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DOMESTIC PROJECT MANAGEMENT

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To focus in on the management of a domestic project, I have chosen to talk about Ontario Hydro's current nuclear mega-project at Darlington, which is located about 75 kilometers east of Toronto on the shores of Lake Ontario. The generating station will consist of four reactor units each producing 881 megawatt of electricity.

I have broken down my presentation into three main categories:

- overview of the history and current status of the Darlington project.
- project management in place on the Darlington project.

and finally,

- performance of the project.

OVERVIEW OF HISTORY AND STATUS OF DARLINGTON PROJECT

The Darlington station was planned in the 1973-1977 time period as part of the generation development program aimed at meeting loads in the 1980's and beyond. Provincial government approval to proceed with site clearing and construction of Darlington was received in July 1977. First concrete was poured at the site in August 1981.

Darlington was part of the review by the Royal Commission on Electric Power Planning (RCEPP), which was appointed by an order in council in July 1975 and filed its report in February 1980 on Ontario Hydro's long-range planning concepts for the period 1983-1993.

At the time of approval in 1977, the in-service dates for Darlington's four units were in the time period 1985-1988. Subsequently, between the years 1978-1982, the forecast load growth progressively reduced. At each stage, the generation program was reviewed and a number of projects were cancelled, reduced in size, or rescheduled. Darlington was one of the rescheduled projects.

There were several major schedule changes on Darlington. In 1979, the first two units were delayed 18 months and the second two units 30 months. Then in 1980, the first two units were further delayed by 18 months and Units 3 and 4 by 12 months. In 1981, Units 1 and 2 were advanced six months, and Units 3 and 4 were advanced 12 months. Then again in 1982, Units 3 and 4 were set back 24 months.

In total, there has been a 30-month delay on Units 1 and 2 and a 54-month delay on Units 3 and 4.

The various schedule delays were the result of a declining load forecast. The one advancement in 1981 was in response to the Provincial Government's "BILD" program which was aimed at reduction in acid gas emissions and the creation of jobs in the construction and electrical equipment industries.

The scheduled in-service dates set in 1982 for the four 881 MW Darlington units are as follows:

Unit 2 - May 1988
Unit 1 - Feb 1989
Unit 3 - Nov 1991
Unit 4 - Aug 1992

At the present time, engineering for each of the four units is approximately 80% complete, construction about 55% complete and commitments have been made for

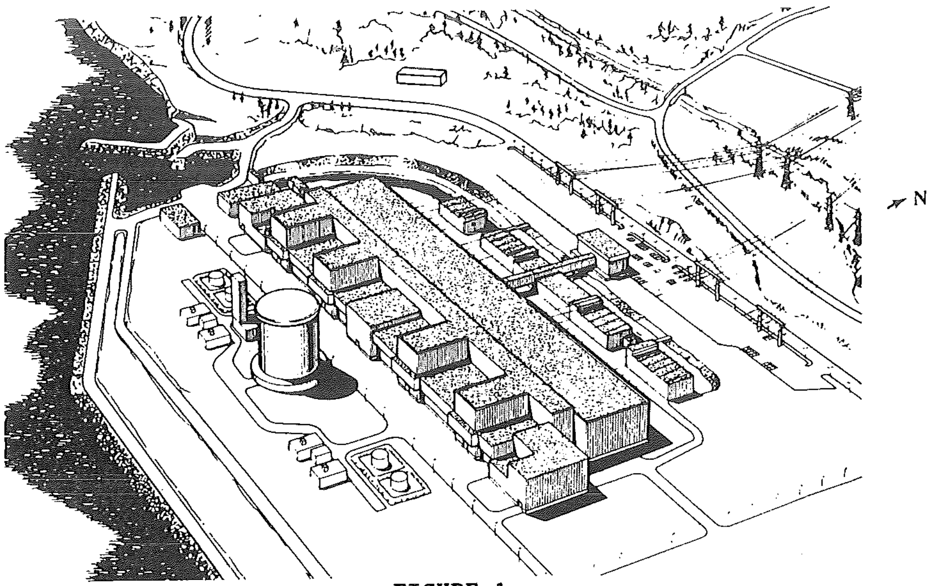

FIGURE 1

about 95% of the permanent material and equipment for the four units.

Figure 1 shows an artist's concept of the complete four unit station. Some of the main features of the station are:

- The vacuum building is the large circular structure in the centre and on the lake side of the picture.
- The tritium removal facility is located to the left of the vacuum building.
- To the north of the vacuum building are the four reactor buildings and the turbine hall. The four units are numbered from left to right with the service area located between the four units.
- A fuel storage bay is located at each end of the four-unit station.
- The administration building is centrally located north of the main station building.
- At the top of the picture is the switchyard which allows electricity from Darlington to be fed into the 500 KV transmission lines.
- The information centre is located on a hill north west of the station.

Figure 2 shows a recent aerial photograph of the site.

Concrete placement continues to be a major activity at site, in particular on Units 3 and 4, with approximately 650,000 cubic metres now in place. To put this into some perspective, this is equivalent to about 17 times the concrete placed in the Toronto CN Tower. With about 22 CN Towers worth of concrete required to complete the four units, 80% is now complete.

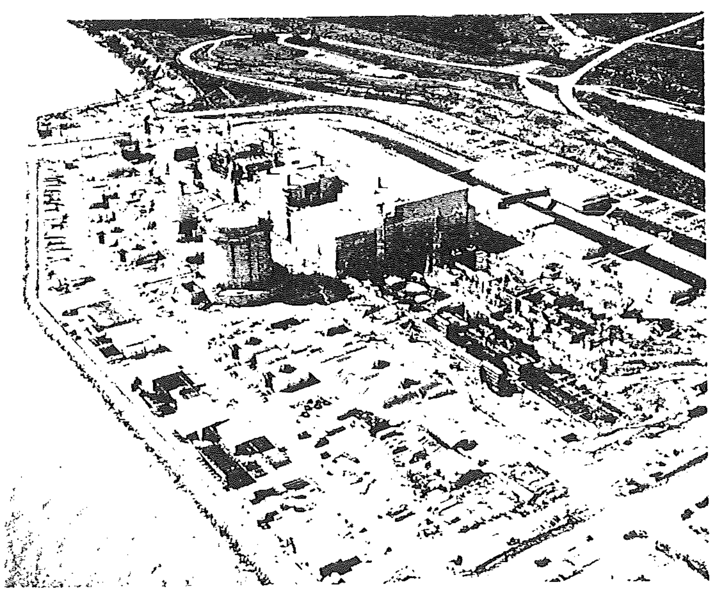

FIGURE 2

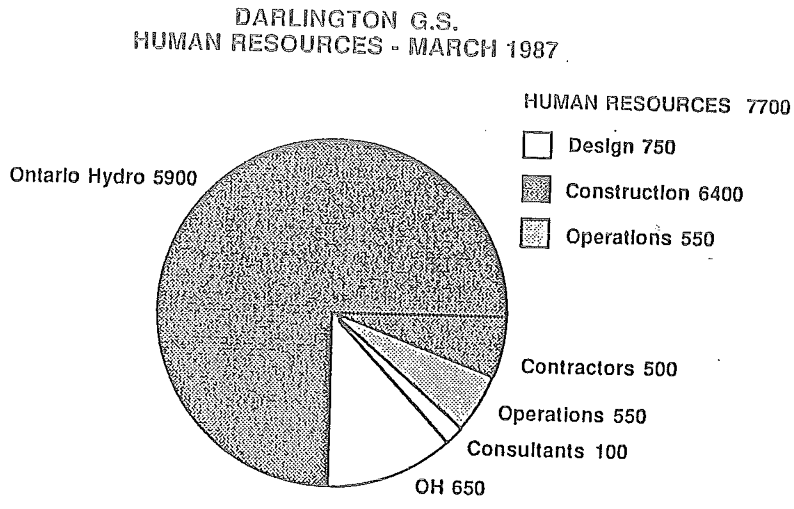

FIGURE 3

There is also now a high level of activity in the installation of electrical and mechanical equipment and piping.

Figure 3 shows the number of people presently working on the project.

As of the end of March 1987, the total number working on Darlington was 7700, with the construction effort accounting for approximately 6400, design for approximately 750, and station operating staff approximately 550.

The construction organization peaked in 1986 at 7000.

The operating staff number will grow to 700 regular jobs by the time all four units are in service.

projected interest/inflation rates). The $10.9 billion total capital cost estimate is the approved figure. As can be seen, $8.3 billion is for design and construction, with $2.6 billion for commissioning, training, and heavy water.

Project Management in Place on Darlington Project

The successful development of Ontario Hydro's nuclear power program has not solely depended on the technological achievements. Of equal importance is the management and staffing for the control of engineering, construction, and operations of major nuclear projects.

Time will not permit a full, detailed presentation on the nuclear program management and in particular,

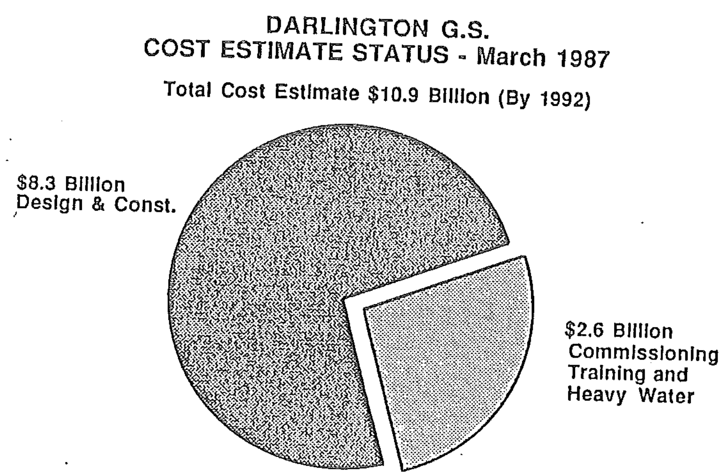

FIGURE 4

Figure 4 shows overall cost information on the Darlington project.

These costs include design and construction, commissioning, operator training, and heavy water costs and are in dollars of the day (that is, include

of the organization and systems in place on Darlington. What I plan to do is to talk a little about the project life cycle for a major project, and then briefly discuss the Darlington project organization and some of the major management systems in place.

Project Life Cycle

As an aid to the management process, Ontario Hydro has defined the life cycle of a station in five sequential phases, each with management structures and techniques appropriate to the objectives of the particular phase as shown on Figure 5. Thus, a station begins in a concept phase, progresses through definition, acquisition and operation phases, and ends its life in its retirement phase. The first two of these are known as the preliminary engineering phases.

Alternatives for future generation are developed, and by a process of elimination, the specific alternatives that best meet systems requirements are chosen. If the choice is a new station, then the concept phase includes the selection and acquisition of the site upon which it will be built. At this point, the project enters its definition phase. During this stage, requirements for major systems and equipment are defined, site and structure layout is developed, environmental and community impacts are analyzed in accordance with Provincial and Federal Governments regulations, and plans for engineering, construction, and commissioning -- including estimates and schedules -- are prepared.

Approval to construct the station is requested, first internally and then from the Provincial Government. When it is received, orders are placed for the major equipment because of the long lead time involved. This leads to the acquisition phase, in which detailed design is carried out, equipment is specified and purchased, structures are built and systems installed, and the equipment is checked, tested and placed in service.

From this point to the end of its life, the station is in its operation phase, producing electrical energy as required by the provincial electricity system. During this time, maintenance activities are carried out on a regular basis and modifications and rehabilitations made as required.

When its economic life is over, the station enters its retirement phase, during which it is decommissioned. This may mean the equipment is stored or removed, or the whole station is demolished.

Moving on, I would now like to talk about some of the specifics of the Darlington project organization. However, before doing that, a brief word on how the project integrates into the overall Ontario Hydro organization and in particular, into the Design and Construction Branch. Figure 6 shows a simplified corporate organization.

Organization and Management

Ontario Hydro is directed by a board composed of a full-time chairman and part-time members. This membership, which is drawn from a wide cross-section of the community and appointed by the Ontario Government, sets Ontario Hydro policy and makes sure it supports and is consistent with that of the Provincial Government

To ensure Ontario Hydro operates in an efficient and effective way, the day-to-day management is delegated to a President, who is also on the Board of Directors. He, together with Executive Vice-Presidents, forms an executive office responsible for the administration of the corporation. The Executive Vice-Presidents are each responsible for a group of functions: planning and administration, human resources, engineering and services, and operations.

The Engineering and Services Group is responsible for providing engineering and construction of generation, transmission, and associated facilities, as well as procurement, computer, and other centralized services.

The functions of the Operations Group pertain to the production, transmission, distribution, and marketing of electricity.

The organizational unit responsible for engineering and construction within the Engineering and Services Group is known as the Design and Construction Branch. Its responsibilities include building nuclear generating stations.

As you can see, the Project Manager for a major project such as Darlington reports directly to the Vice-President, Design and Construction Branch. Other major groups reporting directly to the Vice-President are also shown on this slide, i.e. Director of Design

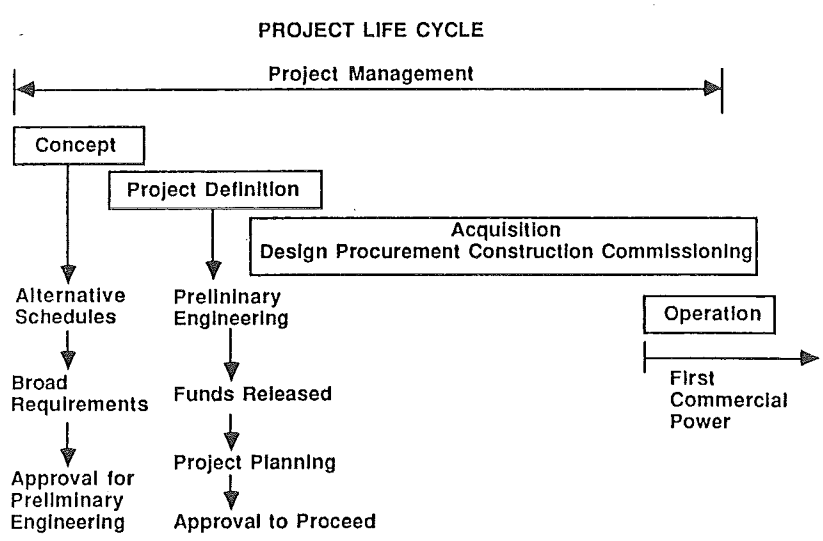

FIGURE 5

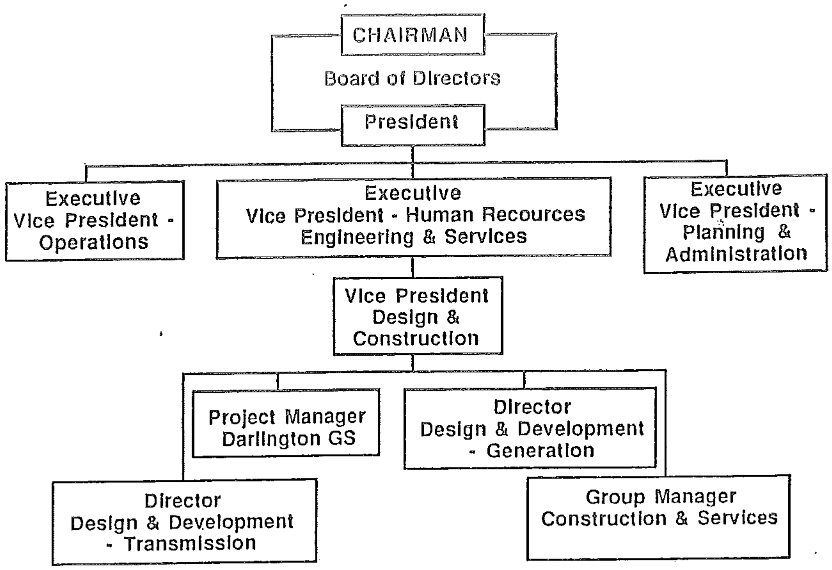

FIGURE 6

& Development - Generation, Director of Design & Development - Transmission, and Group Manager - Construction Services.

Project Management

As leader of the project group, the Project Manager's task is to see that the work is planned, that the plan is carried out, that progress is monitored, that work is done compared with work planned, and that any necessary replanning, adjustments, or corrections are carried out. Figure 7 shows the project organization.

The Project Manager gives specific assignments to the Manager of Engineering and the Manager of Construction, while the Manager of Project Services provides project management services. Also, an important part of the project team is the Community Relations Officer who has responsibility to monitor the impacts of such a large project on the local community and also manage the site information centre.

Project Services Organization

The organization of the Manager of Project Services is shown on Figure 8. He has two major functions on Darlington.

His first function is to ensure all necessary project policies and procedures are developed and available for the Project Manager to manage and control the project.

In this regard, he supports the Project Manager with information for monitoring and provides feedback data on performance in relationship to those necessary policies and procedures.

Also, in this capacity, he ensures the necessary managerial interfaces and controls are identified to ensure that the design/construction and construction/operations interfaces are managed.

His second major function is to provide a support service to the project and the Manager of Engineering in the areas of scheduling, estimating, financial, cost control, procurement, and administrative services.

In this relationship, the four major supervisors under him have a dual role:

- support of engineering
- support of the overall project policies and procedures

To support this portion of the organization, there was a dedicated resource base of approximately 70 at the peak of the project (total 60 as of March 1987).

PROJECT MANAGEMENT ORGANIZATION

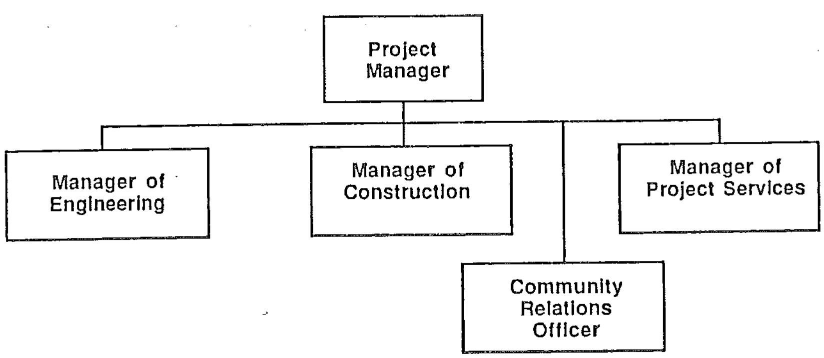

FIGURE 7

PROJECT SERVICES ORGANIZATION

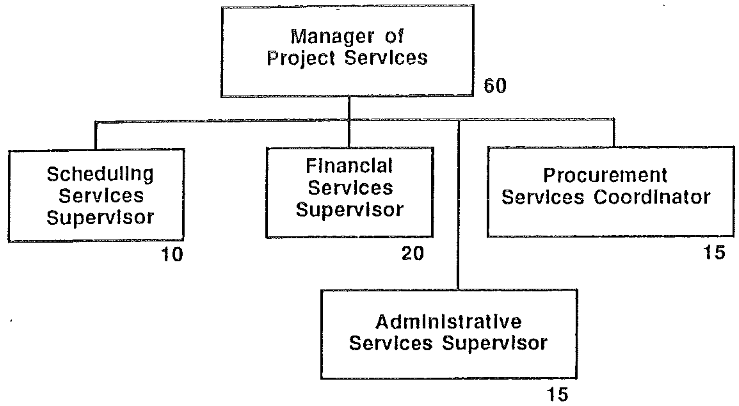

FIGURE 8

Project Scheduling and Time Control

One of the Project Manager's principal management aids is the master schedule, which contains "milestone" events for all stages of the acquisition phase. This schedule is issued by the time the project enters its acquisition phase and is used to monitor and control progress. The technique employed is to make monthly comparisons of work completed with work scheduled, and then to analyze deviations and evaluate their effects of subsequent events. The resulting information is used as a basis of remedial actions such as replanning the work, reassigning or increasing manpower, changing contractual conditions, or expediting suppliers. The master schedule is augmented by more detailed schedules appropriate to the various management levels and these too are monitored to control progress.

Project Estimating and Cost Control

Another important management aid is the process of project estimating and cost control. Early in the acquisition phase, the project costs are re-estimated in as much detail as available information allows. To facilitate this, the project is divided into "work packages". On Darlington we have 15 major work packages which are subdivided into 150 minor packages, each relating to a physical system or structure, or to an area of cost. A detailed estimate is made of the capital cost for each of these work packages, and the estimate is subdivided into areas of indirect cost, costs for material and equipment, and costs for installation. These subdivisions conform to pre-determined areas of management responsibility. As part of this process, annual costs are determined for each management area, and these cost findings become the bases for annual budgets.

As the detail design progresses and additional cost information becomes available, the various estimates are revised, and the revisions are summarized annually and submitted to senior management for approval. The summary is accompanied by an explanation that distinguishes between cost changes caused by uncontrollable phenomena and those due to events controlled by project management. The former include the effects of changes in such things as inflation, interest rates, exchange rates, taxes, and government regulations, while the latter include schedule slippage, estimating errors and other changes. Scope changes occur throughout a project and depending on their origin, may fall into either category.

The annual budget is also used to exercise short-term control over the project. This is done through monthly comparisons of actual expenditures with the relevant portion of the annual projected expenditures. The reasons for any variances are determined and where necessary, corrective action is taken.

Project Engineering

Another important facet of the acquisition phase is the engineering. To handle this function, Ontario Hydro's experience in the nuclear field has led to the evolution of an effective way of managing and coordinating all the engineering activities. The method consists of making the Manager of Engineering responsible for arranging detailed designs, for requisitioning equipment and material, and for providing the documentation and engineering assistance necessary to successfully install and commission the units.

To carry out these activities, the senior engineers and their design staff are assigned to the project team on a full-time basis as shown in Figure 9.

Technical back-up is provided by the discipline-based functional departments in the Design & Development Division - Generation. Certain specialized work not requiring a full-time project team is carried out by the relevant discipline departments as a service to the Manager of Engineering.

To support this portion of the Darlington organization, there was a dedicated project engineering resource base of approximately 250 at the peak of the project (total 190 as of March 1987).

The Manager of Engineering carries out his responsibilities both directly through Ontario Hydro staff and indirectly through engineering consultants. If the work is to be undertaken by the former, then it is accomplished by the project team. On the other hand, work done by an engineering consultant is reported to the Manager of Engineering who is responsible for monitoring and controlling its performance.

PROJECT ENGINEERING ORGANIZATION

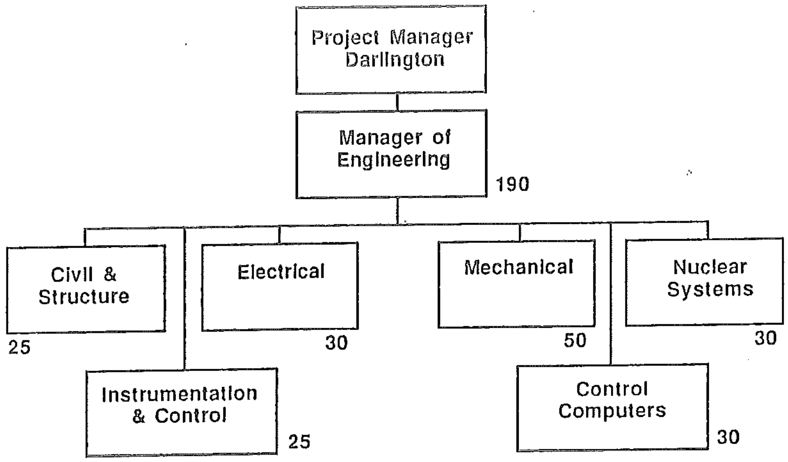

FIGURE 9

Materials Management

Because the successful construction of a large project requires that materials be in the right place at the right time, materials management constitutes another important part of project management during the acquisition phase. Should materials arrive too early, they may incur storage charges and increase interest costs. Similarly, lateness causes delays that result in further costs. To ensure untimely material deliveries are kept to a minimum, the Manager of Engineering is responsible for identifying needs and initiating procurement for all project material and equipment, and for doing so in time to allow delivery to coincide with the installation date specified in the construction schedule. To give some indication of the magnitude of this problem on the Darlington project, about 30,000 equipment contracts have been placed, having a value of approximately $2.2 billion.

In addition, to facilitate management of the thousands of pieces of minor equipment and hardware that must be purchased, delivered, stored, and installed, Ontario Hydro has developed a computerized project material management system. This system is based on a separate, corporation-wide numerical stock code, and applied to all different items supplied to a project. The corporate list of materials contains over 600,000 such items and over 90,000 of these are in use on the Darlington project site.

Purchasing and Supply

In Ontario Hydro, all purchasing operations are carried out by a separate Supply Division, within which are several departments, each specializing in a specific range of products. The procurement cycle begins when the Supply Division receives a requisition for goods or services from the Project Engineering Department. Then tenders are invited and evaluated and orders placed. Evaluation of technical and economic factors is done by the Project Engineering Department, while Supply Division examines the commercial conditions.

After a contract has been awarded, surveillance of the supplier's manufacturing process begins. The Project Engineering Department is responsible for approving the supplier's engineering, while the Supply Division approves the manufacturing schedule and quality assurance program and monitors supplier performance through quality verification, procedures audits, and progress assessment. In the case of work at the site, performance monitoring is done by the Project Construction Department.

Construction

The Manager of Construction is responsible to the Project Manager for all construction and installation activities that take place at the project site during the acquisition phase. His responsibility ends only when the systems and equipment are handed over to the station operating staff for commissioning.

As can be seen from Figure 10, under the Manager of Construction, there are several areas of sub-responsibility.

For example, all construction labour employed directly by Ontario Hydro is managed by the General Superintendent. Most of the construction work at Ontario Hydro's nuclear generating stations is carried out by this labour force. On the other hand, when such work is done by contracted forces, the Resident Engineer supervises their reports. The Resident Engineer is also responsible for all quality verification and inspection at the site and interprets specifications on behalf of the Manager of Engineering. His staff acts as a line of communication between Project Design Engineering staff and the General Superintendent's staff. During commissioning, the Resident Engineer's staff maintains contacts with the operating personnel.

Worker safety is another important area of responsibility associated with the construction process. In every aspect of its operation, Ontario Hydro places first priority on public and worker safety by making all levels of the line organization responsible for preventing injuries and accidents. Corporate safety rules and training aids provide guidelines for this task, and a worker protection code assists in creating a safe working environment for all people who must deal with equipment, some of which may be pressurized or electrically charged.

PROJECT CONSTRUCTION ORGANIZATION

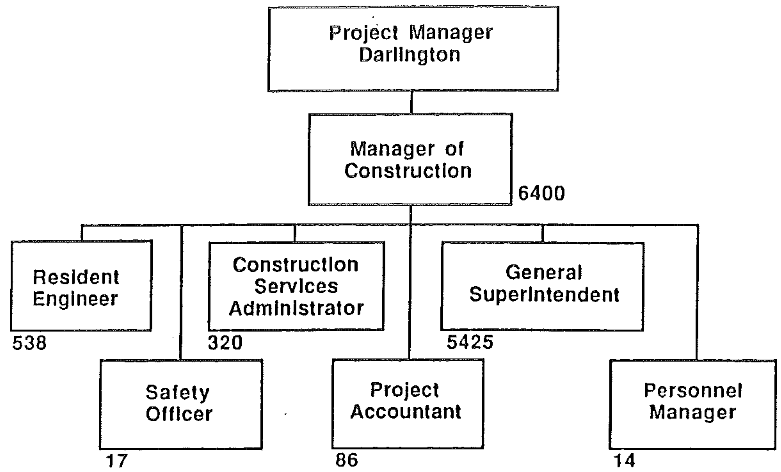

FIGURE 10

To support this portion of the Darlington organization, there was a dedicated resource base of approximately 7,000 at the peak of the project (total 6,400 as of March 1987).

Commissioning

Once the equipment for each system has been installed and connected, the acquisition phase draws to an end. At this point, the Resident Engineer and his staff begin to pass responsibility for the facility to the Station Manager and his staff. Because the latter have been appointed well in advance of the in-service date, by the time they come to test and commission the systems, they are thoroughly familiar with the plant. The turnover of each system and piece of equipment from the construction staff to operations is formally documented.

Although commissioning activities are the responsibility of the station operating team, the Project Manager retains overall responsibility until it has been demonstrated that the generating units meet station specifications to an acceptable degree. Even after the units have been declared in service for commercial operation, the Project Manager remains responsible for ensuring that the equipment suppliers have fulfilled their obligations and that any necessary modifications are carried out.

The complete process of turnover and commissioning is a lengthy one, occupying about two years from its beginning to the time each generating unit is declared in service. From this point on, the plant is in the operation phase of its life and becomes the responsibility of the Nuclear Generation Division, which is part of the Production Branch.

Operation Phase

Once in its operation phase, a nuclear-electric generating facility requires extensive technical support to ensure it performs safely and economically. Much of the day-to-day part of this support is provided by the Nuclear Generating Division and by a separate Technical and Training Services Division, while engineering and design support and fundamental scientific and technical aid are provided by specialists from both within and outside Ontario Hydro. Thus a range of support services that are integrated, systematically applied and flexible are readily available to cope with any problems that arise to perform regular testing and monitoring, to provide the ongoing design and development associated with a nuclear-electric program, and to carry out the fundamental research necessary to further develop nuclear materials, equipment, and systems.

In addition to coordinating the technical support, the Nuclear Generation Division also directs the day-to-day operation of the plant to meet the needs of the electricity system.

Retirement Phase

When it is no longer economical to operate a plant, the facility will enter its retirement phase. Although Ontario Hydro has had no decommissioning experience, it has conducted a number of studies to determine the processes and costs involved in taking a nuclear station out of service and placing and maintaining it in a safe mode. The anticipated costs have been included in the corporation's financial plans, but Ontario Hydro does not expect to need specific strategies to implement this phase for many years.

DARLINGTON PROJECT PERFORMANCE

Finally, I would like to talk briefly about project performance. To do this, I have selected just four of our key result areas as follows:

- schedule
- costs
- worker safety
- citizenship

Schedule

I mentioned earlier in the paper that because of a lower predicted growth rate in the late '70's, there were four major planned schedule delays on Darlington, totalling 30 months on Units 1 and 2 and 54 months on Units 3 and 4. These adjustments started in 1979 and came at a time when virtually all the major equipment, totalling some $1.6 billion, had been purchased and delivery dates set.

As a result, major schedule adjustments had to be made in the engineering and construction programs. Although generally disruptive in nature, it did show the importance of having a good management scheduling system in place which allowed a quick evaluation of the impact of the various changes.

More recently, in 1984, we experienced a six-month strike of electrical workers at site. To compound this, the strike occurred during the most productive summer months. Also, as completion of the detailed design progressed from 15% in 1981 to 80% in 1987, the full impact of the more complex design for Darlington, as compared to our last major nuclear station at Bruce, became apparent.

In summary, primarily as a result of the full impact of the increased complexity and the continuing catch-up program resulting from the labour disputes at site, we expect some changes in the presently approved in-service dates.

Our assessment is that we will not achieve the full catch-up program on Units 1 and 2, and the in-service dates will be delayed by about six months. However, with planning and productivity improvements, we expect earlier in-service dates of Units 3 and 4 of about six months.

The tritium removal facility, which is part of the Darlington project, is in the final stages of commissioning, and we expect it to go into service during August 1987.

Costs

Since the definitive estimate or control estimate for Darlington was prepared in 1981, there have been cost increases as follows:

Definitive Estimate 1981	Current Estimate 1987	Variance $B	%
$7.5 billion	$10.9 billion	$3.4B	46%

These cost increases generally fall into four main categories:

- scope changes
- estimate changes
- schedule changes
- economic changes

The scope changes result in most part from the full impact of increased regulatory requirements as compared to our previous nuclear project at Bruce. One single significant change was the addition of the $150 million tritium removal facility at Darlington, which is the first of its kind at any of our projects. Scope changes account for 9% of the total cost increase.

Estimates for Darlington were based on the costs at our Bruce project. As the Darlington design progressed from about 15% complete in 1981 to 80% in 1987, equipment, quantities, and other requirements were more clearly identified particularly in the construction area. The resulting increase accounts for about 7% of the total increase.

The costs associated with the schedule changes resulted from adjustments in the need dates for Darlington as mentioned previously. This accounts for almost 16% of the total increase and results from the additional capitalized interest and escalation associated with these planned schedule delays.

Economic changes make up the balance of the increase that is 14%. They resulted from fluctuations in interest and inflation rates, and include a financial policy change aimed at better distribution of costs to our customers. Originally, we charged the entire cost of common station facilities (vacuum building, intake structure, etc.) to the first unit; their cost is not shared by all units.

Despite the increased complexity in design and construction at Darlington as compared to Ontario Hydro's other multi-unit stations, cost increases have remained relatively small.

The following shows a comparison in 1987 dollars per kw.

Pickering A – $1195/kW	Pickering B – $1711/kW
Bruce A – $1199/kW	Bruce B – $1322/kW
	Darlington – $1807/kW

Taking the cost comparison one step further, Figure 11 compares Ontario Hydro's design and construction costs with those of utilities in the United States.

The cost data for the U.S. stations was obtained from the "electrical utility cost group" and covers units over 500 MW in size. There are some 40 U.S. utilities that contribute cost data to this group. This figure shows dollars per kW plotted against unit in-service dates. The solid line shows the Ontario Hydro trend and the dotted line shows the trend for the U.S. utilities. It shows that lower design and construction cost is one of the reasons Ontario Hydro projects have a definite economic edge over their U.S. counterparts.

Worker Safety

Worker safety has always had a high priority in our design and construction program and Darlington is not exception.

Whilst there is a lot of detailed information available on our safety program, I will just mentioned some of the Darlington highlights and compare them with what is happening in the rest of the Province of Ontario.

Ontario Hydro trade workers at Darlington have worked over 25 million manhours since 1978 without a fatality. Contract trade workers at the Darlington site have worked almost 3 million manhours and recorded one fatality in 1982. This record is particularly pleasing when considering over the last few years, we have employed an average of over 6,000 people.

By way of comparison during 1986 alone, 40 workers have died on construction sites in the Province of Ontario. Approximately 300 million trades manhours were worked on construction sites throughout the Province of Ontario during 1986. Unfortunately, there have already been 7 fatalities recorded in the first 7 weeks of 1987 on construction sites in the province.

The most common accident rate index is the "frequency" rate, which is defined as lost-time injuries per million manhours worked. Darlington's frequency rate was 54 in 1986, which compared to 53 for all types of construction in the province of Ontario.

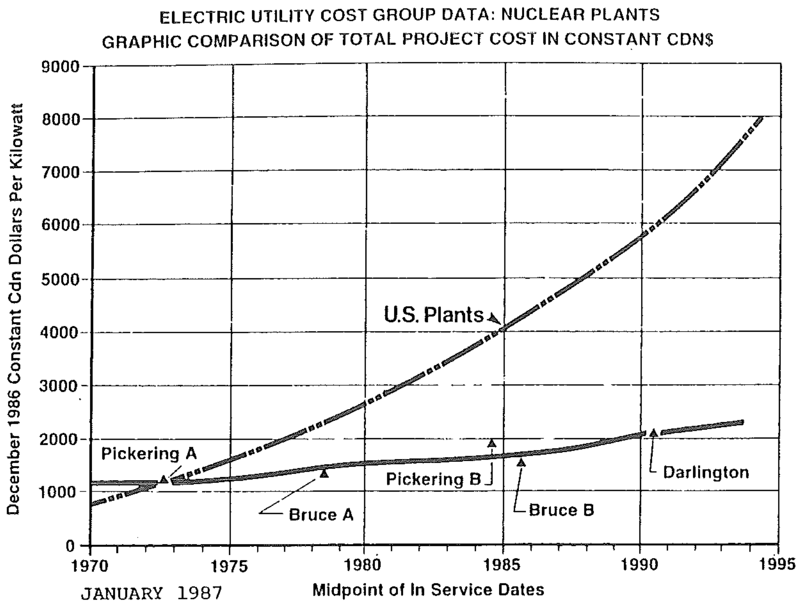

FIGURE 11

The second most common accident rate index is the "severity" rate, which is defined as the days lost per million manhours worked. A more meaningful index is "severity", which is the average days lost per lost time injury.

Darlington's severity for 1986 was 43 average days lost per lost time injury, which is an increase over 33 achieved in 1985. The comparable severity figure for all types of construction in 1986 in the province of Ontario is 90 average days per lost time injury, which also represents an increase from previous years.

Back injuries account for 42% of all our lost-time injuries. This type of injury is of concern to Ontario Hydro and is being addressed at Darlington by the introduction of a back injury prevention program.

We are proud of our worker safety record at Darlington, and this is an area we will continue to strive for excellence.

Citizenship

A project the size of Darlington will have a significant impact on the local communities. As can be seen from Figure 12, the workforce at the Darlington site as of March 1987 totalled about 6,400. If you include family members, this total increases to about 19,000.

On the left of Figure 12, you see the total number of workers from the Region of Durham or the

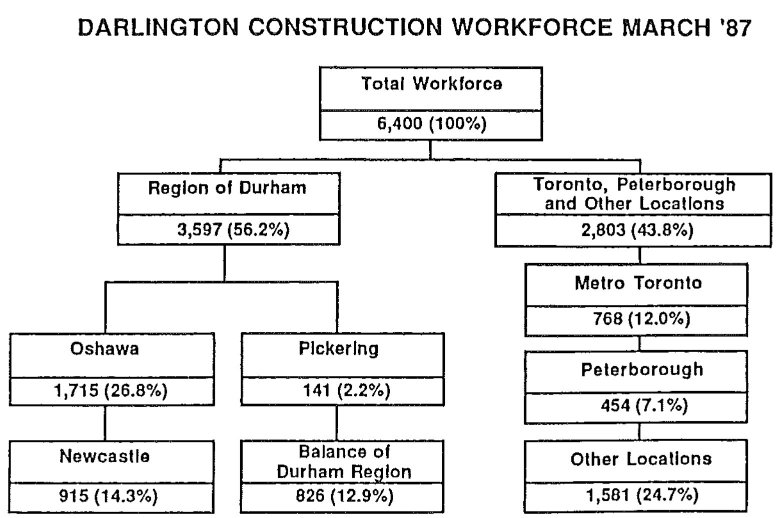

FIGURE 12

communities local to the Darlington project. This group accounts for about 3,600 or 56% of the total workforce. The balance, 44% of the workforce, comes from Metro Toronto, Peterborough, and other locations, as can be seen from the right side of this figure.

Construction and operation of a mega-project affects both the social and economic structure of the local community in a variety of ways. The influx and eventual decline of relocated workers, some with families, results in an increased demand for housing, consumer goods, and all types of services. The latter includes such things as health, recreation, libraries, education, police, fire protection, and municipal administration.

Ontario Hydro recognized at the beginning of the project in the late '70s that impacts would occur and set up a formal community impact agreement with the local communities (Town of Newcastle and the Region of Durham).

This agreement is administered by a liaison committee of Darlington project personnel and local elected officials. This committee meets on a regular basis to monitor such impacts that may occur and agree on the means of financial support to redress these impacts. Impact funds have been allocated to such things as expansion of the local hospital, additions to the local police force, fire fighting equipment, library systems, and upgrading of road access in the vicinity of the site. This liaison committee also provides Ontario Hydro with an opportunity to keep the local elected officials up to date on progress of the project and allows elected officials to ask any questions of concern to themselves or the communities.

Another important aspect of the citizenship program is the operation of the Darlington Information Centre. During 1986, close to 20,000 visitors passed through the centre and most took either bus or in-plant tours. About 50% of all visitors are local with the balance tourists. In addition to its normal use, community groups are encouraged to use the information centre for their activities.

We believe this impact agreement and the availability of a site information centre have worked well and have gone a long way to demonstrate that Ontario Hydro is prepared to meet its responsibilities as a good corporate citizen in the local communities.

That concludes my presentation on some of the highlights of "managing a domestic project". I hope you have found something of interest.