9-million. The incumbent is responsible for assuring that both the PER commitment to Congress and the User's requirements are met within budget and time constraints. Frequent interaction with other personnel in the organization for purpose of consultation, advise, and coordination is required. The incumbent manages a team which covers supervision of both in-house and contractual efforts. The incumbent is responsible for advocacy for the project's progress and any change of plans. Both verbal and written reports to top level Center and NASA Headquarters, Code NX personnel are required.

The incumbent negotiates with appropriate Branch managers for personnel required to support the project as team members. The incumbent assigns team members to various aspects of the project according to need and area of specialization, advises them, and reviews the adequacy of their work. The incumbent is also responsible for the motivation and development of the personnel involved in the project, including support for and implementation of equal opportunity objectives.

Maintaining familiarity with the Center's safety manual is required. The incumbent conducts work in accordance with established regulations and with respect for both his own and co-workers safety. Adherence to proper safety practices at all times and encouragement of fellow employees to do likewise is required. The incumbent is responsible for reporting any unsafe conditions that may exist in an employees work site to the appropriate supervisor or Facility Safety

Representative.

SUPERVISION REQUIRED

The Project Manager works under the general administrative supervision of the Chief of the Mechanical Systems Branch who provides general guidelines for carrying out the assignment. First level, informal reporting, is at the Branch level. Within this framework, the incumbent has full responsibility and authority for carrying out the assignment. Activities, or deviations from project scope require approval of the Chief of the Branch.

GUIDELINES AND ORIGINALITY

The guidelines for the technical approaches being used on the project are based, for the most part, on well-developed engineering principles. Because of the budget (tight and fixed), time constraint, and the need to arrive at a state-of-the-art facility, considerable ingenuity, creativity, and both organizational and administrative ability is required to interact with the User, staff, and contractors in the development and implementation of the project.

QUALIFICATIONS AND CONTRIBUTIONS

The Project Manager must possess a broad background of engineering experience and training in the design and development of experimental

research facilities and equipment. The incumbent must be well grounded in basic engineering and scientific theories and principles, be versed in engineering economics, and be experienced in cost-control. The incumbent must have demonstrated the ability to interface with in-house groups and contractors in solving problems both at the design stage and in the field during implementation. The incumbent must be experienced in making presentations to and conducting negotiations with NASA Headquarters and/or others. The ability to work amicably with everyone, imposing firmness when required, but with fairness, so that progress on the project will not be impaired is crucial.

APPENDIX III

PROJECT MANAGER ASSIGNMENT-MANAGEMENT PLAN

THE PROJECT MANAGER

"The Project Manager has overall responsibility for the execution of the project under the direction of Ames and NASA Headquarters Management. In this role he plans, organizes, directs, and controls the project from the preliminary engineering phase until the facility is completed and turned over to the operations group. He is responsible for all activities of the Project Team, each of whose specific duties are defined elsewhere in this Plan. He is also responsible for reporting to and interacting with Ames Management and NASA Headquarters Management.

During all phases of the project, the Project Manager will be responsible for determining the number and type of team members and making the final selection of team members. The Manager will be responsible for cost, schedule, reporting and safety and reliability. Close control will be kept on all phases of the project so that any inappropriate direction or trend in any team member activity, plan or goal can be detected and corrected in a timely and constructive manner. Errors in team organization will be detected and corrected in cooperation with the Division. Special emphasis will be placed on providing each team member with a clear set of goals and responsibilities as well as a clear understanding of the team member's authority. Requirements for meetings will be developed by

the Project Manager.

The Project Manager will inform and involve Ames Management, the Aerodynamics Division and NASA Headquarters Management of any problem that has material impact on schedule, cost, basic function or safety.

The Deputy Project Manager will assist the Project Manager in any of the above duties and is the User representative on the project. He is responsible for providing the User requirements to the project and keeping these requirements current. All proposed changes to these requirements must be approved by the Deputy Manager. The Deputy Manager is a member of the Project Management team and must approve all change requests, communications with the A&E, other contractors, procurement approaches and packages prior to issue. In summary, he must be in the management approval loop."

APPENDIX IV

INDEX TO USER REQUIREMENTS
SECOND REVISION, MAY 22, 1984

OVERVIEW

- 1.1 Scope of Specification
- 1.2 Project Description
- 1.3 Project Objectives

BUILDING REQUIREMENTS

- 2.1 General Requirements
 - 2.1.1 Building Services
 - 2.1.2 Vibration Isolation
 - 2.1.3 Soundproofing
 - 2.1.4 Cranes
 - 2.1.5 Temporary Walk
 - 2.1.6 Future Expansion
- 2.2 Computer/Control Room
 - 2.2.1 Users Area
 - 2.2.2 Operations Area
 - 2.2.3 Computer/Control Room Utilities
 - 2.2.4 Conference Room
 - 2.2.5 Computer Floors
 - 2.2.6 Compressor Building
- 2.3 Central Experimental Area
- 2.4 Small Scale Research Facilities
- 2.5 Instrumentation Development Laboratory

INDRAFT TUNNELS

- 3.1 Description
- 3.2 Indraft Compressor

SAFETY

- 4.1 Safety Systems
- 4.2 Compressor Automation
- 4.3 Annunciator Panel
- 4.4 Interlocks
- 4.5 Hand Rails
- 4.6 Ground Faults
- 4.7 Fire Protection
- 4.8 Laser Safety
- 4.9 Louvers
- 4.10 Overhead Exhaust Fans

DRAWINGS

- 5.1 Building Drawings
- 5.2 Compressor Drawings

ADDITIONAL REQUIREMENTS

- 6.1 Louver Design

SUMMARY OF MODIFICATIONS TO USER REQUIREMENTS

- 7.1 Changes/Additions

SAMPLE SPECIFICATION

4.2 COMPRESSOR AUTOMATION

Provide automatic controls for the compressor such that only one operator is required to start the compressor, bring it to running conditions and to shut it down. The compressor control system should be capable of automatic unattended operation of 0 to 4 tunnels at one time within the capacity of the compressor. Compressor start up time and shut down time should be less than 10 minutes if possible. A surge control valve with control to match compressor flow requirements should be provided. Continuous operation should be unattended. Provide indication of valve status of each indraft tunnel in the control room, and each bay. Controls for the motorized valves shall be provided in the test bays only.

APPENDIX V

FML BI-WEEKLY, VOL. 84.6.4

PURPOSE:

To summarize the status and planned near-term activities associated with the FY 84 C of F Project: CONSTRUCTION OF FLUID MECHANICS LABORATORY

STATUS:

- 1) Existing Contract NAS 2-11821 has been amended and provided with \$12,000 supplemental funds to accomplish the ductwork at the substation. The work should be completed within the next 30 days.
- 2) The decision has been reached to not use Ames surplus switchgear. Considering removal, rework, and additional items needed for compatibility (reactors and a d.c. emergency power system), the cost trade is even at best.
- 3) Pending a final discussion with Ames Architect, Frank Kouba, approval has been given for a metal compressor building. The project will hold \$30,000 in reserve for acoustical insulation.
- 4) The updated Management Plan is still in typing and will be released the week of June 4.
- 5) The Earthwork package was released June 1, 1984. Bid opening is

scheduled for June 21. Groundbreaking will be June 29, starting at 3:30 PM at the site. The ceremony will adjourn to the 9x7 wind tunnel test-chamber area (N227) around 4:00 PM. A tour of the experimental facilities to be housed in the FML will be conducted and will conclude with refreshments. All FML project participants are invited.

6) Headquarters has released the balance of Project funding (\$2.5M).

7) The 90% review of the rest of the Project will be held June 5, as scheduled.

8) The updated Hazards analysis has been approved.

9) The project will recommend to the contracting officer that the compressor system contract be amended to permit the use of an induction motor. A letter proposing the change is in the mail from Allis-Chalmers to the contracting officer.

10) Don Chaffey and Brent Barnes visited Allis-Chalmers May 23-25, 1984, to view AC's R&QA operations. They found the operations in good order.

PLANNED NEAR TERM ACTIVITIES:

1) Continue with the update of the User's document.

- 2) Complete the order of GFE long-lead electrical items.
- 3) Prepare comments to the 90% review of the Building package.

APPENDIX VI

SAMPLE FROM HAZARDS ANALYSIS

INTRODUCTION

1.1 Purpose

"The purpose of this Preliminary Hazard Analysis (PHA) is to provide a safety evaluation of the Fluid Mechanics Laboratory (FML) at its 90% design point. Hazards are identified and recommendations provided to minimize the risk of personnel injury and equipment damage. These hazards and recommendations are contained in the PHA worksheets located in the appendices section.

This report will be the basis for continuing system design and further system safety analysis. It is not to be considered a design review, but more of an inductive process which identifies potential hazards in broad terms associated with the operational concept."

HAZARD SEVERITY LEVELS

Category I (CATASTROPHIC)

"Personnel error, design deficiency, or subsystem/component malfunction which will result in death or permanent debilitating injury, or which will result in equipment or facility damage greater than or equal to \$250,000."

ASSESSMENT VALUES

Level B (Reasonable Probable)

"Will occur many times during the life of the system...10 to 100 occurrences during the life of the system".

Level E (Extremely Improbable)

"Not likely to occur during the life of the system...0 to .25 occurrences during the life of the system".

CONCLUSIONS AND RECOMMENDATIONS

"There are various items of primary concern where failure of a component or incorrect operation of a system can lead to equipment damage and injury to personnel. These are: 1) operation of lasers 2) an inadvertent compressor start 3) compressor damage from loose objects in the airflow 4) inadequate design of overhead crane and 5) compressor surge. These and some others are listed below along with recommendations."

The hazardous condition of "Compressor damage from loose obstacles in airflow", caused by "Compressor start with tools and/or model parts inside test section and tunnel manifold valve open. Foreign objects placed inside the manifold by personnel after servicing the surge control valve" or caused by "Inadvertent opening of tunnel manifold valve due to erroneous signal" was considered to be CATASTROPHIC and was assessed as "Probable".

Recommendations, which when implemented, would reduce the assessment to improbable or less were:

- a) "Provide key interlock so that a compressor start is not possible unless each individual tunnel manifold valve is closed".
- b) "Provide safety screen upstream of compressor and upstream of surge control and manifold valves".
- c) "Provide control of each individual tunnel manifold valve only at the corresponding tunnel room".
- d) "Provide a single manifold valve (at each tunnel bay) that can be electrically/pneumatically isolated to prevent inadvertent opening when the compressor is operating".

VITA

FRANK WILLIAM STEINLE, JR.

PERSONAL:

Son of Frank William Steinle and Roy Royale (Smith) Steinle; Born July 25, 1939, Poteet, Texas; Married; Permanent Address: 2761 Nicholas Drive, San Jose, California, 95124

FORMAL EDUCATION:

High School Diploma, Jourdanton, Texas, May, 1957

B.S., Aeronautical Engineering, A&M College of Texas, May, 1961

M.S., Aero & Astro/Gas Dynamics, Stanford University, Oct. 1969

Attended Texas A&M University, August, 1982 - August, 1983 for Doctor of Engineering Course of Study. Internship at the Ames Research Center, Moffett Field, California, as Project Manager, FY 84 Construction of Facilities Project: CONSTRUCTION OF FLUID MECHANICS LABORATORY. Doctor of Engineering Degree anticipated for Dec., 1984.

PROFESSIONAL POSITIONS:

USAF Officer, September, 1962 - May, 1965

Research Scientist, NASA Ames Research Center, Experimental Investigations Branch, May, 1965 - May, 1970

Group Leader, Research & Analysis, Experimental Investigations Branch, May, 1970 - June, 1977

Assistant Chief, Experimental Investigations Branch, June, 1974 - present; Organizational name change to Aerodynamic Facilities Branch, Jan., 1984; Detailed as Project Manager, Fluid Mechanics Laboratory, Sept. 1983.

PUBLICATIONS

Thirty-five technical publications as either author, co-author, or contract/grant administrator. References are available on request c/o the author at NASA Ames Research Center, Moffett Field, CA. 94035, tel: 415 965 5850.