

INTERN EXPERIENCE AT
FLUOR ENGINEERS, INC.

An Internship Report

by

Stephen Benton Dobbs

Submitted to the College of Engineering
of Texas A&M University
in partial fulfillment of the requirement for the degree of
DOCTOR OF ENGINEERING

August 1983

Major Subject: Nuclear Engineering

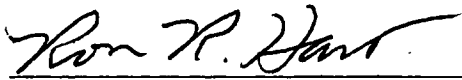
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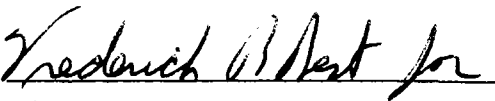
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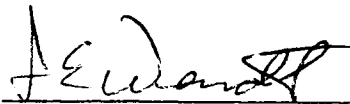
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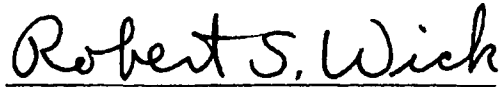
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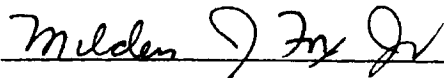
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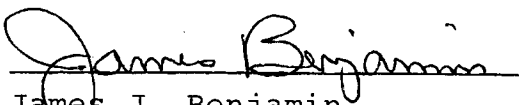
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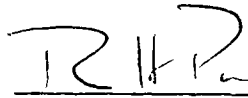
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August 1983

ABSTRACT

Intern Experience at Fluor Engineers, Inc. (August 1983)

Stephen Benton Dobbs, B.S. N.E. Texas A&M University

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Chairman of Advisory Committee: Dr. Ron R. Hart

This report demonstrates how the author's internship with the Houston Division of Fluor Engineers, Inc. fulfilled requirements of the Doctor of Engineering program and met the internship objectives. During the sixteen-month period between May 1980 and August 1981, the intern held the position of Engineer with the Cost and Scheduling Department.

This position allowed the author to observe and participate in a wide variety of projects in both technical and supervisory capacities, dealing primarily with scheduling and cost control for construction of large chemical process plants. Substantial experience was also obtained from interface with other departments of the company, including accounting, procurement, process engineering, project engineering, finance, and design engineering. Additionally, the intern's position allowed regular contact with project and corporate management, providing exposure to the company's top decision makers.

A brief overview of both cost engineering and scheduling engineering is presented to demonstrate the technical aspect of the internship. Finally, several of the author's positions at Fluor are described in order to detail the

intern's experience and show specifically how each objective was achieved.

DEDICATION

TO MY TOLERANT WIFE, DEBORAH

ACKNOWLEDGEMENTS

I would first like to express appreciation to my committee members Dr. Clarence E. Lee, Dr. Robert S. Wick, Dr. James J. Benjamin, Dr. Milden J. Fox, and especially Dr. Ron R. Hart for serving through what must be one of the longest internships in the Doctor of Engineering program.

I also want to thank the management at Fluor Engineers, Houston Division, for making the internship possible. My internship supervisor, Mr. John E. Wendt, offered several opportunities rarely available to beginning engineers. Credit must also be given my immediate supervisor, Mr. Charles W. Wight, for working me hard enough to obtain five years experience in my two-and-a-half years with Fluor.

Finally, much gratitude is due my wife, Deborah, for deciphering my original draft of this report and typing it.

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INTRODUCTION

An important part of the Doctor of Engineering program is the internship. The objectives of this internship are

- 1) to enable the student to demonstrate and enhance his or her abilities to apply both knowledge and technical training by making an identifiable contribution in an area of practical concern to the organization or industry in which the internship is served.
- 2) to enable the student to function in a non-academic environment in a position in which he or she will become aware of the employer's approach to problems, in addition to those approaches of traditional engineering design or analysis. (1)

The author served his internship with the Houston Division of Fluor Engineers as a cost and scheduling engineer.

Before reviewing the specifics of the author's personal internship objectives, a summary of Fluor Corporation will be presented including a brief description of Fluor Engineers and the Cost and Scheduling Department.

Fluor Corporation

Fluor Engineers is a wholly owned subsidiary of Fluor Corporation, a California-based international conglomerate. Fluor provides world-wide engineering, construction, procurement, and project-management services to energy,

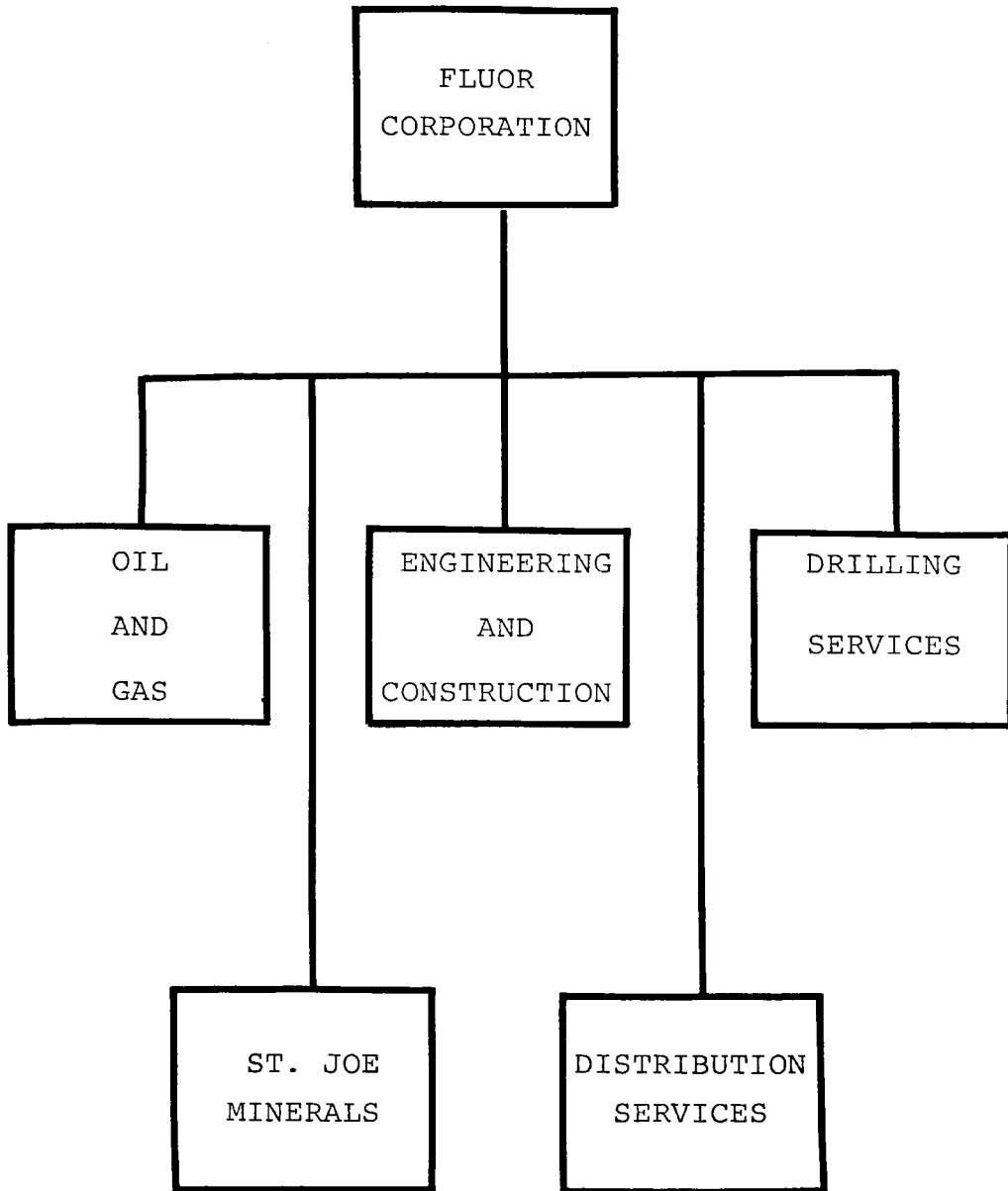
This report follows the general style and format of the American Association of Cost Engineers Journal of Transactions (1982).

natural resource, industrial, commercial, and utility clients. The company is a major producer of diversified natural resources; principally coal, oil and gas, lead, gold, silver, zinc, and iron ore. Subsidiaries are also involved in contract drilling, distribution of tubing supplies, and various industrial services. During 1982 Fluor had projects or operations in forty countries, and during the company's seventy-year history, it has been involved with over seventy nations. (2)

The company has five major operating groups as shown in Figure 1. They are Engineering and Construction, St. Joe Minerals, Oil and Gas, Drilling Services, and Distribution Services. Operational management is the responsibility of David S. Tappan, Jr., who is President and Chief Operating Officer. J. Robert Fluor is the Chairman of the Board and Chief Executive Officer.

The St. Joe Minerals group recorded sales of \$887 million in 1982. Primary operations for this group are located in Chile, Argentina, Peru, Australia, and the United States. Subsidiaries include the largest producer of lead and zinc in the United States and the second largest exporter of coal. St. Joe Minerals is undertaking extensive exploration efforts in the search for additional resources; including gold, silver, and base metals in the United States; tin, diamonds, and gold in Brazil; base metals, silver, and tin in Australia; and precious metals in Chile. St. Joe

FIGURE 1
FLUOR CORPORATION ORGANIZATION



Minerals exploration teams also have projects underway in Canada, Argentina, Spain, and West Germany.

The Oil and Gas Group consists of Fluor Oil and Gas Corporation, St. Joe Petroleum Corporation, and Coquina Oil Corporation. Together, this group had revenues of \$226 million in 1982. In addition to oil and gas production, this group owns over 1.1 million acres of undeveloped petroleum reserves in seven countries. Major holdings are in Greece, Great Britain, Argentina, Indonesia, and the United States.

The Engineering and Construction group is the largest operating group in Fluor Corporation. During 1982, this group's revenues reached \$5.4 billion from a variety of construction projects around the world. A few of the major projects underway or completed in 1982 include a 160 miles-per-hour rail system between Los Angeles and San Diego, the first commercial-sized oil shale project in the United States, the largest coal gasification facility in the world, a 918-megawatt pressurized-water reactor in South Carolina, and construction of the first commercial-scale manufacturing plant to produce genetically engineered products. Fluor Engineers, Inc., the author's internship company, is a member of the Engineering and Construction group.

Fluor Engineers, Inc.

Fluor Engineers, Inc. specializes in the design, procurement, and construction management of large chemical

process plants. During 1980, Fluor had both the largest backlog of work and the largest process plant technical staff of any company in its field. (See Table 1) Some of the company's prominent competitors are Parsons, Bechtel, Brown & Root, and C.E. Lummus.

Since Fluor is organized to handle large construction projects and actively seeks such work, its main clients are the larger chemical firms such as Exxon, Texaco, Du Pont, Monsanto, or Dow. When these firms consider the sale of additional or new products, projections of sales quantities are made for related sale prices. While operating costs can be estimated from raw material costs, the unknown variable is the capital cost of the production facility. To determine these costs and decide on optimum plant characteristics and location, operating firms list a series of project scenarios known as case studies or feasibility studies. Such studies cover a wide range of process schemes, throughput, and plant locations. These studies provide Fluor with one source of revenue; more importantly, the studies many times lead to the award of major design and construction projects.

Once feasibility studies prove the venture to be viable and indicate the optimum combination of parameters, the operating company invites design firms such as Fluor to make a job proposal. Since such projects are done on a cost-plus basis (i.e., all of the contractor's expenses are reimbursable), bids are not the most important factor in deciding on

TABLE 1
 CHEMICAL PROCESS PLANT BUILDERS

COMPANY	PROCESS PLANT TECHNICAL STAFF	VALUE OF PLANT ORDER BACKLOG*
Fluor	7,900	13.6
Parsons	5,400	6.6
Bechtel	5,000	NA
Foster Wheeler	4,500	1.8
C.E. Lummus	5,200	4.5
Brown & Root	3,300	6.0
Pullman Kellogg	5,000	2.0
Stone & Webster	1,900	NA
C.F. Braun	2,400	1.4
Badger	1,950	1.3

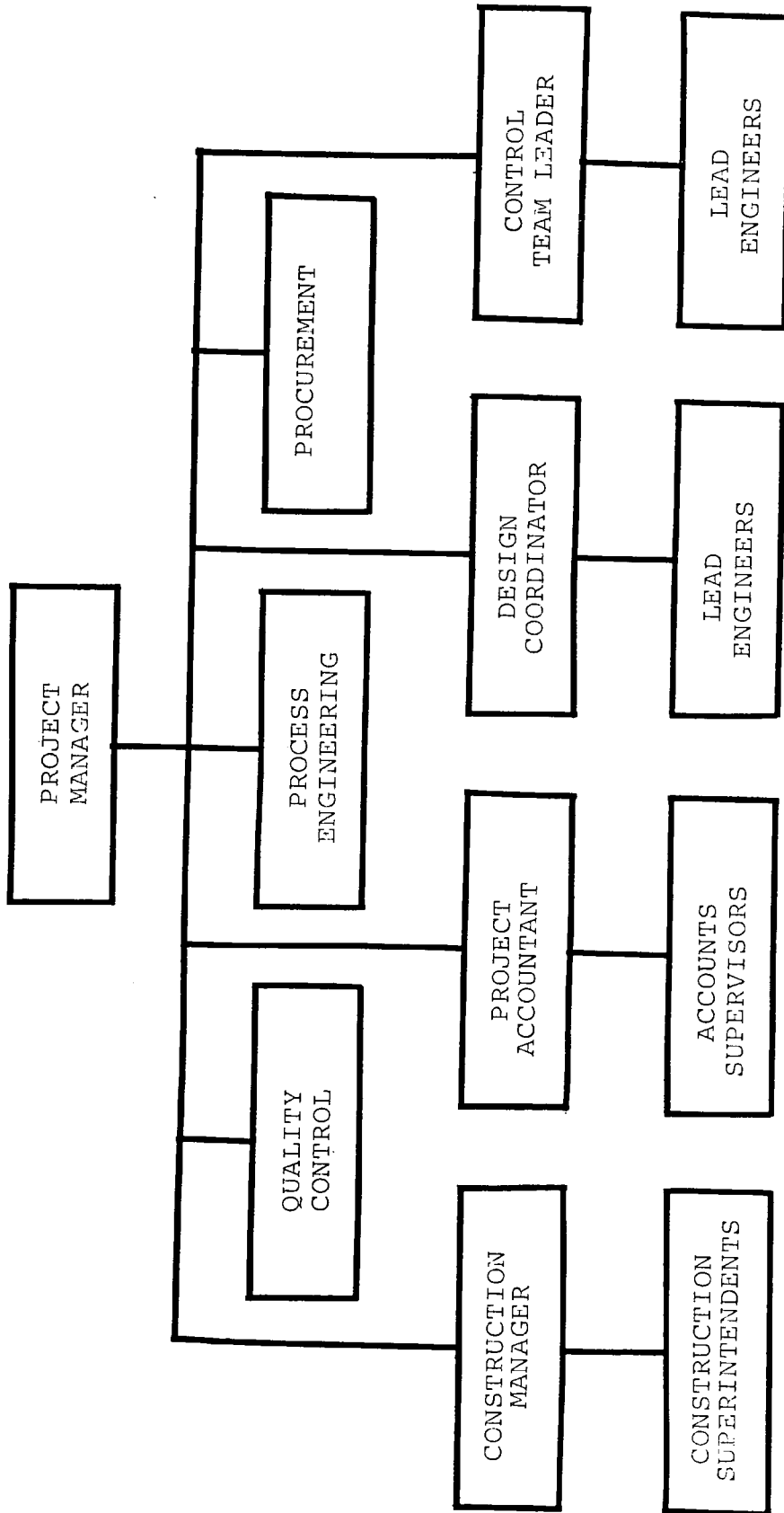
* In billions of dollars

a particular contractor. The output of large chemical plants often exceeds a revenue rate of several million dollars a day. As a result, factors indicating a contractor's ability to bring a project in on time, on budget, and with a low operation down-time easily justify a higher fee.

In some cases, Fluor is asked to only design a project. This occurs when the client wants to do the construction himself or wants to hold construction for a later date. These projects end with the transfer of the final approved drawings and specifications. However, in most cases, clients wish to use Fluor's facility, personnel, and expertise to purchase their construction materials. To provide continuity and optimum performance, many clients also hire Fluor to manage project construction. This construction can be done by one of Fluor's construction companies or another contractor.

Fluor Engineers uses a combination of departmental and functional arrangements in its organizational structure. Projects are run on a task force basis, which is a functional arrangement. Figure 2 demonstrates the format of a typical task force. This organization allows the responsibility for project success to be given to one individual, the project manager. In this manner, each project can be handled as a self-contained entity organized for a single purpose.

FIGURE 2
TASK FORCE ORGANIZATION



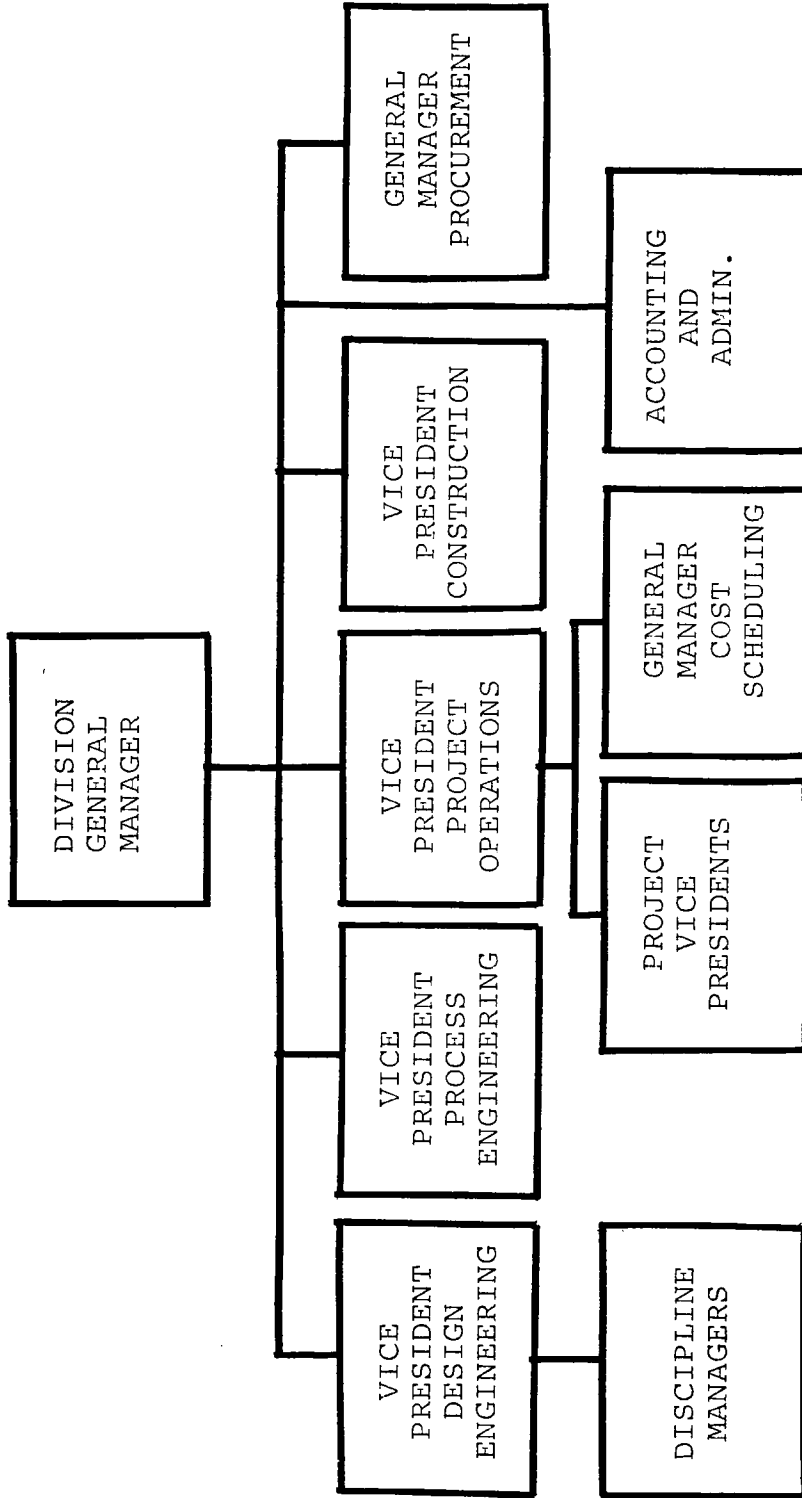
At the division level, Fluor is organized on a departmental basis as shown in Figure 3. Here, task forces appear as separate organizational components. Departments such as Engineering or Accounting act as pools of employees to be drawn from in forming a task force. These departments also maintain control of administrative functions for members, provide specialized services to task forces, and act to insure quality of technical work done by members on particular task forces.

Cost and Scheduling

Since the ultimate goal of construction projects is to complete the plant on time and on budget, the cost and scheduling engineer plays a key role in project management. As late as the 1950's, expenses were handled by accountants and all other cost control and schedule matters were left to the construction superintendent. However, as multi-billion dollar projects were undertaken, the role of the cost and scheduling engineer evolved to assist the project manager in his decision-making process. This new field developed into a complex and highly technical system of defining, analyzing, estimating, and reporting project cost information as well as projecting and controlling the intricate interface activities of the design and construction process.

FIGURE 3

DIVISION ORGANIZATION



At Fluor, the head of the cost and scheduling group on a project is called the control team leader. The control team leader reports directly to the project manager. As shown in Figure 4, cost and schedule functions are divided and lead engineers head each group. When the project progresses sufficiently to begin construction, a separate cost and scheduling unit is established at the job site and the two control team leaders are supervised by a control team manager.

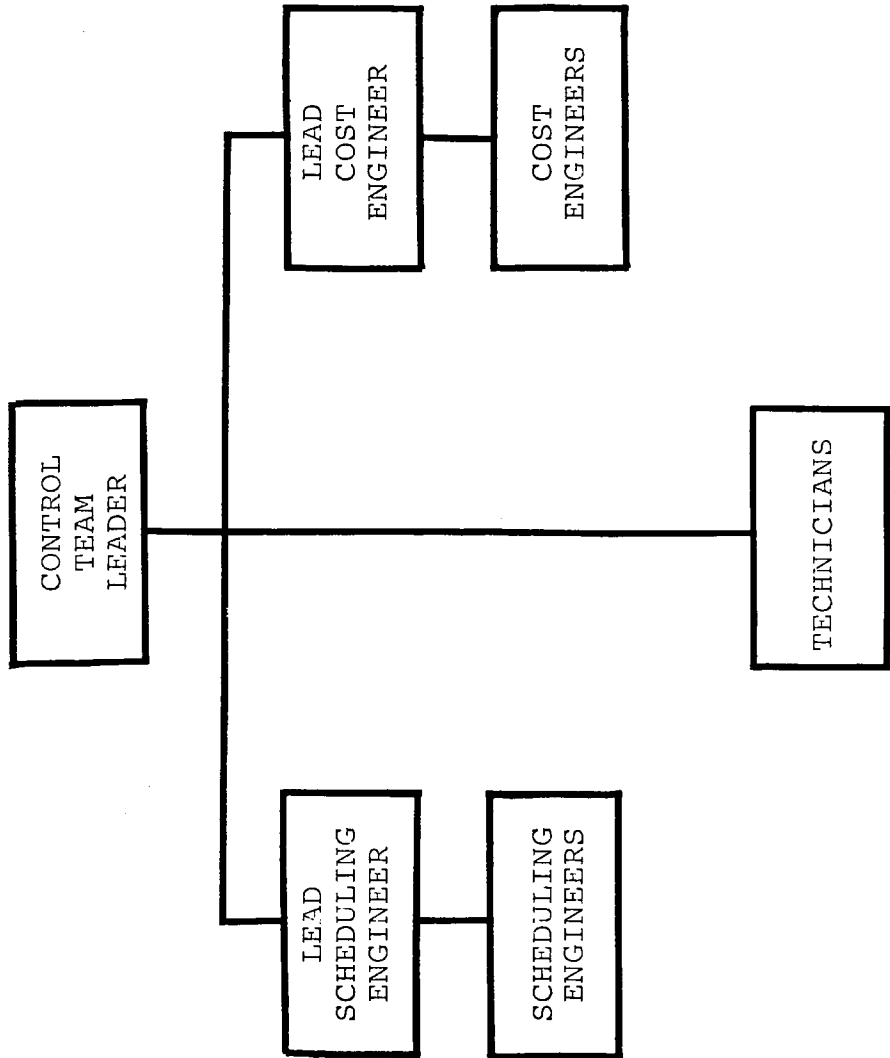
Unlike many groups on the task force, the cost and scheduling control team remains on the project for its entire lifetime. The teams begin by preparing initial estimates and schedules for feasibility studies requested by clients. Later, team members help in the preparation of proposal packages when Fluor tenders for a particular job. Finally, the cost engineer is one of the last members to leave the task force; leaving after completion of the job's final cost report. This final report is used as an estimating base for new projects and helps to point out exceptions and areas which can be improved in future work.

Internship

As stated previously, the author served his internship as a cost and scheduling engineer. The internship supervisor was Mr. John E. Wendt, P.E., who held the position of General Manager of the Cost and Scheduling Department at

FIGURE 4

CONTROL TEAM ORGANIZATION



Fluor Engineers, Houston Division. During the majority of the internship period, the author's immediate supervisor was Mr. Charles W. Wight, P.E., holding the position of Control Team Manager.

At the outset of the internship, the author, along with Mr. Wight and Mr. Wendt, developed a set of internship objectives that would satisfy the requirements of the Doctor of Engineering program as well as provide experience that would prove useful to both Fluor and the author's career. These objectives were approved by the author's advisory committee (Appendix A) as listed below.

1. Learn as much as possible about cost engineering.
2. Learn the basics of scheduling engineering.
3. Become familiar with process industry technology.
4. Develop a consistent set of computer output formats for cost reporting.
5. Develop guidelines for producing the job's final cost report and prepare a typical financial cost report for a selected project.
6. Produce a model and computer program for performing estimate risk analysis.
7. Take responsibility for cost engineering on one phase of a project.

The remainder of this report will explain how these objectives were met. A chapter each will be devoted to general concepts in Cost Engineering and Schedule Engineering. These chapters are intended to explain the technical nature

of the internship and provide the reader with sufficient background to understand the requirements of the author's work assignments. An additional chapter will describe a few of the intern's assignments and demonstrate how each was used in meeting the objectives. Finally, the conclusion will show specifically how each objective was fulfilled and sum up the author's internship experience.

COST ENGINEERING

The American Association of Cost Engineers defines cost engineering as "that area of engineering practice where engineering judgment and experience are utilized in the application of scientific principles and techniques to the problems of cost estimation, cost control, and profitability". The author has found that if properly conducted, the cost engineer's job should consist of preparing a base or cost plan, observing actual cost information as it is acquired, noting exceptions to the plan, and informing management of options to return the project to the plan base. However, before development of the base plan can be explained, a description of some of the types of costs is required.

Types of Costs

Before attempting to control costs or even record expenses, costs must be divided into manageable categories. The categories developed are referred to as the cost code of accounts. Ideally, the subdivisions should contain enough detail to adequately track expenditures, allow for accurate estimating, and provide information to identify significant deviations from the plan. However, excessive detail causes needless effort in expense tracking and wasted labor in estimating the detail. The basic divisions of

construction costs are divided into home office costs, indirect field costs, and direct field costs.

Home office costs contain costs for engineering labor, burdens on the labor, indirect costs, and office expenses. Labor burdens include items such as vacation time, paid holidays, and sick leave, while indirect costs cover items related to maintaining the engineering facility where the home office design effort takes place. Examples of indirect costs would be rent payments for the engineering office space, office furniture, building security, and utilities. Office expenses include office supplies, telephone and postage, computer time, and use of outside consultants.

Direct field costs are split into three main categories: direct field labor, direct field subcontracts, and direct field materials. Direct field material costs cover the cost of all materials purchased for the construction effort in the field which will become a permanent part of the plant. These costs are subdivided into accounts for concrete, steel, equipment, piping, etc. The direct field labor category covers costs related to the installation of direct field materials. This cost does not usually include labor benefits, which are included under indirect field costs. Direct field subcontract costs result from the use of specialty subcontractors to erect certain portions of the plant instead of using direct-hire field labor. Some typical uses of subcontractors include piling, boilers,

insulation, and painting. However, in some cases such as developing countries, entire projects are subcontracted in small packages in order to develop local companies.

Indirect field costs include all field costs which are not associated with the permanent physical plant. Examples of indirect field costs include field engineering staff labor, field offices, craft burdens, site vehicles, small tools, rental equipment, and first aid.

In addition to these three main divisions of costs, some special costs are accounted for separately, depending on the job. These costs include spare parts, taxes, surplus materials, commissioning the plant, escalation, contingency, and fees for the main engineering contract.

To maintain computer files of project costs, each of the cost divisions above is assigned a number. Appendix B gives a condensed version of a typical cost code. The computer implementation of such codes will be discussed in later sections of this report.

Estimates

The cost base or control plan described previously is established with estimates. Cost estimates represent the expected or predicted costs for the project. Differences between estimated costs and actual costs represent deviations from the control plan that require management action for correction.

Estimates may be prepared for many purposes; some of the principal reasons are:

1. Feasibility studies.
2. Selection from among alternate designs.
3. Selection from among alternate sites.
4. Presentation of competitive bids.
5. Appropriation of funds. (3)

Estimates vary in the amount of accuracy and detail. The accuracy of an estimate normally depends on the amount of design detail used. In increasing order of accuracy, the various major types of estimates are shown in Table 2.

Typically, order of magnitude estimates, sometimes referred to as "quickie" estimates or "back of the envelope" estimates, are performed early in the project before any detail design information is available. Such an estimate can be completed in one or two days by a single engineer and generally uses an estimating process called ratio estimating or capacity factor estimating. This process uses the exponential relationship between cost and plant capacity to predict the cost of a new plant from the known cost of a plant already constructed but of a different size.

Preliminary estimates are undertaken after the project design is underway. Normally, the first design information available is a list of required major equipment. Therefore, preliminary cost figures are usually calculated by a method

TABLE 2

ESTIMATE ACCURACY

TYPE	ACCURACY
ORDER OF MAGNITUDE (RATIO ESTIMATE)	-30%, +50%
PRELIMINARY (BUDGET AUTHORIZATION ESTIMATE)	-15%, +30%
DEFINITIVE (PROJECT CONTROL ESTIMATE)	- 5%, +15%

Source: Humphreys and Katell, Basic Cost Engineering, p. 1

called equipment factoring, where total plant cost is estimated by applying factors to known or estimated major equipment costs. Factor estimates require from one to five engineers and may take up to three weeks to prepare, depending on the size of the project.

Finally, definitive estimates are prepared after a majority of the design engineering is complete. These estimates require five to ten engineers and may take up to three months to develop. Definitive estimates are often called detailed estimates because they are based on the pricing out of actual design drawings.

To demonstrate the technical nature of cost estimating, a brief description and example will be given of the three main methods of estimating chemical process plant construction projects.

Capacity Factored Estimates

As mentioned previously, capacity factored estimates use the exponential relationship between cost and plant capacity to predict the cost of a new plant from the known cost of a plant already constructed, but of a different size. The unknown cost CX of a plant with capacity EX can be related to a known cost CK having a capacity EK as follows:

$$CX = CK \left(\frac{EX}{EK} \right)^n$$

where n equals the cost capacity factor. The capacity factor is normally between .5 and .6, but can vary over a wide range depending on the type of plant. Table 3 lists capacity factors suggested by Humphreys and Katell (3). However, most major design firms, such as Fluor, maintain their own cost libraries composed of data from previous projects. This data allows the calculation of capacity factors for almost any type of plant, based on actual recent projects. These factors are determined from the least squares slope of the cost capacity relationship on a log-log basis. The project library data base is highly proprietary in nature and is included in the company's technical expertise. Often, potential clients are swayed in their decision on whom to award study contracts, based on a contractor's history of performing similar projects. Experience with a particular type of plant provides a more accurate base for performing feasibility study estimates.

The requirements and considerations for performing a capacity factored estimate are:

1. Need historical data on similar plant.
2. Must be a near duplicate.
3. Should be reasonably close in size.
4. Proration factor is critical; must be analyzed.
5. Must adjust for off-sites and utilities.
6. Must adjust for project execution differences.

TABLE 3

EXAMPLES OF COST CAPACITY FACTORS

PLANT OR PROCESS UNIT	EXPONENT
Desalting Crude Oil	.60
LP-Gas Recovery	.70
Solvent Extraction	.73
Lubricating Oil Manufacture	.89
Catalytic Cracking	.83
Thermal Cracking	.60
Desulfurization of Gases	.41
Coking	.81
Vacuum Distillation	.57
Sulfuric Acid Production	.78
Sulfur Production	.64
Oxygen Plant	.65
Styrene Plant	.65
Ammonia	.90
Ethylene	.86
Chlorine Plant	.75
Refineries, Small	.57
Refineries, Large	.67

7. Must escalate for time difference.
8. Must account for location-dependent costs. (4)

Figure 5 shows an example of an improper and poorly prepared capacity factored estimate, while Figure 6 indicates the proper way to implement the capacity ratio procedure. In both cases, the estimates are of the cost of a 100,000 barrels-per-day refinery located in Midland, Texas, based on data from a 150,000 barrels-per-day refinery built in New Orleans, Louisiana, during 1975. In the first example, the estimator simply applies the capacity factor of .67 to the capacity ratio and multiplies by the known cost to get an estimated cost of \$40 million. However, Figure 6 demonstrates how a minimal amount of forethought and proper use of the estimate technique can produce a much more accurate estimate. This proper example recognizes that, although the two plants are similar, there are some important differences. First, the plant in New Orleans required piling and tankage, and incurred state taxes that the new plant would not require. After deducting these differences, an adjustment is made for the average escalation over the period between 1975 when the New Orleans plant was constructed and the present. Additionally, an amount is added to account for location-specific factors, such as the Panhandle's harsher weather conditions and short supply of qualified labor.

FIGURE 5

EXAMPLE OF AN IMPROPER CAPACITY FACTORED ESTIMATE

PROBLEM: ESTIMATE COST OF 100,000 BPD REFINERY LOCATED IN
MIDLAND, TEXAS.

SOLUTION: RATIO FROM A 150,000 BPD REFINERY CONSTRUCTED IN
NEW ORLEANS, LOUISIANA, DURING 1975.

150,000 BPD REFINERY - NEW ORLEANS (1975)

FINAL COST = \$50 MILLION

COST OF A 100,000 BPD REFINERY - MIDLAND =

$$\left(\frac{100}{150}\right)^{0.67} \times 50 = \$38 \text{ MILLION}$$

USE: \$40 MILLION

FIGURE 6

EXAMPLE OF A PROPER CAPACITY FACTORED ESTIMATE

PROBLEM : ESTIMATE COST OF 100,000 BPD REFINERY LOCATED IN
MIDLAND, TEXAS.

SOLUTION: RATIO FROM A 150,000 BPD REFINERY CONSTRUCTED IN
NEW ORLEANS, LOUISIANA DURING 1975.

150,000 BPD REFINERY - NEW ORLEANS (1975)	
FINAL COST	= \$50 MILLION
DEDUCT PILING, TANKAGE, STATE TAX	- <u>\$10 MILLION</u>
SUBTOTAL	= \$40 MILLION
ESCALATE TO 1983 ADD 20%	= \$48 MILLION
ADJUST FOR LABOR PRODUCTIVITY ADD 25%	= \$60 MILLION
CAPCITY RATIO $60 \times \left(\frac{100}{150}\right)^{.67}$	= \$46 MILLION
ADD SPECIAL POLLUTION REQUIREMENTS	+ <u>\$ 5 MILLION</u>
TOTAL COST	= \$51 MILLION

USE: \$50 MILLION

After these corrections are made to the original data, the capacity ratio can be properly applied to give the cost of a similar plant at reduced capacity in Midland. Finally, an addition is made to account for special pollution equipment to be added to the Midland refinery that was not included at New Orleans. Note that by not considering the major difference between the two plants, the poor estimate was off by 25%.

Capacity factored estimates have the advantage of being quick and all-inclusive. In other words, the estimate does not require many pieces of the plant to be estimated and then added together; the cost of the whole plant is calculated at once. However, these benefits give rise to the disadvantage of poor accuracy, approximately 30% to 50%. To obtain higher accuracy, different estimating techniques such as equipment factoring are required.

Equipment Factored Estimates

The equipment factored estimating technique is one of the most useful estimating methods available to the cost engineer. This technique can provide accuracies in the 15% to 30% range and can be completed during the early stages of the design process.

The original development of factored estimates was done by H.J. Lang in 1947. He proposed the estimating formula:

$$C = (\Sigma E) F$$

where

C = capital cost

E = cost of purchased
equipment

F = estimating factor:

4.74 for fluid proces-
sing plants

3.63 for fluid-solid
processing plants

3.10 for solid proces-
sing plants

According to various sources (5), Lang's technique of single-factored estimates are still used, but accuracy falls between 30% and 50%.

To improve the accuracy, W.E. Hand proposed that separate factors be used for each piece of each type of equipment. For example, there would be one series of factors for columns, heat exchangers, tanks, and other equipment made with carbon steel, and other series for the same items of stainless steel or other materials of construction.

An advantage of Hand's method is that it avoids the necessity of having to classify a plant as fluid, solid, or fluid/solid. As a result, the estimated cost will more truly reflect the particular character of the process. Another disadvantage of using overall factors is that since

the factors are averages, they tend to make the costs of all plants conform to an arbitrary norm.

Additional improvements in accuracy are added by using factors only to estimate the direct field cost of the plant instead of the total installed cost. Implicit in the use of factors is the assumption that all elements of the cost of a plant are directly proportional to the value of the equipment. This is true for some elements, but equally untrue for others. The direct cost of pipework, as well as the cost of steel structures, buildings, electrical systems, and insulation do correlate with the cost of equipment. However, indirect field cost and home office cost are not directly dependent on equipment cost.

Consider two plants, identical in all respects except size, being built by two different organizations with no exchange of information. Each organization will have to spend the same amount of time on design and supervision, so the indirect costs will be approximately equivalent. Therefore, the estimating factors should only be used to determine direct field costs.

It should also be noted that some sources believe that instrument costs are not directly proportional to equipment costs. In these references, factors are corrected to exclude instrument costs so they can be estimated separately.

Table 4 lists some example equipment factors suggested by Cran. (5) Similar to capacity factors, each design firm

TABLE 4
EXAMPLE EQUIPMENT FACTORS

EQUIPMENT	FACTOR
Agitators	1.3
Air Heaters	1.5
Blenders	1.3
Blowers	1.4
Boilers	1.5
Centrifuges	1.5
Columns (Carbon Steel)	3.0
Columns (Stainless Steel)	2.1
Compressors (Motor Driven)	1.3
Compressors (Steam Driven)	1.5
Cooling Tower	1.2
Drums	2.0
Fans	1.4
Filters	1.4
Furnace	1.3
Heat Exchangers (Air Cooled)	2.5
Heat Exchangers (Shell and Tube)	2.1
Pumps (Centrifugal, Carbon Steel)	2.8
Pumps (Centrifugal, Stainless Steel)	2.0
Reactors (Carbon Steel)	1.9
Tanks (Storage)	2.3
Turbines	1.5

calculates their own factors from data collected on past projects and holds this information in strict confidentiality. Some of these factors are collected with a high degree of detail to distinguish between different sizes of equipment, metallurgical composition, or method of manufacture.

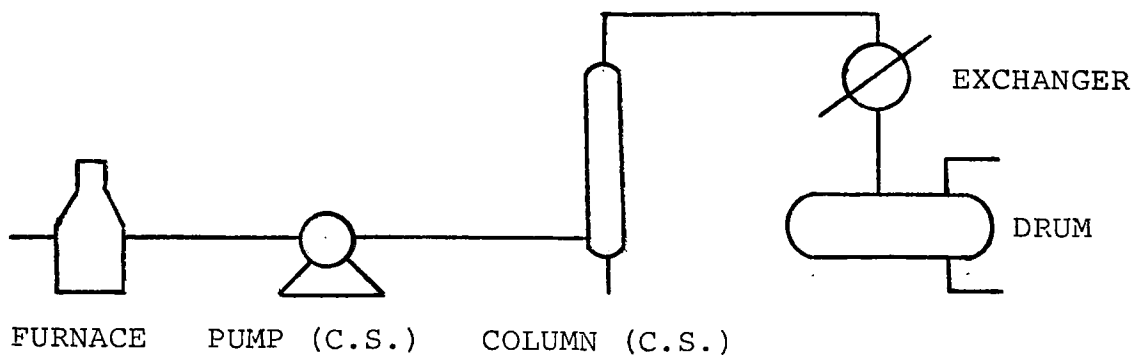
Factor estimating relies on the principle that a ratio exists between the cost of a particular equipment item and the associated nonequipment items that need to be added to the project in order to complete the installation of that item. For example, if a drum is added to an estimate, the nonequipment items that are also added as a result of including the drum in the project are:

1. A foundation for the drum to sit on.
2. Excavation for the foundation.
3. Structural steel for the drum platforms.
4. Piping to connect the drum to other process vessels.
5. Supports for the piping.
6. Instrumentation for the drum.
7. Paint and insulation for the drum and for the related steel and piping.

In addition, a pro-rate share of other nonequipment items must be added, such as paving, sewers, control-house, area lighting, power distribution, etc.

Figure 7 is a simple example of an equipment factored estimate. The process flow diagram shows five pieces of

FIGURE 7
EXAMPLE OF EQUIPMENT FACTORED ESTIMATE



IN 1,000'S OF \$

FURNACE COST	= 650	FACTOR = 1.3	(650) (1.3)	= 845
PUMP COST	= 50	FACTOR = 2.8	(50) (2.8)	= 140
COLUMN COST	= 120	FACTOR = 3.0	(120) (3.0)	= 360
EXCHANGER COST	= 80	FACTOR = 2.1	(80) (2.1)	= 168
DRUM COST	= 50	FACTOR = 2.0	(50) (2.0)	= <u>100</u>
SUBTOTAL DIRECT FIELD COST				1,613
ADD INDIRECT FIELD COST AND HOME OFFICE COST				+ <u>950</u>
TOTAL INSTALLED COST				2,563

USE = \$2,600

NOTE: C.S. REFERS TO CARBON STEEL

equipment. The material cost of each piece of equipment is multiplied by the corresponding factor from Table 4. As noted previously, these factors are determined from data collected on previous projects. There are a variety of ways to obtain the material costs of equipment items. The most common ways are:

1. Firm bids and quotations.
2. Previous project equipment costs.
3. Published equipment cost data.
4. Preliminary vendor quotations.
5. Scale-up of data from similar equipment of other capacities.

The sum of the multiplications of Figure 7 represents the total direct field cost. A separate estimate of indirect field costs and home office costs is added to obtain the total installed cost. These indirect costs are estimated in a variety of ways, including percentage of direct field cost, drawing counts, equipment number counts, and ratios of estimated field labor.

Equipment factored estimates have the advantage of reflecting costs of specific designs and take less time to complete than detail estimates. The only prominent technique that is more accurate than equipment factoring is detail estimating.

Detail Estimates

As the name implies, detail estimates require a significant amount of effort and provide high accuracy. Accuracy on the order of 5% is possible for highly detailed estimates.

Since a large amount of design information is required to perform detail estimates, they are usually not undertaken until the project is well underway. Almost all direct field material costs are based on quantities obtained from drawing take-offs and specifications. Equipment costs are based on vendor quotes of design specifications. Piping cost is one of the most extensive and time consuming portions of the estimate. Material take-offs of the isometric piping drawings produce volumes of material quantities, even on moderately sized projects. These quantities of pipe, fittings, valves, and attachments for all the varying sizes, schedules, and alloys must be extended by the unit rates of suppliers to obtain a preliminary cost. Then allowances must be made to account for piping contained on drawings not yet complete and piping required by later design changes and drawing revisions.

Electrical quantities and costs are obtained in a manner similar to piping costs, but additional allowances are required as cable quantities are usually one of the last to be calculated. Numbers and types of instruments are obtained from piping and instrument diagrams, while painting

and insulation quantities are calculated from piping line classifications or equipment specifications.

Even after a cost has been determined for all the material on the drawings, additional allowances must be added for damage on site or during shipping, final modifications, theft and loss, and field modifications.

Field labor is calculated by craft operation. Each material item has standard labor content associated with it. As an example, the butt welding of a schedule 80, six inch, 45° elbow may require .6 man hours of pipe-fitter time, 1.2 hours of welder's assistant time, and .9 man hours for the welder. These "chart" labor figures must then be adjusted for the productivity of the project location, as well as for weather conditions, amount of congestion in the work area, shift length, and number of shifts being worked.

The detail estimate is a very tedious and complex operation. It can be seen from the number of tasks and number of people involved that preparing a definitive estimate is a project-wide team effort which requires a substantial amount of coordination. The cost engineer provides a majority of this coordination.

Even though information in the form of quantities, vendor quotations, specifications, etc., are prepared to a large extent by other disciplines and passed to the cost engineering group, the cost engineer has the responsibility of translating the data into an estimate. Additionally, the

cost engineer must do a considerable amount of estimating of his own to determine allowances, field labor costs, indirect field costs, and home office costs.

Once the estimate is complete, an extensive management review is carried out. Other disciplines on the task force are also given the opportunity to comment on the estimate to insure nothing has been omitted. After spending significant amounts of time and money in preparing the detail estimate, it is critical to insure that the final product justifies the expense from the client's viewpoint.

Cost Control

Three of management's main concerns on a project are:

Quality control: The plant and its parts must be designed and constructed to the owner's quality standards. The plant should be built to operate safely for a specified number of years, producing the specified products.

Schedule Control: The plant should be completed and on-stream at the specified time so that the owner can meet product delivery commitments to his customers.

Cost Control: The plant should be completed within the budget so that the owner can realize his expected profits and keep financial requirements within anticipated limits. (4)

These three responsibilities are interrelated. For example, quality can be improved with the expenditure of additional

money. Likewise, if premiums are paid to equipment vendors and overtime to construction workers, schedule improvements can also be made.

The cost engineer prepares an initial estimate, based on levels of quality and schedule, that predict the final job cost. This estimate becomes the cost control base. The engineer then monitors project costs against this base and notifies management of significant deviations. It is the project manager's duty to maintain the equilibrium between quality, schedule, and costs.

One of the objectives of cost control is to focus management attention on potential cost trouble spots in time for corrective action to be taken. Another objective is to keep each project supervisor informed of the control base cost for his own area of responsibility and how his expenditure and commitment performance compares. Cost control should create a cost-conscious atmosphere so that all persons working on the project are aware of how their activities impact the cost. Finally, cost control minimizes project costs by viewing all activities from a cost reduction point of view.

Accounting should not be confused with cost control. Accounting functions alone will report cost overruns, but not forecast them. There is a decided difference between reacting to a problem, and anticipating the problem and correcting for it.

Once a control base has been established, the cost engineer monitors project costs against the base. When deviations or potential deviations are observed, corrections must be made to update the prediction of the final job cost. The term used for this constantly updated prediction is indicated total cost. The correction is called a trend, and a trend report is used to record the corrections and alert management to deviations in the final cost.

As an example, if the estimate assumed labor productivity to be 20% less than typical chart figures, but actual productivity was lower, a trend would be issued to increase the indicated total cost. This trend serves to notify management that an overrun will occur unless productivity is increased. Other trend examples might arise from concrete overpour higher than estimate allowance, labor wage increase requests higher than estimate labor rate, or schedule slippages requiring extended duration of construction supervision.

The cost report is a valuable tool to the cost engineer. It provides the information necessary to compare actual cost data to the control base, serves as a historical record of project costs, and is the formal means cost engineering provides management with the information necessary to make cost effective decisions. Cost reports usually contain values for the control base, the current indicated total cost, explanation of monthly change in indicated total cost, value of purchase order and contract commitments, and expenditures.

All of this information is collected and maintained by the cost codes described earlier. On a typical project, between 2,000 and 5,000 individual pieces of cost information are monitored. To track this information, each component of the data is assigned an individual code, called a key, so that it can be stored, sorted, and retrieved by the computer.

As indicated in Figure 8, the cost code described in Appendix B forms part of this key. Additional requirements include a company identification number to indicate a specific subsidiary or division, a contract number, and an identification to indicate physical division within a single project. The key provides each separate cost component with a separate and unique location in the computer, and allows all information about a particular component to be collected from various sources. For example, the indicated total cost and control base value for a particular pump can be retrieved from cost engineering records. However, using the key the value of the purchase order and amount paid to date on the same pump can be retrieved from accounting files. Additional information which may be stored under the same key includes identification of the vendor, type of currency the vendor is paid in, monthly expenditure, and monthly commitments.

Using computer storage, a variety of cost reports can be generated out of the same data base. Some of the more common reports include home office costs, materials cost by purchase order, and direct field subcontracts by subcontractor.

FIGURE 8
COST KEY FOR COMPUTER STORAGE

DIGIT OF KEY	DESCRIPTION
1	
2	COMPANY I.D.
3	
4	
5	
6	CONTRACT
7	NUMBER
8	
9	
10	
11	AREA
12	UNIT
13	
14	
15	
16	COST
17	CODE
18	
19	

SCHEDULING

Bringing a project in on time can be as important as bringing the project in on budget. Current high interest rates and competitive markets for chemical products serve to highlight the importance of proper scheduling. Some of the reasons for project planning include:

1. Eliminate or reduce uncertainty.
2. Improve efficiency of the operation.
3. Obtain better understanding of the objectives.
4. Provide a basis for monitoring and controlling work.

When preparing a schedule, one of the first requirements is to define the basic goals and requirements of the project. These objectives, which include overall milestones such as the date for start of design, date for field move-in, and required project completion dates, can be placed on a time frame referred to as the master schedule. Once dates on the master schedule are agreed upon, the scheduling engineer can begin to establish the secondary milestones required to achieve the overall objectives. These secondary milestones form the basis of project control schedules, which include the process and design schedule, procurement schedule, and construction plan. The control schedules are in turn used to produce the work plans used by the lead discipline engineers or construction superintendents to direct the progress of their respective groups. Normally these plans

take the form of 90-day work plans, which are updated monthly, and the more detailed two-week work plans, which are updated on a weekly basis.

There are many formats available for producing work plans and schedules. These formats run the range from sketches on a chalkboard to intricate networks drawn by computer which display a range of symbols to indicate completed milestones, optimistic completion dates, missed milestones, and absolute deadlines. However, all these formats conform to either the familiar bar chart or the CPM-PERT network representation.

Bar Chart Schedules

One of the oldest planning techniques involves the use of bar charts, sometimes referred to as Gantt charts after their originator Henry Gantt. (6) These charts have been in widespread use as a valuable scheduling aid since the early 1920's. Not only are bar charts easy to construct and interpret, they are also readily adaptable to a great variety of planning requirements.

A typical bar chart is exhibited in Figure 9. This simple example represents a two-week work plan for a construction painting crew. Notice that the plan is drawn on a scale directly proportional to calendar time. The length of each bar indicates the duration of the related activity.

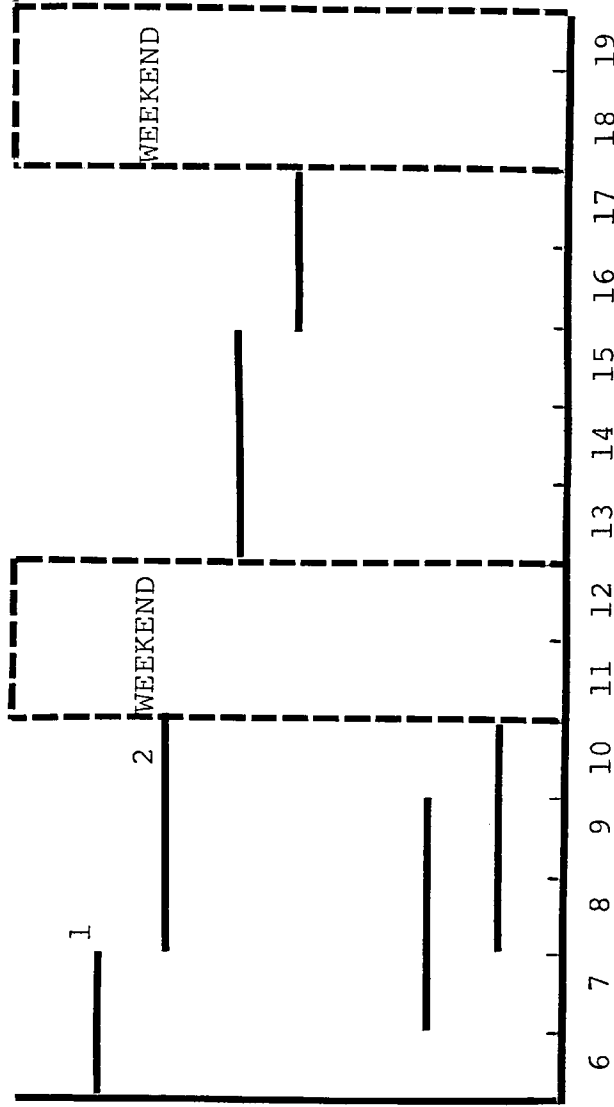
One disadvantage of the bar chart method of formatting schedules is the lack of indication of activity dependencies.

FIGURE 9

EXAMPLE OF GANTT BAR CHART

TWO-WEEK WORK PLAN - PAINTING CREW A

JUNE 6, 1983 - JUNE 19, 1983



JUNE 1983

VESSELS:

2ND COAT 2T105

BLAST/PRIME 2T201

1ST. COAT 2T201

2ND COAT 2T201

PIPE :

2ND COAT 05-1356N

2ND COAT 05-1383N

- NOTES:
1. 2ND COAT 2T105 CARRIED OVER FROM PREVIOUS WEEK
 2. WEEKEND WORK AUTHORIZED IF PRIMING OF 2T201 NOT COMPLETE BY 6-10-83

For instance, in Figure 9, there is no indication that tank 2T201 cannot be painted before it is sand-blasted and primed. While this seems to be only common sense in such a simple example, overlooking links between activities can result in very costly mistakes. An example of some important dependencies are vessel closures, dependent on final hydrotest and inspection; equipment erection, dependent on foundation curing; and road paving, dependent on arrival of the last heavy delivery. Some bar charts attempt to indicate dependencies with dashed lines or special symbols, but these methods become too burdensome as the number of activities increases.

Network Scheduling

Network analysis is used for several project planning methods, of which the most widely used are PERT (program evaluation and review technique) and CPM (critical path method). These methods were developed for application on large scale defense projects. However, in the late 1950's, network analysis was put into use by private industry. Significant improvements over earlier control methods have led to their widespread adoption for project planning.

The building block of any network technique is the arrow diagram. This diagram replaces the bar in the Gantt chart. There is an important difference though; arrow diagrams are not drawn proportional to a time scale. Instead, they are carefully constructed to indicate the interdependence of each activity in the project.

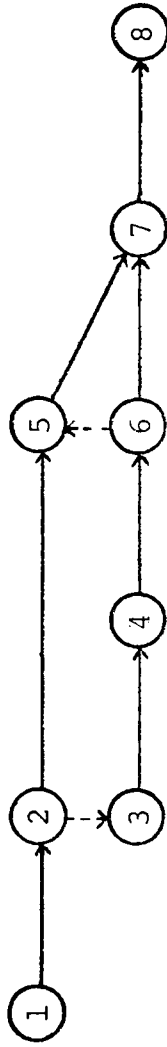
Figure 10 is a simple example of the network representation of a purchase order procedure. Each circle indicates some program event, such as the completion of a task. The arrow connecting the two circles in the example represents the activity which must take place before the next event can be achieved. This form of network analysis is called "activity on the arrows". An alternate representation labeled "activity on the nodes" uses the circles to represent a particular activity, with arrows only indicating the sequence of events. While the two methods require different procedures for calculating various durations, the general logic of both is similar.

In Figure 10, it is obvious that the engineering group must develop preliminary specifications before the purchase order process can begin. Once the preliminary specifications are complete, the procurement group can prepare the request for quotation package, while the engineering group continues refining the specifications. Note that the dashed line between nodes 2 and 3 does not indicate an activity, only that the preparation of the request for quotation can not begin before the preliminary specifications are complete.

After a vendor receives the request package, he prepares and submits his bid. This bid is reviewed by both the purchasing group (to determine low bidder) and the engineering group (to insure that specifications are met). Once again, a tie is used to indicate that the engineering group cannot

FIGURE 10

EXAMPLE OF NETWORK SCHEDULE
SIMPLE PURCHASE ORDER PROCEDURE



LOCATION	ACTIVITY
1 - 2	Engineering Development of Preliminary Specification
2 - 3	Dummy Tie Indicating Dependence
3 - 4	Procurement Preparation of Request for Quote
2 - 5	Engineering Development of Final Specifications
4 - 6	Vendor Preparation of Bid
6 - 5	Dummy Tie Indicating Dependence
5 - 7	Engineering Review of Bid
6 - 7	Procurement Review of Bid
7 - 8	Preparation of Purchasing Order

begin to review until final specifications are complete. Finally, when a bid is accepted, a purchase order can be issued.

Since there are many excellent references on the CPM and PERT procedures (7, 8), and since this report is not designed as an instruction in the use of these techniques, only a brief outline of each will be given.

Once the network is complete, each activity is assigned a duration. In PERT analysis, three durations are assigned to each activity: an optimistic duration, a most likely duration, and a pessimistic duration. The CPM method calls for calculating the entire duration of the project through each possible path of the network. The longest path is called the "critical path" and its duration is the duration reported for the entire project. The difference in time between the critical path and other routes through the project network is referred to as "float". Float represents the amount of time these activities may slip and still not affect the project completion date.

PERT uses the three activity durations described above to calculate a probable time for each activity on a statistical basis, assuming a normal distribution of estimating errors for each duration. In some cases, the normal distribution is substituted with a weighted normal distribution to reflect the fact that activities are generally estimated too optimistically. Whichever statistical basis is chosen, the

PERT network will produce a critical path in the same manner as the CPM process.

The benefit of determining the critical path is the ability to identify which activities directly affect the completion date of the project. These critical activities can then be monitored with more attention than those operations which have float. Additionally, once critical activities are identified, they can be studied to determine the unit cost involved with decreasing their duration. This allows cost-benefit analysis to determine the most cost effective project duration.

With the use of computer-aided network analysis, large construction projects can be modeled with 20,000 - 40,000 identifiable activities. In addition to duration, each activity can be assigned "resources" such as manpower, material quantities, or even cost. This allows optimum resource use through resource leveling, as well as increased management information, since the same data base can be used to generate manpower curves, bulk material delivery curves, and cash flow analysis by computer.

Progress Reporting

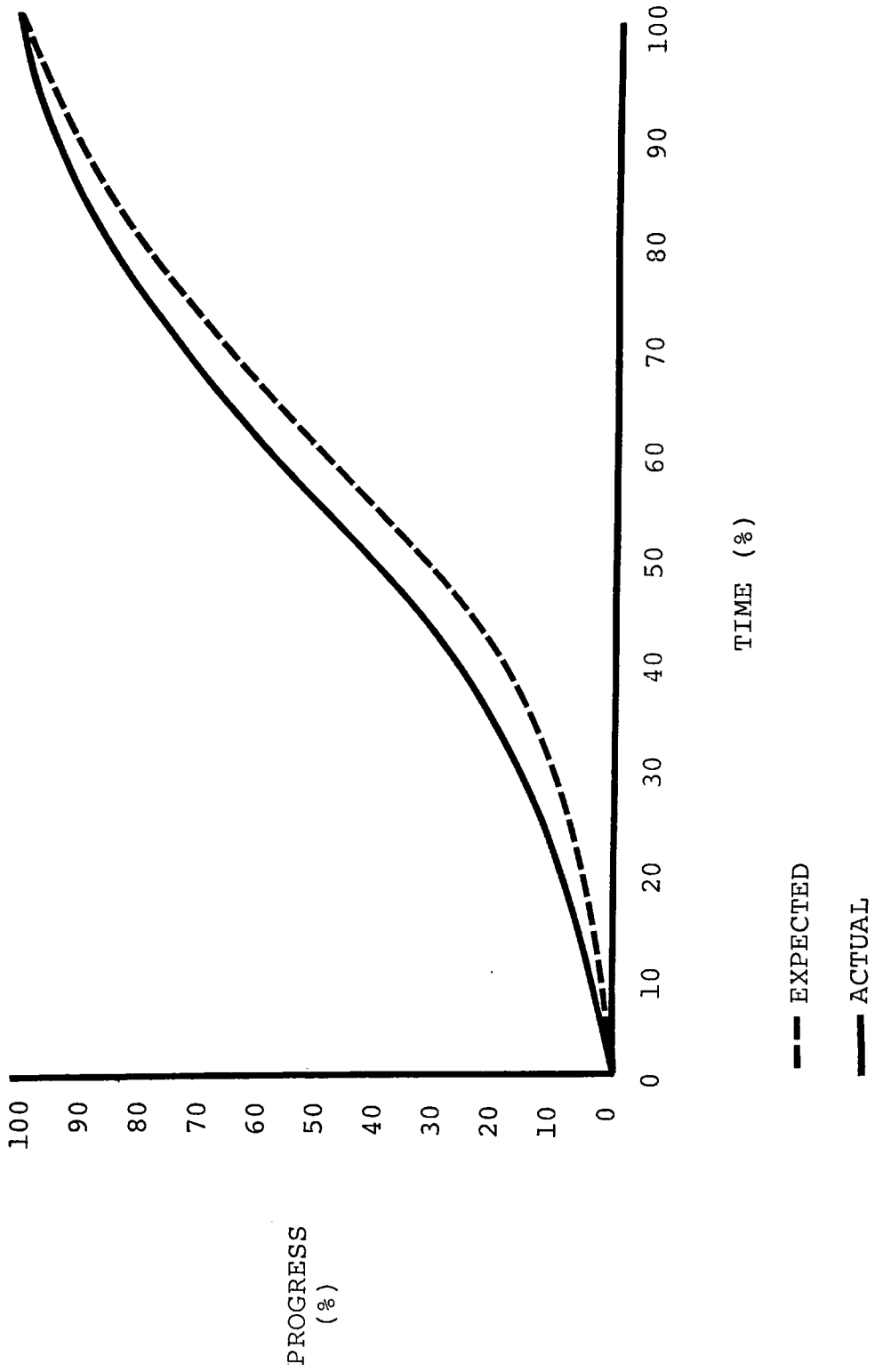
Once the schedule is complete, an expected progress curve can be developed. Progress curves are the most highly visible planning reports. They are constantly referred to by management and the client as an indicator of performance.

To construct progress curves, each activity on the control level schedules must be assigned a progress value. Normally, this is initiated by determining the progress contribution of each construction discipline. For example, 10% of the project is civil work, 45% is piping, 15% is electrical, etc. Then each operation inside a discipline can, in turn, be assigned a corresponding percentage of the discipline's allotted progress. In this manner, each discipline can report its progress against its plan. For example, piping is 75% complete. Following through, if piping represented 45% of the project as indicated above, this 75% would contribute 33.75% to the overall project completion.

Progress weights are assigned in a variety of methods usually dependent on weights which worked satisfactorily on previous projects. Normally, the basis of these weights depends heavily on the labor content of the associated activities. However, labor content is not the only factor, as it is obvious that most activities cannot be completed in half the time even though twice as many laborers are assigned to it. Additionally, some milestones on the schedule, such as concrete curing or foundation settling, have no labor content.

Figure 11 shows a typical project progress curve with both expected and actual curves shown for reference. Typical of most large construction projects, there is a long lead-in period as site preparation and underground piping are completed. Once equipment is installed and pipe fabrication

FIGURE 11
EXAMPLE PROJECT PROGRESS CURVE



and erection are started, progress increases rapidly. Finally, the last 10% is slow to be achieved as painting and insulation are completed and punch lists worked.

WORK ASSIGNMENTS

During the internship with Fluor, the author had the opportunity to be involved in many projects and serve in a variety of positions. This was very advantageous since it allowed the intern to observe all phases of project life and to obtain valuable experience from being exposed to many different situations. This section of the report will describe some of the major projects and explain experience gained in each.

The internship began in May 1980, and degree plan requirements for Engineering 684 were complete by August 1981. However, the author was given the opportunity to go on an international field assignment, and as a result, continued to work at Fluor until December 1982. Since this extended stay was considered by the intern and the company to be a continuation of the learning process, experience gained during that time period will be reported as well. By nature, cost information is held to be strictly confidential, so no client names or exact cost figures will be mentioned.

Directorate Cost Engineer - Houston, Texas

The process of establishing cost/scheduling directorates began with a multi-billion dollar project Fluor managed in Saudi Arabia. The concept involves the establishment of a small group of engineers to coordinate and maintain the consistency of cost/scheduling activities on many projects for

the same client. The directorate also provides special assistance to individual contracts in the group as required. The author's position was cost engineer on a directorate coordinating twelve contracts for a major client with construction projects in Texas, Louisiana, and Washington. When the intern was assigned to this project, it was just starting. This provided an excellent opportunity to observe a project in its early stages.

One requirement of this position was to develop initial staffing plans for the various contracts and a total staffing curve for the entire series of contracts. These curves were calculated from the preliminary home office cost estimates based on average wage rates for the engineering and staff labor. Once completed, they provided management with the information necessary to determine the required number of new employees and the lead time available for recruitment.

During preparation of these curves, the author was required to contact cost engineers working on other projects "in house" at the time, to request actual expenditure records from their jobs. This data was used to calculate the average wage rate necessary to compute the staffing requirements. Additionally, some interface was required with the client to determine the amount of time the projects could be staggered in order to level the manpower requirements.

The author also had many client contacts, both formal and informal, regarding cost control and cost reporting. Since there were so many projects being reported to the

same client management, it was essential that the control and reporting procedures were consistent and were introduced early in the project before it became difficult to make corrections. From these meetings, the intern developed a set of guidelines for reporting formats, covering both cost and manpower information, which were issued to the control teams on each of the contracts.

Not only was the client interested in reporting current estimate and expenditure information but also in the preparation of the final cost report. Even though the final report would not be required for several years, the amount of detail requested, necessitated that the data be collected while the job was in progress. The information of interest was requested by the client to be used later in preparing modular estimates. This type of estimating is similar in principal to the equipment factored estimate described earlier, but is expanded to include material quantities and cost by account.

Basically, modular estimates provide detailed information on nonequipment items associated with an individual piece of equipment. For example, a specific pump might require a 3.5 cubic yard foundation with associated excavation, 0.2 tons of structural steel bracing, 65 feet of 6 inch pipe, etc. It was the author's responsibility to develop a procedure to collect this information from available drawings and to develop the associated actual costs at

the end of the job. Not only did this task provide experience in cost engineering, but from review and mark-up of design drawings, experience was also gained in process and design engineering.

To add to this experience, the author also attended several lunch-time seminars that explained the technical processes of the projects underway. These seminars provided an overview of the plant operation, detailed explanation of the function of each sub-unit, and review of the thermodynamic and chemical processes involved. Additionally, Fluor provided funding for the intern to attend a chemical engineering course at the University of Houston on process unit operations.

In order to develop an optimum set of guidelines, cost managers on other projects were interviewed about their philosophies on cost control. While their opinions on the degree of detail required to adequately control a project varied widely, their experiences regarding methods which had been tried previously proved valuable. The guidelines and cost code which were ultimately developed represented a collection of each individual's best suggestions.

One special project, while on the directorate, was to decide whether to use structural steel pipe supports or pre-cast concrete pipe supports. This task took the author a week to complete and required very detailed estimation. First, structural engineers provided overall dimensions of the supports. Several construction supervisors were

interviewed to determine the construction procedures used on each, and Fluor standards were used to determine the labor content. Material costs were obtained from expenditure records of projects in-house and calls to local suppliers. Finally, the project procurement manager was consulted on the availability and delivery schedules of the required materials.

The result of the study indicated that precast concrete supports should be used. This method of construction was the most cost effective and allowed the construction manager more control over the delivery and erection schedule. The intern presented the results to both Fluor and client management.

The directorate also provided close contact with cost engineers, specialty groups, and other disciplines. Contact with others allowed the intern to use some of the technical expertise gained in course work at Texas A&M. The first occasion involved the use of statistical procedures to determine the accuracy of estimates. Fluor uses a computerized package based on the Monte Carlo method to model error distributions of various estimate parameters. From the derived cumulative error, a figure for estimate accuracy is obtained. One of Fluor's clients asked for a back-up calculation to benchmark the computer generated prediction. The author used linear distribution functions as approximations and provided the resulting analytical solution. This solution

was close enough to the computer estimated risk to satisfy the client.

In another instance, the procurement department required assistance in developing bid evaluation procedures. The material buyers were looking for a way to equate bids which had different payment schedules. The author developed a series of present-value tables based on the project's cost of capital that the buyers could use to determine a numerical value for the benefit of later payment schedules.

Finally, the position of directorate cost engineer provided supervisory experience. While at this position, the author directed the efforts of two other engineers and two technicians. This responsibility included the preparation of 90-day work plans for the group and the review of these plans with management and group members.

Cost/Scheduling Team Member - Coal Gasification Study

Another position held by the intern was cost and scheduling team member on a coal gasification project feasibility study. The object of the study was to evaluate six separate cases and provide heat and mass balances, overall process diagrams, plant layout, capital cost estimate, operating cost estimate, and a project master schedule. The cases represented different gasification processes, different plant locations, and different product capacities. The author was given responsibility for all cost and scheduling activities on the study.

Before the project could start, an estimate was made of the cost and time required. After meeting with Fluor management to review requirements, several other previous studies were reviewed. These similar feasibility studies provided an indication of the duration required for each case. Once complete, the proposed staffing included five full-time staff, and as many as thirty part-time support personnel. These included accountants, procurement and construction personnel, additional cost engineers, draftsmen, and marine engineers.

The study estimate indicated the feasibility study would require approximately six weeks and cost \$150,000. These figures were reviewed with Fluor management and presented to the client, who approved the project.

Once the project was accepted, the author prepared detail work plans for all team members. These plans were reviewed and approved by the project manager. The overall study schedule was an accumulation of the work plans and the review cycle required by Fluor and client management.

This position provided the intern with a variety of estimating experience. Once the process engineers indicated the type and capacity of process units required, a capital cost estimate was made of each. Capacity factored, equipment factored, and detail estimates were made, as well as several educated guesses. Over \$8 billion worth of capital cost estimates were contained in the six cases. Each case contained approximately 40 separate process or offsite units,

each with a separate estimated cost. Some of these units, such as oxygen production, acid gas removal, sulfur recovery, and tail-gas treating, are common process packages with a substantial amount of estimating data available. However, other requirements, such as a barge unloading system, coal stacking and reclaiming facility, deep well injection, and an ash disposal area, are not routine projects for Fluor Engineers. To estimate these items, contact was made with vendors, or the systems were approximated with the closest items available.

While preparing the estimates, specific knowledge was acquired about the different methods used for coal gasification. During the study, the intern also helped in some of the engineering calculations. From ash rates supplied by the process group, he sized the clay berms required for the ash disposal area. Rainfall rates were used to determine run-off water quantity and thus size the waste-water disposal system.

The author was also responsible for producing master schedules for each case. These schedules indicated major milestones for the engineering, procurement, and construction phases of the project. Dates required for obtaining various environmental permits and licensor agreements were also marked. Project duration was determined to be on the order of six to seven years. Directly from the master schedules, cash flow curves, and manpower staffing requirements, were determined and included for each case.

The project was completed within the allotted time and finished within the budget. The intern had the opportunity to review the study with the highest level of Fluor management and eventually present the report to the client. The client indicated that the results satisfactorily met all requirements.

Lead Scheduling Engineer - Houston, Texas

After almost a year at Fluor, the intern assumed responsibility as lead scheduling engineer at the front end of a heavy crude upgrading and desulfurization project located in southern Louisiana. This facility included a vacuum residuum hydrocracker, hydrogen generation unit, air separation plant, and numerous offsites. Fluor's portion of the work was estimated at approximately \$600 million, and the design effort was expected to exceed two million man-hours.

This position allowed the author to take on a supervisory role by directing the efforts of two senior engineers and several technicians. Additional administrative duties performed while on this job included recruitment of recent college graduates and conducting employee performance reviews for technicians in the group.

The intern was responsible for supervision of the preparation of all project schedules, including master schedules, critical equipment procurement schedules, initial engineering schedules, licensor interface schedules, and numerous

special schedules. This required close contact with lead engineers of all the other disciplines to determine the duration of various activities under their control and to estimate their required manpower.

As a result of these schedules, several critical equipment items were identified. Shop time for the high pressure vessels indicated a need to expedite preparation of initial specifications in order to issue request for bid packages. Additionally, interface problems were found with one of the tall columns which indicated it would need to arrive at site early enough to be set prior to the erection of surrounding structural steel.

The author also continued to assist the cost group on the project while acting as lead scheduling engineer. This assistance included preparation of an offsites capacity factored estimate, preparation of a heavy cycle gas oil equipment factored estimate, and help in completing an equipment factored estimate of the vacuum residuum hydrocracker unit. Additionally, the intern developed a cost code of accounts for the project and issued the cost scheduling portion of the project procedures manual.

Directorate Planning Engineer - Johannesburg, South Africa

The author was also the member of a cost/scheduling directorate for a synthetic rubber plant under construction in the Republic of South Africa. This project was an international project in design, procurement, and construction.

Directorate responsibilities required coordination of Fluor cost and scheduling activities in Manchester, England; Basingstoke, England; Johannesburg, South Africa; and Newcastle, South Africa. Cost and scheduling groups were situated in each of these locations.

One of the author's initial responsibilities was to produce a set of procedures and guidelines to control the groups at all four locations. These procedures included a new cost code of accounts, new organization arrangements, methods for reporting trend information, and guidelines on the use of the computerized cost control base.

The author also participated in preparation of the first consolidated control base for the project. This control base represented the sum of estimates done at the four cost group locations with overall allowances added. This control base was presented to the client and became Fluor's budget for the job. When construction was completed one-and-a-half years later, the control base proved accurate to within a few percent.

One of the intern's main responsibilities was to coordinate planning information between the four international groups. Each group was responsible for producing their own plans off of directorate-prepared master schedules. The author updated these master schedules, checked that group work plans met the master schedule objectives, and collected all project schedules for a monthly scheduling report. This report also included construction schedules by plant area

and work plans for individual subcontractors on site. Completion dates set in the first schedule package were ultimately met, enabling Fluor to receive bonuses for commissioning the plant by the agreed date.

Commodity Scheduler - Newcastle, South Africa

The author also had the opportunity to work at the construction site, scheduling work activities for the coatings construction gangs. Coatings work included painting, insulation, and water deluge safety systems. Fluor construction supervision was organized in teams, with teams controlling individual disciplines or commodities. For example, there were teams to control civil work, structural steel, buildings, piping, coatings, etc.

Each team consisted of four controlling members, a representative each from construction, subcontract administration, quality control, and scheduling. The amount of support staff each member controlled depended on the amount of field work the group controlled. The role of the scheduling member was to provide the construction supervisor with weekly work plans which would achieve the milestones to complete the project on time. The construction supervisor directed the subcontractors on a daily basis to ensure that the work plans were carried out. The subcontract administrator developed the original subcontract packages and produced amendments to the contract as additional work was required. The subcontracts team member was also responsible for all formal

communication between Fluor and the subcontractors. Finally, the quality control team member was responsible for determining if the subcontractor's performance met required specifications.

The intern was responsible for preparing work plans for all three subcontractors controlled by the coatings group. Both 90-day work schedules and weekly work plans were maintained. To prepare these plans, the author worked from milestones listed on the area master schedules and release dates provided by schedules for other commodities. For example, the intern worked closely with commodity schedulers in the structural steel group, equipment group, and piping group. Once structural steel was accepted and final alignment was complete, the structures were released to the painters. The painters were given precise completion dates so that cladding construction could begin in time to cover the structure before instruments were installed inside. Likewise, coatings work was also dependent on hydrotest completion dates on piping and equipment. It was also necessary to account for other factors, such as early morning low dewpoint causing moisture on vessels to be painted, work down wind from sand blasting operations, and amount of slippage due to lost work days during the rainy season.

The intern worked closely with each of the contractor's site agents in suggesting improved work methods, determining proper size and deployment of labor forces, and explaining progress reporting methods. The weekly progress meetings

were of particular concern to contractors, as their performances were based on the ability to achieve required progress. As long as satisfactory performance was maintained, the contractor was awarded additional work as construction was started in other areas of the plant. Overall, coatings work on the project amounted to over two million dollars, and at peak, the labor force exceeded 300 laborers.

The intern was also involved in the selection of individual contractors controlled by the coatings' group. Working closely with subcontract administration, the author attended pre-bid meetings to explain the amount of work and time available for completion to prospective bidders. Once bids were received, he conducted a detailed analysis of each to determine the most cost effective choice. Consideration was also given the contractor's performance on past Fluor jobs, number of trained laborers available, and proposed site organization.

One final responsibility was to control the subcontractor's work, develop an invoice value from this progress, and ensure that the invoice submitted contained only charges for the authorized work.

Computer Cost Control - Newcastle, South Africa

On the same project described above, the intern was required to develop a computerized cost control system. The basis for this system was a Fluor file manipulating routine called P.C.R.S. (Project Cost Reporting System). The routine

worked much like a compiler, and required programs to be defined to gather, sort, format, and print project cost information stored on disk.

At the time the author started developing the new system, cost information was being kept in an old file system which only allowed the data to be printed and sorted by cost code. This made comparison of costs related to a particular subcontractor, vendor, or currency very difficult. The benefit of P.C.R.S. was the ability to sort and format information in a variety of ways. Therefore, one of the first tasks was to meet with individual engineers, Fluor management, and client management to determine what types of reports were desired. Each group responded enthusiastically to the ability to request "tailor made" reports, and eventually fifty separate reports were available.

Subcontract engineers and cost engineers controlling subcontracts received reports which contained budget, indicated total cost, and expenditures for their particular subcontracts; sorted by plant area and cost code. Additionally, these reports were printed in local currency which allowed quick comparison to contract documents and invoices. Management received a summary report which listed each of the seventy active subcontractors on site, the total budget for each, as well as the current indicated total cost and expenditure figure.

A report was also developed which provided current cost control information on materials sorted by the purchase order

number of the vendor. This report also grouped vendors by the type of currency in which they were paid to allow easier reconciliation with purchase order documents. This report proved beneficial in locating purchase orders which had been missed from the indicated total cost and some purchase orders which had been issued twice.

Another series of reports tracked home office cost information. Since the project used world-wide procurement, Fluor maintained buying staffs in ten different countries, including Germany, Italy, Japan, Holland, and Canada, to meet project procurement requirements. The P.C.R.S. program sorted these costs by home office location and tracked labor manhours as well as monetary expenditures.

To initiate the new control system, the author was required to travel to Fluor's office in Manchester, England, where the computing facility was located. While in Manchester, the intern directed as many as five cost engineers as well as various technicians and computer programming personnel in loading project cost data into the new system. At the same time, cost engineers at the job site had to be coordinated from Manchester to supply the additional information required to properly sort the different costs.

Once computed, the intern had to reconcile the resulting information to prove to the client that no budget allowances had been altered in the process. Cost engineers in Manchester also had to be trained in the use of the new program and the author prepared a procedure to be followed in updating

the files. These procedures allowed field cost engineers to raise cost trends indicating potential changes in the project cost. The trends were input into the data base and were sorted and added to the proper accounts. After the client had been notified of a trend and agreed to its impact, the program would indicate the agreement by shifting the value to an approved trend file.

Monthly trend reports were generated which printed out the resulting changes in indicated cost. These trend reports provided very detailed accounting for all monthly changes. In total, over 6,000 separate pieces of cost information were tracked by the new system.

Eventually, the author had to return to the Manchester office to modify the programs for preparing a final cost report. The plant under construction was being completed in two phases. Each phase produced a different type of synthetic rubber. By having a portion of the plant in operation by tax year end, the client received a substantial tax savings. After meeting with client accounting personnel, the intern identified all costs associated with Phase 1 of the project. The programs were then rewritten to track and account for these costs on a separate basis. From the resulting information, Fluor prepared a Phase 1 final cost report which was used by the client to back up the tax exemptions they were claiming.

In summary, both the P.C.R.S. reports and the final cost report were deemed a success by the client. The reports

provided cost information in formats easy to explain to management and the final cost report was adequate for the client to obtain his tax credit.

CONCLUSION

The extended internship and varied positions held by the author aided in achieving the internship objectives. In fact, all the objectives with the exception of one were fulfilled several times over. The following section explains how each of the objectives were met.

Achievement of Internship Objectives

The first objective was to learn as much as possible about cost engineering. Almost all of the author's assignments provided experience in the field of cost engineering. From the assignments described in the previous chapter, the intern obtained exposure to all phases of the project life cycle including feasibility study, home office design, field construction, and job close out. These positions also allowed experience with many types of estimating methods including capacity factored estimates, equipment factored estimates, and detail estimates. During the internship period, the author also made use of Fluor's computerized cost control systems and assisted other departments in their cost control or cost related problems. Requests for the author to develop cost control guidelines on several projects best indicate that the first objective was met.

The second objective was to learn the basics of scheduling engineering. This objective was set early in the internship when it was assumed the author would remain in cost

engineering positions. However, the intern's positions as lead scheduling engineer, directorate planning engineer, and commodity scheduling engineer provided much more scheduling experience than originally anticipated. As a result, the intern learned much more than just the basics. Again, exposure to the different parts of the project life cycle aided in providing experience in different types of planning. These different types included master schedules for a feasibility study, work plans for design engineering, critical equipment procurement schedules, area master schedules for construction and weekly work plans for individual construction gangs. The author also worked with many resource projections, including cash flow projections, manpower curves, and bulk commodity purchasing.

The next objective was to become familiar with process industry technology. Since the intern's background is nuclear engineering, it was necessary to learn some basic process operations in order to relate to the projects. The majority of this knowledge came from the author's work with process flow diagrams used in estimating, with some instruction from the intern's immediate supervisor, a chemical engineer. Additional training in process industry technology was provided from reading periodicals such as Chemical Engineering and Hydrocarbon Processing, asking questions of process engineers on the project, attending lunchtime process seminars, and taking a course in process unit operations at the University of Houston. From these experiences,

the author gained the ability to confidently discuss major process requirements for various types of plants.

The fourth objective was to develop a consistent set of computer output formats for cost reporting. This objective was met early in the internship when the author was acting as directorate cost engineer. A series of formats were developed for presenting both management level and detail level cost information from a computer cost reporting system. However, additional experience was gained in this area when the intern was required to develop a computerized cost control system for the South African project. This assignment resulted in preparation of over fifty different reporting formats sorted by currency, subcontractor, and vendor, as discussed previously. Eventually, the author gave training sessions on the use of the reporting system in both England and South Africa and became the project expert on the subject.

Another objective was to develop guidelines for producing a final cost report. This process was started when the intern was a directorate cost engineer. A preliminary set of guidelines were developed concerning the preparation of modular estimate data required in the final cost report. Several meetings were also held with the client to determine additional requirements and format. However, on the South African project, the author not only developed guidelines for the final cost report but was involved in the preparation and presentation of two such reports. This project was unique

in the fact that final cost reports were required on two phases of the plant and cost data on each phase had to be reported separately.

The sixth objective was to produce a model and computer program for performing estimate risk analysis. Of all the objectives, this is the only one not completely achieved. When preparing the internship objectives, the author had already assisted in providing analytical solutions to approximations of the Monte Carlo calculation used in the risk analysis programs. To build on the experience already gained in performing this exercise, the intern constructed a model which could be used in determining the accuracy of factor estimates. However, before completing the computer program required to implement the model, the author had the opportunity to work on the coal gasification feasibility study. As a result, the computer program was never completed. Even though the program was never completed, the intern did learn how to use the risk analysis program and determine risk associated with various estimating techniques. The experience gained by participating in other projects outweighed the benefit of following through and completing this single computer program.

The final objective was to take responsibility for cost engineering on one phase of a project. The intern assumed this objective had the least chance of being met due to lack of time necessary for gaining enough experience to assume such a position. However, the intern was able to take

responsibility for cost engineering on the coal gasification feasibility study. This responsibility included frequent interaction with the top levels of division management as well as presentation of results to the client. The intern was also allowed to take responsibility for computerized cost control on the South African project, and in addition to the internship objectives, the author was allowed responsibility for scheduling when he acted as lead scheduling engineer.

Concluding Remarks

From a review of his experience, the author concludes that the internship objectives were satisfactorily achieved as were the requirements of the Doctor of Engineering internship. The intern's position with the cost and scheduling department provided a mixture of experience which combined requirements of technical training as well as non-technical skills related to business and management. This experience allowed the author to apply a considerable amount of the training received at Texas A&M and provided direction in choosing courses for the final semester of degree requirements.

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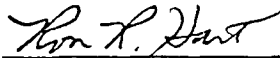
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APPENDIX A
Internship Objectives

Internship Objectives

1. Learn as much as possible about Cost Engineering.
2. Learn the basics of Scheduling Engineering.
3. Become familiar with Process Industry Technology.
4. Develop a consistent set of computer output formats for cost reporting.
5. Develop guidelines for producing the job's Final Cost Report and prepare a typical Financial Cost Report for a selected project.
6. Produce a model and computer program for performing Estimate Risk Analysis.
7. Take responsibility for Cost Engineering on one phase of a project.

Approved by:



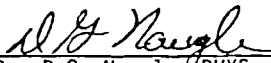
Dr. Ron Hart, NE
Committee Chairman



Dr. C.E. Lee, NE
Committee Member



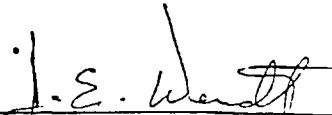
Dr. J.J. Benjamin, ACCT.
Committee Member



Dr. D.G. Naugle, PHYS.
Graduate College Rep.



Dr. R.G. Cochran, NE
Department Head



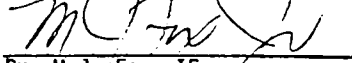
Mr. J.E. Wendt, P.E., Fluor
Intern Supervisor



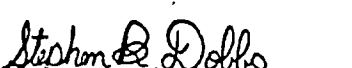
Dr. R.S. Wick, NE
Committee Member



Mr. C.W. Wight, P.E., Fluor
Immediate Supervisor



Dr. M.J. Fox, IE
College of Engineering Rep.



Stephen B. Dobbs, NE
Intern

APPENDIX B

Example Cost Code of Accounts

Fluor cost codes are typically six characters in length. The last character in the field, often referred to as the significant digit, represents the broadest division in cost categories. Examples of significant digits are:

Significant Digit	Cost Category
1	Field Labor
2	Field Materials
3	Field Subcontracts
4	Not used
5	Home Office Labor
6	Home Office Expense
7	Home Office Payroll Burdens
8	Contingency
9	Labor Indirects

The first digit of the six character representation indicates the next division of accounts. This digit is called the account prime and examples are:

Prime Account	Cost Category
0	Excavation and Civil
1	Concrete
2	Structural Steel
3	Buildings
4	Machinery
5	Piping

Prime Account	Cost Category
6	Electrical
7	Instruments
8	Paint and Insulation
9	Indirect Costs

The second digit of the field provides for subdivision of each prime account and is thus referred to as the subprime. As an example, the subprimes listed below are typical of the equipment account (prime digit 4):

Prime 4 Subprimes	Descriptions
1	Field Fabricated Tanks
2	Vessels and Columns
3	Compressors
4	Exchangers
5	Heaters
6	Pumps
7	Material Process Equipment
8	Material Handling Equipment
9	Miscellaneous Equipment

The three remaining digits are known as the detail account and provide for further differentiation of costs. Often the detail account contains definitions particular to a specific project.

To demonstrate the definitions provided above, some example cost codes are:

Cost Code	Description
611002	Material Cost of Transformer
724001	Labor for Installing Level Instruments
852003	Subcontract Cost of Pipe Insulation
921802	Fuel Cost for Site Staff Vehicles
932405	Labor Cost of Cost Engineers
974006	Home Office Computer Costs

APPENDIX C
Internship Reports

FLUOR ENGINEERS AND CONSTRUCTORS, INC.

4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

June 30, 1980

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843

Dear Dr. Hart:

I have completed the first month of my internship at Fluor Engineers and Constructors, Inc. in Houston. Presently, I have been assigned to the Cost and Scheduling Group on a newly established task force which will be handling projects for one of Fluor's major clients. These projects will include modernization of existing refineries, as well as, design and construction of new units. The scope of this work may eventually involve costs of approximately one-billion dollars and four million man hours of labor over the next three years.

A majority of my time this month was spent moving in and getting acquainted. However, I have already been involved with several responsibilities of the Cost and Scheduling Engineer. My first assignment was to review Fluor's Project Cost Reporting System (PCRS), a computer implemented cost recording and report generating program. As the projects develop, this program will be an important tool in tracking and controlling costs.

Presently, my responsibilities include preparation of reports on expenditures of money and man power to project management on a weekly basis. These reports are in turn used by the project managers to produce their weekly progress reports for upper management and our client. I have also been involved in preparing the Project Financial Status Report. This confidential information is prepared for corporate management on a monthly basis and contains gross profit margins for each project.

FLUOR

Dr. Ron Hart
June 26, 1980
Page 2

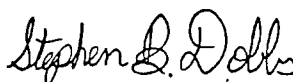
Some of my time has also been spent developing estimates of future resource utilization. This includes the use of funds in the form of cash flow curves as well as predicted use of man power over the project life. These estimates will become more important as the scope of the projects grow and resource limitations are approached.

During my first month I was also able to attend a meeting with our client, which dealt with cost control methods to be used on our projects. Several basic cost control philosophies were discussed and specific formats for final cost reporting were established.

Another aspect of my introduction to Fluor has included interviewing managers of Cost and Scheduling. These interviews have allowed me to meet members of management individually, as well as learn from their past experiences. I hope to continue these interviews and eventually compile a complete collection of management philosophies.

My internship supervisor, Jack Wendt, has delegated some of his responsibilities regarding my internship to my immediate supervisor, Charles Wight. Together we are developing a set of objectives for the internship period which I will include in my next monthly progress report.

Sincerely,



Stephen B. Dobbs

SBD/dd
cc Dr. C.E. Lee
Dr. J.J. Benjamin
Dr. D.G. Naugle
Dr. R.G. Cochran
Mr. J.E. Wendt
Dr. R.S. Wick
Dr. M.J. Fox
Mr. C.W. Wight

FLUOR ENGINEERS AND CONSTRUCTORS, INC.4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

September 11, 1980

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843

Dear Dr. Hart:

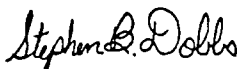
My learning experience has continued since my last internship report. However, the experience already gained has allowed me to begin making contributions to the task force. This experience allowed me to take some supervisory responsibilities for two employees. One has an undergraduate engineering degree while the other has just received a Masters of Business Administration.

This month's activities involved a significant amount of estimating. One task was to select the most cost effective type of pipe supports. The options available were either pre-cast reinforced concrete supports or fire-proofed structural steel supports. This involved pricing materials, equipment, labor, and estimating the amounts of each for the different designs. A savings of \$3,300 per pipe bent could be realized by use of the pre-cast design.

Another assignment allowed me to assist Fluor's cost and scheduling support group with technical training received at school. This group acts as a centralized source of historical and technical information for all cost and scheduling personnel in the Houston Division. One of their jobs includes providing risk assessment of estimates with a computer program using the Monte Carlo technique. At their request, I developed an analytical method of checking the program output.

I also met with my internship supervisor, Jack Wendt, and immediate supervisors, Charles Wight and Ernest Broussard, to set my internship objectives. During the next month a schedule will be developed indicating when each objective will be met.

Sincerely,



Stephen B. Dobbs

SBD.dd

Enclosure

cc J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle, J.E. Wendt,
R.S. Wick, C.W. Wight

▼ FLUOR ENGINEERS AND CONSTRUCTORS, INC.

4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

November 11, 1980

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843

Dear Dr. Hart:

About 75% of my time this month was spent preparing estimates. One case involved reconciling differences between a capacity estimate and factor estimate on a portion of our job involving approximately one hundred million dollars. The capacity estimate is obtained from an exponential relationship of cost as a function of plant capacity. However, the factor estimate is determined by multiplying equipment prices by standard factors to get the total plant cost.

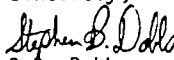
My assignment involved a detailed examination of the process equipment used in the plant being estimated as well as two similar plants already in operation. A report was then prepared listing all costs associated with equipment items which were unique to one particular unit. It was important to account for these equipment items since they could not be expected to be included in the capacity estimate. The resulting report was presented to project management at the vice-presidential level.

This month I was also given full responsibility for providing an estimate on a portion of new work which was in excess of one million dollars. This work involved coordination with design disciplines, supervision of other cost engineers, and successful presentation of results to project management.

Additional projects I was involved with this month include:

- development of cash flow curves
- development of a cost accounting code
- study on different methods of taking up project PGM in order to receive tax advantages
- calculation of project escalation
- determination of field wage rates from union craft mixes and foreman ratios
- operation of computer codes for performing scheduling network analysis

Sincerely,


S.B. Dobbs

SBD/dd

cc J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle, J.E. Wendt,
R.S. Wick, C.W. Wight

FLUOR ENGINEERS AND CONSTRUCTORS, INC.4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

November 30, 1980

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843

Dear Dr. Hart:

This month I was involved in a study to determine an optimum method of upgrading bitumen recovered from tar sands. The bitumen is extracted by an in-situ method of steam flooding tar sands in remote, northern Canada. Recovered material undergoes preliminary processing at the remote location before it is pumped south to a more populated area. At the southern location additional upgrading will yield a product of syncrude or transportation fuels.

The study involved evaluation of capital cost for the two upgrading facilities for seven different cases. Each case involved different capacities and different distribution of process units between the upgrading facilities. The total cost of these facilities was approximately two billion Canadian dollars including escalation.

I was involved in all of the cases and was responsible for the cost work on one particular case. This responsibility included presentation of results to Fluor management as well as the Client.

Sincerely,


S.B. Dobbs

SBD/dd

cc J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle,
J.E. Wendt, R.S. Wick, C.W. Wight

FLUOR ENGINEERS AND CONSTRUCTORS, INC.

4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

January 3, 1981

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843

Dear Dr. Hart:

During the last six weeks, I have been involved with an intensive study of coal gasification plants. This study was undertaken for one of Fluor's major clients in order to determine the feasibility of six specific cases involving various coal gasification processes as well as different geographic locations for the plant sites. My position on the task force was that of control team leader. In this position, I reported directly to the project manager and was responsible for all cost and scheduling activities on the job.

My first task was to prepare a budget estimate and schedule for the study and present these to Fluor management for approval. As the project was underway, progress and expenditures were tracked against this initial plan. The cost of this six week study was approximately \$150,000. On December 21, it was completed on budget and on schedule.

During the study, I prepared estimates of capital costs for the six coal gasification plants. The cost of the plants ranged between one and three billion dollars before escalation. The estimate of each plant involved capital costs for as many as twenty process units as well as coal handling systems, docks and barge unloading facilities, power plants, waste water treatment facilities, solid waste disposal areas, buildings, etc. These estimates also allowed me to work closely with the process engineers and learn about their work.

I prepared engineering, procurement, and construction schedules for the various cases. For these schedules I incorporated durations necessary for obtaining environmental permits, licensor negotiations, and delivery times for critical equipment. The schedules also required a careful study of manpower density and buildup during construction, and in several cases also involved phased plant startup in order to recover plant capital cost in a shorter period of time.

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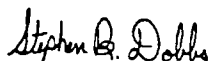
Page 2
Dr. Ron Hart
January 3, 1981

This study allowed me to progress on several of my internship objectives:

1. Learn cost engineering.
2. Learn scheduling engineering.
3. Become familiar with Process Industry Technology.
4. Take responsibility for cost engineering on one phase of a project.

I have enclosed a copy of my first performance appraisal for your review.

Sincerely,


Stephen B. Dobbs

SBD/dd

Enclosure: 1

cc: J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle, J.E. Wendt,
R.S. Wick, C.W. Wight

FLUOR ENGINEERS AND CONSTRUCTORS, INC.4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

February 9, 1981

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843


Dear Dr. Hart:

This month the Coal Gasification Study described in my last report was concluded. A book was prepared from the results, followed by a presentation to the client. This presentation was successful and the client indicated interest in further study work.

Following the Gasification work, I took responsibility for scheduling a job which is just getting started. The new work will include design, procurement, and construction management for work, in excess of one billion dollars, involving various process units. These process units consist of the latest technology for using once wasted bottoms products. They include a Vacuum Residuum Hydrocracker (VRHCU) and a Hydrogen Generation Unit (HGU) using a partial oxidation process. Other process units include several sulfur recovery units and tail gas treating units for processing higher sulfur content feedstocks. From the schedules I have prepared so far, the plant will be in operation by January 1, 1986.

The schedules completed include Master Schedules for the VRHCU and HGU. These schedules indicate major milestones for the project, such as, process and design completion, procurement activities for critical equipment, and site preparation and construction duration. I also completed a licensor interface schedule showing dates which Fluor will require specific information from licensors who are preparing basic process packages for their portions of the work. During the next month I will be working on a front end process activity schedule and initial engineering schedules for the HGU and VRHCU.

Sincerely,


Stephen B. Dobbs

SBD/dd

Enclosure: 1

cc: J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle, J.E. Wendt,
R.S. Wick, C.W. Wight

V FLUOR ENGINEERS AND CONSTRUCTORS, INC.

4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

March 13, 1981

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843

Dear Dr. Hart:

This month I continued acting as lead scheduling engineer on the residuum upgrading project, which was described in my last report. The project is staffing up and I am presently supervising two scheduling engineers, as well as, two technicians. My immediate supervisor, Charles Wight, transferred to another Fluor project in South Africa this month, and, a new control team leader has filled his position. As a result, I am the only cost/scheduling member of the task force who has been on the project since kick-off. For this reason, I am still doing a substantial amount of cost engineering until the new members become familiar with their jobs.

During February my scheduling group completed several schedules for review with our client. First, Master Schedules described in my last report were completed and reviewed by both Fluor and Client management. Also completed was the Process Activity Schedule. This schedule describes, in detail, process activities necessary to prepare specifications for over 200 pieces of major equipment in one section of the project alone. These specifications are then used for requesting quotes from vendors. Schedules were also completed which described all of the activities needed to procure critical equipment on the project. These schedules include dates for specification transmittals, bidtab evaluations, client approvals, and arrival in the field.

During the next month, home office staffing plans will be developed as well as manpower loading curves for the construction in the field.

Sincerely,



S. B. Dobbs

SBD/dd

cc: J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle, J.E. Wendt,
R.S. Wick, C.W. Wight



FLUOR SOUTH AFRICA (PTY) LIMITED

AFPRENE PROJECT NEWCASTLE

ENGINEERS AND CONSTRUCTORS
1613 SANLAM CENTRE
JEPPE STREET
JOHANNESBURG 2001
P.O. BOX 9586
JOHANNESBURG 2000
TELEX 8-9462
PHONE 28-3591

May 31, 1981

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843
USA

Dear Dr. Hart:

My remaining three internship reports will be sent from Johannesburg, Republic of South Africa. I am now in my third week on the Afprene project as Directorate Planning Engineer. A copy of the Job Description is attached.

Fluor is acting as managing contractor on the Afprene project. This means that Fluor is responsible for all work on the project, including Design Engineering, Procurement, and Construction of this isoprene and polyisoprene production facility. The construction site is located near Newcastle, RSA. This is approximately 300 km south-east of Johannesburg. The construction is being done by as many as thirty subcontractors. The major ones are Goldstein, Naco, and Genrec. Site management, including the construction manager, is by Fluor-South Africa (Pty)Ltd. Major design work is subcontracted to Snamprogetti Ltd. (Basingstoke, England), E.L. Buteman (Pty)Ltd. (Johannesburg, RSA) and Fluor G.B. Ltd (Manchester, England). International procurement activities are being managed by Fluor South Africa (Johannesburg).

In March of this year it was decided by the client that it would be necessary to form a "Directorate" to coordinate the entire job. This management group includes an Executive Project Director and Directorate Cost/Scheduling Team headed by the Directorate Cost/Scheduling Manager. In my position, I report directly to the Cost/Scheduling Manager. After becoming established, I will oversee all scheduling and planning activities for the entire project. This includes work done by all subcontractors, both field and home office.

To date I have prepared the cost base for the job. On May 19th this document was reviewed by the client, who accepted it as the new budget. Presently I am writing cost procedures which will be used for the remainder of the project.

Sincerely,

Stephen B. Dobbs

SBD/dd

cc J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle, R.S. Wick
FLUOR SOUTH AFRICA (PTY) LTD, A CALIFORNIA, USA CORPORATION - DIRECTOR: D.S. TAPPAN JR. (USA)



FLUOR SOUTH AFRICA (PTY) LIMITED

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1613 SANLAM CENTRE
JEPPE STREET
JOHANNESBURG 2001
P.O. BOX 9586
JOHANNESBURG 2000
TELEX 8-9462
PHONE 28-3591

19 July, 1981

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77843
USA

Dear Dr. Hart:

Since the last report, I have been involved extensively with developing cost control procedures for the Afprene project. These procedures describe the responsibilities of all four Fluor cost groups on the project (Manchester, England; Basingstoke, England; Johannesburg, South Africa; and Newcastle, South Africa). A majority of the procedures deal with grouping of costs into particular cost codes, methods of cost forecasting, and details on cost reporting. Cost reporting and tracking becomes complicated on international projects with worldwide procurement. On the Afprene Project, Fluor maintains buying groups in the following locations:

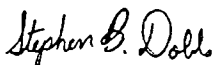
<u>Locations</u>	<u>Currency of Expenditure</u>
Irvine, USA	U.S. Dollar
Houston, USA	U.S. Dollar, Canadian Dollar
Tokyo, Japan	Yen
Haarlem, Holland	Dutch Floren
London, England	Pound Sterling
Manchester, England	Pound Sterling
Johannesburg, R.S.A.	Rand
Milan, Italy	Lira
Dusseldorf, Germany	Deutch Mark, Belgium Franc
Paris, France	French Franc, Swiss Franc, Swedish Crone

I also worked this month on evaluating subcontractors bidding on the electrical portion of the work (approximately \$2 million U.S.). This involved rough material take-offs of electrical drawings and unit rate negotiations with the bidders. The contract will be awarded by the end of next week with work to commence within the next four weeks.

Page 2
Dr. Ron Hart
19 July, 1981

My last report will be sent from Newcastle, Rep. of South Africa. In about two weeks I will be moving to the job-site for the remainder of the project. Most of the Home Office Engineering effort is complete and the offices are being staffed down.

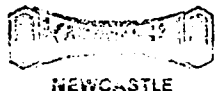
Sincerely,



Stephen B. Dobbs

SBD/dd

cc Dr. J.J. Benjamin, R.C. Cohran, J.J. Fox, C.E. Lee, D.G. Naugle,
R.S. Wick



FLUOR SOUTH AFRICA (PTY) LIMITED

AFPRENE PROJECT NEWCASTLE

ENGINEERS AND CONSTRUCTORS
 KARBOCHEM SITE
 NEWCASTLE 2940
 PRIVATE BAG X5659
 TEL.: (0343)-27024

September 13, 1981

Dr. Ron Hart
 Nuclear Engineering
 Texas A&M University
 College Station, TX 77843
 USA

Dear Dr. Hart:

The design and procurement phases of the Aprene Project are near completion. Design teams in Manchester and Johannesburg are in the process of demobilization. Design teams in Basingstoke are completing drawings and schedules of the last units of the plant, which will start construction in October this year.

Since all construction on this project is subcontracted, field staff have been divided into teams, each assigned to manage one or more subcontractors. These teams consist of a construction superintendent, a subcontracts engineer and a scheduling engineer. The superintendent is responsible for quality control, acceptance of completed work, and interface between Fluor and the subcontractor's work force on the site. The subcontracts engineer is responsible for ensuring that the subcontractor fulfills contractual requirements, sends letters of enquiry, and writes contract amendments and work orders. The scheduling engineer provides work assignments to the subcontractor on a weekly basis, measures subcontractors progress and productivity, assures continuity of work, and arranges for a good access interface with other subcontractors in the same area.

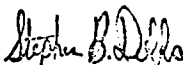
As the international home office efforts are completed, my responsibilities of directorate planning are decreased. As a result, half of my time is now spent as scheduling engineer for the work team responsible for coatings (paint and insulation) and deluge water fire protection system. As a member of this team over the last month, I have been involved in negotiations on the painting subcontract and awarding of the same contract. The successful bidder has already been mobilized and I am presently issuing the painting weekly work plans. Presently, negotiations are underway in selecting the insulation and deluge systems subcontractors.

Still performing some directorate duties, last month I completed a steel erection study indicating heavy interface problems between the steel erection subcontractor and mechanical erection subcontractor in certain structures of the isoprene plant. As a result, negotiations have been completed to re-award portions of the steel erection work to avoid these problems.

Page 2
September 13, 1981
Dr. Ron Hart

It is still my intension to complete my doctorate the fall semester of 1982 or 1983, depending on how the Afprene project developes. I will continue sending progress letters to my committee on a periodic basis.

Sincerely,



Stephen B. Dobbs

SBD/dd

cc J.J. Benjamin, R.C. Cochran, M.J. Fox, C.E. Lee, D.G. Naugle, R.S. Wick

Dr. Hart: Please distribute.

POBox 3157
Newcastle 2940
RSA
August 23, 1982

Dr. Ron Hart
Nuclear Engineering
Texas A&M University
College Station, TX 77840
U.S.A.

Dear Dr. Hart:

Since last October, Phase I of the Afprene Project has been completed on schedule and on budget. The client is currently producing product which exceeds all quality requirements and has received a large tax incentive as a result of the project being completed on time. During this period I have been primarily involved with Cost Engineering. However, during December I had the opportunity to act as Commissioning Engineer. The responsibilities of this position included developing legal documentation for Transfer of Care Custody and Control of completed portions of the plant, listing exception items to the turnover, obtaining Fluor and Client agreement for the turnover, and insuring commissioning milestones were achieved.

Since January, I have worked on implementing a new computer based cost reporting system for the project. This required two trips to England. The first to set up the computer programs and the second to modify formats to suit Afprene Project reporting requirements.

As discussed over the phone, it is my intention to continue as a cost engineer on the project until December 1982; to handle subcontractor backcharges and claims. I also intend returning to Texas A&M to complete my Doctor of Engineering Degree during the Spring Semester of 1983.

Dr. Ron Hart
 August 23, 1982
 Page 2

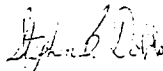
The following is a list of degree plan deficiencies;

Course	Title	Credit
NE 681	Professional Development Seminar	1
ET 604	Industrial Communications	3
IEn 663	Engineering Management	3
Mgmt 615	Envireonmental Law	3
ME 617	Mechanical Vibrations	4
ME 647	Vibrations of Plates and Shells	<u>3</u>
Total		17

Since several of these courses are not offered in the Spring Semester, I will be seeking to petition substitute courses, possible related to law, management, finance, communication, and the chemical process industry.

Deborah will be leaving South Africa in October and visit College Station to process my preregistration at the required time.

Sincerely,



Stephen B. Dobbs

SBD/dd

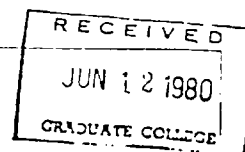
cc JJ Benjamin (TAMU), MJ Fox (TAMU), CE Lee (TAMU), DG Naugle (TAMU), RS Wick (TAMU), JE Wendt (Fluor GB, London), CW Wight (Fluor Eng., Houston Div.)

Dr. Hart: Please make TAMU distribution

CW Wight: Please copy EE Broussard

APPENDIX D
Internship Supervisor Approval

TEXAS A&M UNIVERSITY
COLLEGE OF ENGINEERING
COLLEGE STATION TEXAS 77843



DEPARTMENT OF NUCLEAR ENGINEERING
713-845-4161

May 22, 1980

Dr. G. W. Kunze, Dean
The Graduate College

Through

Dr. R. H. Page, Dean
The College of Engineering
Campus

Subject: Appointment of Mr. John E. Wendt as a member of Stephen B. Dobbs' Advisory Committee

Dear Dr. Kunze:

Mr. Stephen B. Dobbs has begun his Doctor of Engineering Internship at Fluor Engineering and Constructors, Inc. in Houston, Texas. His internship supervisor is Mr. John E. Wendt, General Manager, Cost and Scheduling Engineering. According to the College of Engineering "Guidelines for Industry Participation in the Doctor of Engineering Internship", June 1979, I recommend that Mr. Wendt be added to Stephen B. Dobbs' Advisory Committee. Mr. Wendt's resumé is attached.

Sincerely,

Ron R. Hart, Chairman
Student's Advisory Committee

APPROVAL RECOMMENDED:

Dr. J. J. Benjamin, Accounting
Committee Member

Dr. C. E. Lee, Nuclear Engineering
Committee Member

Dr. R. S. Wick, Nuclear Engineering
Committee Member

APPROVED:

Dr. R. H. Page, Dean
College of Engineering

Dr. G. W. Kunze, Dean
The Graduate College

cc: Drs. D.G. Naugle, Physics, GCR; M. J. Fox, Industrial Engineering; R. G. Cochran, N.E.

APPENDIX E

Notification of South African Assignment

FLUOR ENGINEERS AND CONSTRUCTORS, INC.

4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77098
TELEPHONE (713) 662-3000

April 15, 1981

Dr. Ron Hart
Nuclear Engineering
Texas A&M
College Station, TX 77843

Dear Dr. Hart:

I understand Steve Dobbs has advised you of his opportunity to take a short assignment on a Fluor project in South Africa. I believe this is an excellent assignment for Steve. He will gain firsthand experience on the construction of a plant at an overseas location in a relatively short period of time. I estimate he will be there approximately 1 year.

I want to assure you that I feel it is mandatory that Steve finish his course work at A&M for his Doctors Degree and that he will start this in the fall of 1982.

I hope this assignment meets with your approval. Please advise if I can provide any more details of the assignment.

Very truly yours,

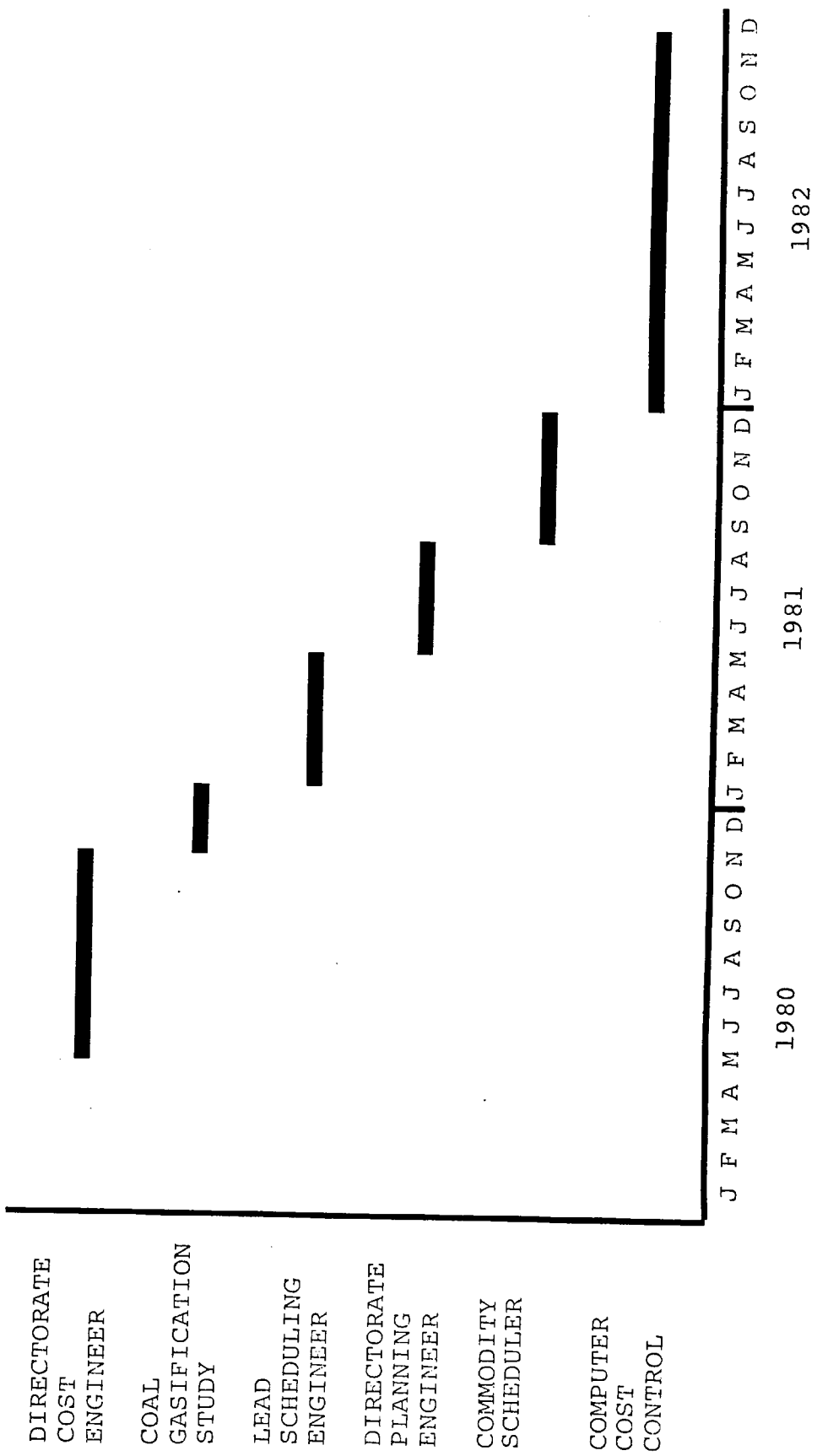


J. E. Wendt, General Manager
Cost/Scheduling Department

JEW:rr

APPENDIX F
Schedule of Assignments

SCHEDULE OF ASSIGNMENTS



1980

1981

1982

APPENDIX G

Internship Supervisor's Report



4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE (713) 662-3000

June 27, 1983

Dr. R. R. Hart
Texas A & M University
College Station, Texas

Dear Dr. Hart:

Stephen B. Dobbs completed his internship at Fluor late last year. His internship was a success and achieved all of the established objectives.

Steve worked in Fluor's Houston Engineering office from May, 1980 to August, 1981. During this period I had close association with Steve and his work as a Cost and Scheduling Engineer. He demonstrated skills in cost, scheduling, and estimating. He had a close working relationship with other technical disciplines, Fluor management, and clients.

Steve gained additional experience on an assignment in South Africa. Although my association was not as close, I did maintain contact with Steve and his supervisor during this assignment.

Steve exhibited strong technical capabilities. He has excellent communication abilities. He is innovative in solving problems and does his work in a timely manner.

Steve met his internship objectives and demonstrated the ability to function as a practicing engineer.

I appreciate the opportunity to participate in Steve's internship program.

Sincerely,

A handwritten signature in cursive script that reads "J. E. Wendt".

J. E. Wendt

VITA

Stephen Benton Dobbs

10111 Kerrwood

Houston, Texas 77080

Birthplace: Artesia, New Mexico

Birthdate: September 10, 1956

Parents: James B. and Billy F. Dobbs

Family: Married with one daughter

Education: B.S., Nuclear Engineering
Texas A&M University, 1978

M.E., Nuclear Engineering
Texas A&M University, 1980

Experience: May 1980 - December 1982
Doctor of Engineering Internship
Cost/Scheduling Engineer
Fluor Engineers
Houston, Texas

June 1978 - May 1980
Graduate Teaching Assistant
Texas A&M University
College Station, Texas

May 1975 - May 1976 (Part Time)
Research Technician
Nuclear Science Center
College Station, Texas

The typist for this report was Deborah A. Dobbs.