

**REVIEW OF R&D MANAGEMENT PRACTICES IN  
SELECTED LABORATORIES IN CANADA AND ABROAD**

March, 1991

Prepared for Energy, Mines and Resources Canada

By

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**BACKGROUND**

This report is part of the overall evaluation of CANMET that is being conducted by the consulting firms of Price Waterhouse and Associates, and Hatch Associates of Toronto.

**OBJECTIVE AND SCOPE OF THIS REVIEW**

The objective of this aspect of the CANMET evaluation is to identify, if possible, any R&D management practices, employed elsewhere, that CANMET senior management might find of value in improving the quality of management in CANMET.

The scope of this review is quite limited and is restricted to conducting a small number interviews (personal and telephone) with senior officials in R&D establishments that have some similarity with CANMET, and to reviewing the R&D management literature to provide some insight into the information gained through interviews.

**METHODOLOGY**

Through discussions with senior officials of EMR, a list of ten organizations considered to be similar to CANMET, in some way, was developed. These ten organizations were contacted by

telephone to determine their interest in taking part in this review. Two private sector organizations declined to take part as they were about to launch a similar examination of their R&D management practices in-house and did not want to confuse their people with two overlapping studies. Another private sector firm, after initially agreeing to take part, did not return phone calls.

The organizations taking part in the interview survey were:

- Commonwealth Scientific and Industrial Research Organization, Sydney, Australia
- Pittsburgh Research Center, U.S. Bureau of Mines, Pittsburgh, PA
- Syncrude Research Centre, Edmonton, Alberta
- Ontario Hydro Research, Toronto, Ontario
- Noranda Technical Centre, Pointe Claire, Quebec
- Atomic Energy Research Company, Ottawa, Ontario
- Sheritt Gordon Research, Fort Saskatchewan, Alberta

The interviewees were asked questions dealing with the following general R&D management areas:

- R&D Planning
- R&D Funding
- Personnel Management
- R&D Control
- Technology Transfer
- Joint R&D Ventures

## INTERVIEW RESULTS

### U.S. Bureau of Mines - Pittsburgh Research Center

#### Background

The Pittsburgh Research Center is the oldest of the nine research centres operated by the U.S. Bureau of Mines. Its research program deals primarily with two areas: health, safety and mining technology; and environmental technology. The budget for the former area in 1990 was \$21.9 million and for the latter, \$3.18 million. Other research centres operated by the Bureau are concerned with minerals and material science.

Personnel at the Pittsburgh site consists of 190 full-time and 23 part-time professionals, 89 full-time and 12 part-time technicians, and 45 full-time and 16 part-time clerical for a total of 324 full-time and 51 part-time staff.

The two major research program areas break down as follows:

#### Health, Safety, and Mining Technology

- Occupational Health
- Ground Control
- Human Factors
- Mine Safety Systems
- Mine Disaster Prevention
- Advanced Mining Systems

#### Environmental Technology

- Control of Mine Drainage and Liquid Wastes
- Solid Waste Management and Subsidence
- Abandoned Mined Land Reclamation Research

#### R&D Planning

Headquarters in Washington plays a major role in determining their R&D program. They develop research proposals and send them to Washington for approval. Research projects are selected based on their long range plans.

The only outside elements that have an impact on their research program are officials of the Mine Safety and Health Administration. The overall budgets of the Bureau are, of course, reviewed by congressional committees prior to approval.

The balance between basic/strategic research and more applied research and development appears to some extent to be a function of who is in the White House. During the Carter Administration, there was an emphasis on applied research and cost-shared research; during the Reagan years there was greater empha-

sis on applied research; the Bush Administration has reversed this trend and has directed the labs towards more basic/strategic research of a more high-risk nature. The breakdown of their research programs was 50% basic, 40% applied and 10% development. He felt that, "the ability of an entity like us to be viable depends on our ability to develop new ideas and fresh approaches. Too much applied work kills this ability".

The majority of the research being conducted at Pittsburgh can be described as "public good" research. They tend not to work on site-specific problems, but work on generic problems that affect a large number of companies.

### R&D Funding

As noted earlier, their budget is \$25 million of which most comes from the federal government. They get considerable "in-kind" support (about 20% of their resources) from their industry in the form of test sites for demonstration projects. The interviewee stated that they could not do the things they do without this support.

They conduct some work on a charge basis, primarily in the explosives area. They are designated by the Transport Department as an organization for evaluating hazardous material. They also evaluate explosives for EMSHA.

Externally funded R&D is not significantly different from their internally funded projects. In some cases it tends to be a bit more applied, and in some more fundamental.

With the exception of the money earned from EMSHA, they can retain all the money they earn less a headquarters overhead assessment.

Some of their money does not lapse at fiscal year-end so that they can continue to pay salaries for a while despite problems in Congress.

### Personnel Management

There are two layers of management below the director; research supervisors and group supervisors. All managers are supposed to have 80 hours of management training; any kind of management training. While all of the research supervisors and many of the group supervisors have had all or most of the 80 hour exposure to management training, this management training was not specific to R&D.

The interviewee believes that the best way to train an R&D manager is on-the-job training (mentoring by senior managers), general courses, and moving people around to other sites.

Significant R&D achievements are recognized by both internal and external mechanisms. Internally there is an "Innovator of the Year Program" that awards plaques (at both bureau and local level). There are also awards open to all federal employees in the Pittsburgh area for best scientist, best manager, etc. They have a "Publication of the Year" award that consists of three categories: best paper in the internal report series; best paper in a non-technical or trade journal; and best paper in a refereed journal. The award is a certificate and \$500. The U.S. Bureau of Mines has an annual "Tech-Transfer Person of the Year Award" which consists of a plaque.

In addition, they encourage their scientists and engineers to go after external recognition such as the "R&D 100" awards sponsored by the American publication Research and Development. In the period 1978 to 1984, the Pittsburgh lab has won nine of these awards. They have also received six "5-Star Awards" from the Pollution Engineering Magazine in the period 1981-82. In 1989, the Bureau won two R&D 100 awards for a personal toxic gas alarm and a hydrometallurgical treatment technique.

The lab does employ a dual promotion ladder for R&D personnel but it has not operated as well as it should.

Productivity is encouraged by means of performance plans and personnel appraisal. The interviewee believes that the greatest motivator for his staff is the ability for them to do their work.

Researchers have a fair bit of freedom to influence their projects as long as their actions are covered within their long range plan.

Conference attendance is judged on a case-by-case basis. Their budget for conferences is more than adequate. People who want to give a paper must get prior approval. Attendance is judged on the basis of the relevance of the conference to the work, and who it might attract that their people should talk to.

American government researchers can receive 15% of licence fees for something developed in the laboratory. In addition, they have an internal award of \$300. for filing a patent. An inventor can patent on his/her own if organization has no interest in patenting. Inventors can request retention of foreign rights on patents.

They consider that they work hard to maintain the skills of their staff at the cutting edge. They have 30 different professional disciplines represented in their lab. They encourage people to take university courses (locally and through the National Technological University's satellite TV programs), take sabbaticals, attend conferences and meet with their peers in other organizations. Technological obsolescence is avoided through assignment of challenging projects and through a post-doctoral program that takes in two people per year. They also employ summer students.

## R&D Control

At the laboratory level, program managers in Washington conduct an internal review of programs across research centres and look at such items as publications, research proposals, and technology transfer activities.

At the program level, the quality of reports, products and new ideas are judged. Projects are evaluated against previously set out milestones to determine either positive or negative deviations from plan. Publications and technology transfer activities are also evaluated.

At the level of individual researchers, the number of publications in both refereed and non-refereed journals are counted; citation analysis is used to some degree but not very much.

Lab management is evaluated by looking at the quality of R&D output and personnel management vs their plan. They have considered having a program whereby subordinates evaluate their supervisors. They asked for information on AECL's Upward Feedback Program.

R&D projects are terminated prematurely if they are not meeting their objectives. i.e. not able to validate a hypothesis or lack of progress.

## Technology Transfer

The Bureau maintains an Office of Technology Transfer in Washington (approx. 6 people) and each research centre has a technology transfer officer. The Bureau has had a technology transfer program in place for 16 years.

Projects are reviewed from a technology transfer perspective to identify transferable technology. In addition, publications, briefings and exhibits are used by the Bureau to create industry awareness of promising research and to provide information on emerging technologies. One publication is "Technology News", a single sheet article that gives an overview on some technological development. People pre-register with the Bureau and indicate their areas of interest. If a Technology News brief is in an area of interest to a person, they are sent the brief. They presently have a list of 30,000 subscribers to their service. In 1989, 35 issues of Technology News were published. (See Appendix 2 for samples). Other publications include both learned journals and trade magazines.

In 1989, the Bureau exhibited at 34 major trade shows and conventions, and sponsored 10 technology transfer seminars and open industry briefings that focused on health and safety, advanced mining, and environmental compatibility technologies. One of these industry briefings was done as a satellite conference using the Galaxy 2 satellite. They also make use of technical films and videos to transfer information.

The most effective technology transfer activity mentioned is having their people out in the field talking to prospective recipients and conducting work under a cooperative agreement, such as field tests.

In the past, their inability to grant exclusive licenses to recipients hindered technology transfer, but no longer. A minor barrier to technology transfer is the lack of expertise among receiving companies. Their laboratory has little money for demonstration projects and needs joint ventures with companies to be able to demonstrate a technology; the companies provide the test site and some "in-kind" resource support.

They have the ability to temporarily transfer people to the receiving organization for as long as they are needed. Few private sector personnel come in to work in their labs as the R&D capability of the private sector has diminished so few could send in people and benefit.

They contract out less than 5% of their R&D activities. They contract out to universities where there is special facilities or people such as Carnegie-Melon University for control research on robotics.

Their researchers keep abreast of their fields through journals, conferences, contacts with peers around the world, and courses.

Technology transfer legislation deals with confidentiality of results and ownership of intellectual property. If a client pays for most of the project they can get exclusive ownership.

They have approximately 100 cooperative agreements with industry.

#### R&D Joint Ventures

They consider that the main mechanism for identifying potential joint ventures was through dialogue; they have people at the forefront of their fields and they are known to others. Prospective partners seek them out.

Funding arrangement are determined through negotiation.

Generally one organization, where most of the work is conducted, takes on the management role.

Ownership of the intellectual property depends on circumstances. i.e. who puts up the most resources.

# Commonwealth Scientific and Industrial Research Organization (CSIRO)

## Background

CSIRO is Australia's largest scientific research organization. It is equivalent to a Canadian crown corporation with about 70% of its funding coming from government appropriations. It employs approximately 7500 people of which 2500 are scientists and engineers.

In 1988 CSIRO underwent a major reorganization to, among other objectives, make it more relevant to the Australian economy. Its resources were regrouped into six Institutes that are closely associated with industry and the community. These Institutes are:

- Institute of Information and Communication Technologies
- Institute of Industrial Technologies
- Institute of Animal Production and Processing
- Institute of Plant Production and Processing
- Institute of Natural Resources and Environment
- Institute of Minerals, Energy and Construction

This review involved an interview with a senior official of the Institute of Minerals, Energy and Construction. This Institute consists of approximately 1100 people divided into six divisions: building, construction and engineering; exploration geoscience; geomechanics; mineral and process engineering; mineral products; and coal and fuel technology. This Institute accounts for approximately 17.1% of CSIRO's operating funds.

## R&D Planning

Appendix 3 is copy of a description of CSIRO's corporate planning activities.

The following are the results of the interview and give the perspective of the planning process from the point of view of an Institute.

Each of the Institute's divisions develop a five year rolling plan that includes both operational and strategic aspects. Headquarters develops a strategic overview and operational plan which is the sum of the divisional operational plans. They examine their budgets and what projects they want to undertake, and discuss with the Chief of CSIRO what the priorities are and what can be accomplished. The last three months of the year,

they review all of the divisions and discuss their five year plans and provide input to the CSIRO planning activity. Part of their planning activity is a determination of who, in industry, is striving for technological dominance. R&D intensity in the mineral industry is higher than in other areas of the Australian economy.

Chiefs and program managers of each division develop their five year plans, increasingly now using retreats, to look at strategic issues. The administration manager and all the program heads (5-6 people) go on these retreats.

Each of the divisions has a divisional advisory committee of about 10 people drawn mainly from industry, but also including representatives from government and academia. They meet once or twice a year to advise the division chief on the five year plan.

Just recently they have created an Institute level advisory committee consisting of very senior industrial people, such as managing directors of companies in Australia, as well as people from the Department of Finance. They held their first meeting in November, 1990. This committee will advise the Institute's director on their strategic view and comment on the operational management of the Institute.

Environmental concerns are not well represented on their committees. Representatives from the Dept. of Industry, Technology and Commerce, and the Dept. of Primary Industries and Energy are on some of the divisional advisory committees.

The Institute's thrust is very much toward delivery to industry, therefore they are very much focussed on strategic research. They see basic research as very necessary for the underpinning of their strategic research and applied research. There are always elements of basic research in any applied research program. The balance between basic/strategic research and development (which changes with time) is largely determined by the strategies of the director who believes very strongly in being very close to industry. i.e. to be focussed on delivery to their company clients. He also believes that there should be a strong component of basic research to underpin our work and that we must have world class research to be relevant to industry. All our research is strategic, but around 5-20% (depending on the area) can be considered more basic.

They conduct relatively little "pure" public good R&D. R&D for the public good is determined by a priority setting process and by their strategic plan. The balance between client specific and public good R&D reflects the director's views. He believes that they should have a very high proportion of clients' specific R&D. i.e. generic R&D work of interest to industry sectors such as exploration and mining.

## R&D Funding

The major source of funds for CSIRO comes from government appropriations. Their present budget is \$86 million of which \$63 million comes from government and the remainder from industry and other indirect government sources. Since 1988, they have been given a target of 30% of their budget that must come from other sources than direct government appropriations.

The government funding level is determined by a corporate priority setting process. They are responsible for four main subdivisions of the Australian socio-economy: mineral resources, energy resources, energy supply and construction. One factor used in setting their budgets is the ability of an industry to benefit from their R&D.

In their Institute, their salary to operating ratio is 65:35. Directors determine the allocation of budgets to the various divisions.

The services they provide on a charge basis are the same as they conduct from internal funds. They no longer separate out the source of funds; all funds are the same. They do some contract research for a client but their preferred mode is collaborative research with both parties bringing something to the project and sharing the resulting intellectual property. The bulk of the work they do for industry is not greatly different from what they do with their internal funds. The research they conduct with their own funds lays the groundwork for attracting industry money in a few years time. e.g. CSIRO funded projects in the aluminum area.

The requirement for conducting externally funded R&D (30% of their budget) has had a huge impact. Over the past three years their external funding has gone up 45%. It has made a difference in that most of their projects have an external sponsor thus their work is far more market driven today. It is still the same type of work because industry has moved along with them. They had a lot of difficulty in 1988/89 turning their divisions around. They believe that they should become stabilized in a couple of years. They were faced with the problem of now charging industry for information that they previously received for free. Companies are involved with their divisional advisory committees and so they feel they have some input to the planning process. They still get complaints from companies about their fees. Their charge rates, compared to other government and private sector labs, fall in about the middle. "Industry has to learn nothing comes for free anymore".

The Institute can retain 100% of the externally earned funds. Some of the other CSIRO Institutes charge their divisions a tax so that they can use this money for some strategic, non-sponsored research. Their Institute has a small fund of money (\$1 million) that is allocated back to their divisions in proportion to their private sector fees.

## Personnel Management

All six of their division chiefs have had R&D management training. They have an internal six week R&D management course. Two of their chiefs have attended the MIT course and two have gone to IMI. Program and project managers are all required to attend two week R&D management courses presented by CSIRO. Instructors are drawn from both inside and outside CSIRO.

Their merit promotion system strongly recognizes industrial achievement as well as research achievement. Each year people can put up cases for promotion; these are reviewed by the director and the six chiefs, and the chiefs argue for promotions for their people on a case-by-case basis. They have recently established a new reward structure which allows the awarding of temporary promotions. A person may get a double salary increment for a year that can amount to \$10-15 thousand. These temporary promotions might reward, for example, the delivery of a significant product to industry that is well received. They also have a system of CSIRO medals which people can win.

They also encourage their people to go after external rewards that are either Australian wide in nature or outside awards such as the R&D 100 sponsored by the American magazine Research and Development.

They have just established a dual promotion ladder with the top step on the research side paying \$100,000. at top end of the scale.

The division chiefs are responsible for the selection, etc. of projects. Researchers must prepare a case to the chief if they want to terminate or materially change the direction of their research project.

Conference attendance is subject to the availability of funds which the division chief determines. Most of their senior scientists go to overseas conferences, but they are very selective. Many of their visits are sponsored by companies. They make a lot of use of bilateral agreements with countries to sponsor travel.

Individual researchers can no longer financially benefit from patents or licences. They used to have a bonus scheme based on licences but they have scrapped it because it was too divisive and caused a lot of headaches.

There are libraries in each division to assist researchers keep up-to-date. "Our view is that we need to have the best science so obviously we will always want to make sure that there is a proportion in each division of what we would call leading science projects". That is very much determined by the division chief who puts forward projects with no external clients but involves excellent science. The chief will take that on board because he believes it is a showpiece for the division and is

needed to stimulate and challenge the scientists. There is no fixed policy regarding scientists doing personal interest research. Their scientists do believe that they need to do some personal research and that the organization is not allowing them to do it at a level they feel is satisfactory.

Technological obsolescence is of some concern. Some areas of the Institute come under criticism from industry for not being up with the times. They believe that by being in close contact with the client companies they will be able to keep up. They are open to scrutiny by people who are up-to-date and they rely on the mineral industry to point out where they might be deficient. For example, the Australian Mineral Industry Research Association is a good indicator of what industry is interested in and where the leading areas of research are located. It is represented on all of their advisory committees.

### R&D Control

The major factor used to evaluate R&D projects is service to the client. They look at quality of output such as publications or patents. They don't use citation analysis. They have contracted with private and public sector organizations to perform research evaluations for them using standard cost-benefit analysis.

At the individual R&D performer level, the division chief evaluates publications as it is part of the promotion process and the annual career development review.

Premature project termination occurs in about 10% of their projects. Projects are terminated when they are not succeeding, defined as:

- the project has not delivered as expected
- the researcher has been unable to get external sponsorship after working for a reasonable time
- external sponsor not happy

They will also cancel a project/program if they decide the research area is no longer of interest to them.

### Technology Transfer

They identify what their customers want and get them involved at the beginning. They work with them on developing the technology. i.e. technology participation rather than transfer.

Their approach is to form strategic alliances with major companies at all levels. Their project managers are in discussions with companies several times a week. Each division has its

client base that it services. Groups of researchers visit groups of companies to find out what they need. Companies visit their labs finding out what their capabilities are. They have MOU's with companies. They prefer to have individual project agreements.

The most important activity (to improve the probability of successful technology transfer) is getting their researchers out of the lab and into companies at the very first stage (i.e. when they have an idea for a project). "Not much point of them beaver- ing away at something companies don't want". Their technology transfer company SIROTECH provides them with assistance in negotiations.

The biggest technology transfer problem occurs when they go outside their mining company client base. If they develop, for example, a new instrument, that must be picked up by a manufacturing company and then sold to the mining industry, the mining companies will not support them and Australian manufacturing companies are quite weak. Mining companies prefer them to help the industry improve their processes and product development. They have worked successfully with one instrument manufacturer who has marketed product overseas and won a R&D 100 award.

The only minor barrier to technology transfer has been an "old guard" of researchers who don't want to change. Intellectual property issues have been all right although negotiations with companies is always tough.

CSIRO strongly encourages temporary transfers and has people in laboratories around Australia. The transfers are generally part of a project agreement although people can be seconded to industry. e.g. had a person at ICI for 18 months. People from company labs come to their labs as part of a project. They are charged a 30% overhead charge which the companies scream about.

Less than 1% of their research is contracted out (\$200,000.) and this is usually as part of an externally funded project. Recipients would be universities or other special CSIRO labs.

CSIRO does not publish research results if the client doesn't allow it. Ownership of intellectual property depends on who puts the most resources into the project. If the client pays the full cost of the project plus the Institute's profit, then the client has many more rights than if they just pay part of the costs. CSIRO prefers to own the property and get licence fees. "Ownership of intellectual property is a real pain; it has always been a bugbear of any agreement".

In the event of sequential or simultaneous requests for particular R&D work, the Institute would have different teams working on the same project and they wouldn't be allowed to talk to one another about the detail of their work. Individual researchers sign secrecy agreements. Scientists appear to be getting quite used to this situation. The Institute would still

charge a second client for previous done work as their is always some unique aspects to every project.

### Joint R&D Ventures

Potential joint ventures are identified through their contacts with industry.

Funding arrangement are determined through negotiations. It also depends on who is bringing what to the project.

There always has to be one project manager responsible and it is usually the CSIRO manager. If however, CSIRO is a minor player, the private sector will manage.

Ownership of the resulting intellectual property depends on what each brings to the project.

### Miscellaneous Comments

CSIRO, since 1988, operates more like a private company. The whole culture was changed and government tasked them with a 30% private sector funding target which they believe will take them four years to achieve. "1988 was a very gruesome year".

They have gone through a managed outplacement activity to get rid of researchers who could not change to the new style of doing research. They still want to get rid of more researchers in each division "who think they have a God-given right to taxpayers money to perform their science".

Since October, it is easier for CSIRO to fire people for reasons such as lack of funds to support their research or lack of interested in their field of research.

"If we had the restructuring without the external income target (30%) we would not be where we are today; and if we just had the external income target, we would have had to restructure to achieve it".

CSIRO is under some criticism by government departments as to what they do with the taxpayer's money; are they giving it away to companies?

The government's Bureau of Mineral Resources in Canberra has much more public good research. They have a budget of approximately \$50 million but an external income target of about \$500 thousand. They have a very different culture than that of CSIRO.

## Ontario Hydro

### Background

This organization conducts research into the generation and transmission of electrical energy. Areas of research include: expert systems, plastics/polymers, metals/alloys, ceramics, biotechnology, superconductivity and lasers. They employ approximately 3500 scientists and engineers.

### R&D Planning

Corporate planning gives the general direction of the lab program and internal knowledge of technical disciplines provides direction on what technologies to pursue.

Senior staff, managers and client groups through their participation in research panels are involved in the planning. In addition, information from other utilities is used.

Legislation (Bill 308) and the plans of other utilities, the Canadian Electrical Association (CEA), and the U.S. Electric Power Research Institute (EPRI) affect their R&D plans.

The level of basic research is restricted to no more than 10% of their effort; at present it is about 5%.

All of their R&D is thought to be in the area of the public good.

### R&D Funding

The major source of funds is from internal divisional clients and headquarters (OM&A). Ontario Hydro spends approximately \$185 million on R&D, of which about \$80 million is spent on in-house R&D and the bulk of the remainder is spent on joint projects through the CANDU Owners Group (COG) with AECL.

The funding level is determined by the needs of the organization for R&D, availability of funds and corporate budget constraints.

All services to clients are provided on a charge-back basis and do not differ from the R&D funded internally.

They cannot retain any of the funds earned from external clients.

### Personnel Management

They consider that most of their managers have received R&D management training at some time in their careers.

Significant technical achievements are recognized by the Corporate Technology Awards for innovations, and by the research division's annual award program (e.g. W.P. Dobson Award for significant technical achievements). They also have a W.H. Smith award to reward some activity that resulted in a financial payoff for the organization. There is also the Director's Award, of which several can be awarded per year to reward people who have done something beyond what was expected. Corporate awards involve financial awards which amount to approximately \$20,000. split among all the recipients. The division awards do not involve financial rewards.

They also have an idea suggestion program called TIPS (The Ideas People Suggest) which provides some recognition at the idea stage of a potential project.

They do encourage people to go after the R&D 100 awards.

They employ a dual promotion ladder with four rungs: two lower runs, and then senior and principal research scientist or engineer. The top two levels are paid on the Executive Salary Role scale.

The major encouragement of productivity is the possibility of working on more interesting projects.

The researchers have quite a bit of freedom to modify projects within the broad guidelines set down by the R&D strategy as given in the Business Plan.

Conference attendance is driven by both the need to learn, and by the need to interact with peers and test their work.

Researchers can benefit from patents and licences through their technology award program which pays for future benefits to the Corporation.

Technological obsolescence is prevented through staff taking short courses, attending conferences/seminars, and workshops, and being encouraged to publish. No R&D is done simply to develop and maintain capability; all R&D must have some other purpose. Researchers keep up-to-date through personal contacts, conferences and reading the literature.

### R&D Control

On a five year rolling year average, they look at those projects that have had a million dollar payback to see what they have cost in order to determine whether the laboratory has covered their own costs. (Winners List).

Factors used to evaluate quality/quantity at the project level are: implementation success or failure, and meeting pre-set quality, timeliness, and cost criteria. At the personal level a

varying set of criteria are used: quality, quantity, client interaction, keeping up to date, innovativeness of ideas/approach, etc. Somewhat different criteria are used in each lab section.

The lab management is judged against budget performance and the ability to meet the needs of their clients. This is evaluated during operational audits and discussions in the RAC, etc.

Termination of an R&D project will occur if:

- work of higher priority demands the resources
- scientist loses interest in project
- the need for the work disappears
- the project results are developed elsewhere

### Technology Transfer

Factors which have improved the transfer of technology are having greater interaction with clients and their early involvement; and obtaining a better understanding of their client's work environment and how they conduct their business.

Activities that have reduced technology transfer include trying to get the sole credit for something, and being unaware of the pressures on clients.

The major barriers to technology transfer have been the NIH (Not Invented Here) Syndrome, failure to win over clients, and trying to bludgeon them with their innovations.

Personnel can be transferred to a receiving organization but it is decided on a case-by-case basis.

They contract out very little R&D, but about \$3 million worth of "services".

Confidentiality of results and ownership of intellectual property on external R&D for clients is negotiated before the work starts. In most cases, the payer gets the property rights.

### R&D Joint Ventures

Joint ventures come about based on mutual interest of both parties, and their knowledge of the potential partners work or needs.

Funding arrangements are negotiated and the project managed by teams from all concerned. Intellectual property ownership is negotiated beforehand, if possible.

## **AECL Research**

### Background

AECL Research is Canada's main research organization conducting research into nuclear power reactor development, radiological protection, and nuclear waste management.

### R&D Planning

Their research program is determined by means of a "Program Evaluation Process (PEP)" which is held annually. (See Appendix 4.) People submit projects for funding in one of four categories (underlying research, generic support of new products and business; health and safety, current products; pure research; and site support services) and show how the end result meets the objectives of AECL Research. The executive management committee (EMC) judges the prospective projects.

The planning process is a top down/bottom up approach with as many people as possible being involved. They also have a small group of people (12-14) who look for new ideas for new small projects ("Unit 2000" group). This technology scanning group has people submit articles or newspaper items that have caught their eye in the last 3-4 months that might be a source of a new project. It is not being used as much now as in the past.

The major outside influence on their R&D plans is COG, the CANDU Owners Group. This is a group of utilities (New Brunswick Power, Hydro-Quebec, Ontario Hydro) who operate nuclear power reactors. They have major cost-shared programs with AECL.

In October, 1989, a seven-member Environmental Assessment Panel was appointed by the Federal Government to review AECL's nuclear waste disposal program.

AECL plans on establishing a peer review panel of eminent scientists and engineer (Research and Development Advisory Panel) from outside the firm to be an independent voice on the scope and appropriateness of their R&D programs.

The Executive Management Committee determines the balance between pure, strategic research and development. Underlying strategic basic research is driven by the need to know in order to advance a technology. At present, about 16-20% of their work is pure or basic research. They now have little discretionary R&D, most is now end-product, client oriented which is a major shock to old R&D people and managers.

The balance between client specific R&D and internal R&D is determined by how much R&D is jointly funded with COG.

## R&D Funding

Their budget for 1990 is approximately \$290 million of which the federal government provides \$140 million; the electrical utilities \$80 million, revenues from product/service sales 45 million and the remainder from miscellaneous sources.

The \$45 million external funding for charged services or products come from selling isotopes (to Nordion and Theratronics), conducting R&D contract work (same as internally funded R&D) and from their commercial centres that sell instrumentation and monitoring devices/services. (e.g. Sensys)

The requirement to increase their inflow of non-government funds was needed for their survival, but it hasn't changed the type of R&D they conduct very much. They conduct some research projects that are not nuclear in nature but they have the expertise to do them, such as analyzing space shuttle "O" ring seals. A lot of their people didn't like to do commercial work rather than research.

They can retain all commercial revenues but it simply compensates for the lowering of the federal government contribution.

## Personnel Management

They provide their people with general management training; possibly only 10% have received R&D management training. [During the mid-1970s, our company gave four R&D management courses to personnel in their Chalk River and Whiteshell laboratories.]

Internal rewards for significant R&D achievements include:

- "Discovery Award" for a new idea that has led to a new thrust; recipients receive money (<\$5,000.) and maybe dinner with the president, a silver tray and a pin
- Cash awards for a major contribution, above and beyond normal performance e.g. solving a major problem
- Smaller awards such as use of the company suite in Ottawa, or a dinner out locally

Researchers also obtain external recognition through their publications. AECL recently won one of the R&D 100 awards.

They have just recently revamped their internal reward program because their employees indicated that they wanted more and smaller rewards, rather than the present fewer, but larger rewards.

They have employed a dual promotion ladder since the beginning of AECL and finds it works well. A scientist can reach a

division managers level. They also have a "Research Emeritus" honorary title for retired scientists.

They have no special rewards to encourage productivity.

The researchers have a lot less freedom to select, modify etc. projects than they had in the past. With fewer dollars, the R&D projects are examined very carefully; they must involve good science and be linked closely to program thrusts.

There is an unwritten rule that a researcher can get to an North American conference once a year, and an international conference every three to four years. They do not follow the Treasury Board guidelines on conference travel. Managers have travel budgets and they must be selective on who goes to conferences. Researchers must obtain prior approval before submitting a paper to a conference; if a paper is approved for submission and is accepted by the conference then conference attendance is usually approved. Another way to get to a conference is to be on the organizing committee or be chairing a session. Conferences are considered to be useful in keeping up-to-date.

Prior to April 1, 1988, researchers were able to obtain royalties on their patents, but now they just get \$500. on filing, and another \$500. when patent awarded. They dropped the royalty payment because most patents that they file are defensive and are not licenced.

Technological obsolescence is staved off through conference attendance, reading the literature, having a network of contacts around the world, sending people on sabbaticals and bringing in attached staff from other organizations. There is an annual review (peer review) of programs that tries to ensure that they are in the forefront of their technical areas. They also watch whether researcher's papers are not accepted for publication. Some researchers have asked for some free time for personal research projects.

### R&D Control

At the lab level they have recorded the total amount of money spend on R&D and compared it to the benefits of nuclear power electrical generation (cost-benefit analysis) versus what it would have cost using alternate technologies. At the project level, there are key targets set out in the business plan that have to be met on a quarterly basis. Researchers need to meet 70% of the targets.

At the individual level, the number and quality of internal reports or solving a technical problem is used to evaluate performance on a commercial project while in the case of more pure science projects, the number and quality of papers published is evaluated.

AECL uses a system, developed internally in 1985, called "Upward Feedback" to evaluate their managers. Each employee completes a questionnaire (see Appendix 5) about their supervisor and the findings are tabulated by an external organization. The results are given to the supervisor who then must discuss the results with his or her staff. After this discussion, the manager must develop a plan to improve identified managerial weaknesses and discuss this plan with his or her supervisor. They have run this exercise twice already and are about to have a third. It includes all managers, except those who have less than three people. It has had a participation rate of greater than 80%.

In addition, AECL has a list of "Executive Criteria" that is used to judge the performance of managers (See Appendix 6).

### Technology Transfer

They have eleven business centres attached to the laboratories that market their existing expertise using existing equipment. They use sophisticated market analysis and research to identify potential technology transfer opportunities. They also give talks to Canada's Science Counsellors and trade commissioners.

Customers sometimes approach AECL on big-ticket items.

They have found the following supportive of technology transfer:

- Having people from the recipient organization spend 12-18 months in their laboratories
- writing technology transfer agreements that benefit both sides
- having knowledgeable people who can draft a fair contract and who understand technology transfer

Factors that inhibited the successful transfer of technology are:

- transferring technology by reports only
- giving away too much during negotiations; being naive
- publishing information about technology that could be retained as a trade secret

Major barriers that have impeded technology transfer are:

- being overoptimistic about the technical abilities of the recipient organization (country) to utilize the technology
- lack of time and resources to properly transfer the technology
- losing technology transfer experts through retirements
- language barriers

AECL will send out their people as instructors for up to a year.

AECL does contract out some R&D work to organizations that have special expertise (e.g. Columbia University - hydraulics; Westinghouse - thermo hydraulics).

Confidentiality of research conducted for a client depends on who pays the most and AECL's interest in the results.

Appendix 7 outlines AECL's general principles for guiding technology transfer.

#### R&D Joint Ventures

In some cases, other organizations approach them because their facilities and capabilities are well known. They also actively market their capability.

In some areas such as with the small SLOPOKE reactors, they need partners to continue the research.

Funding arrangements are determined through negotiations.

AECL usually takes the lead in managing the joint venture.

Ownership of any intellectual property tends to be shared. It depends on how much background information AECL must provide.

#### Miscellaneous

One interviewee mentioned that at the Oakridge Laboratories operated by Martin Marietta in Oakridge, Tennessee that they have reward system to make use of royalties from licences. The named inventor(s) get 15% of the royalties, with the remaining fees pooled. From the pool, 5% goes to inventors of technology that is not licenced (classified technology), and 5% to the people who supported the technology development but are not named as inventors. The balance is used to fund the development of new technology that is just outside the mainstream business of the labs.

## Sheritt Gordon Limited

### Background

The research centre employs approximately 132 people in research and 70 in engineering.

They conduct research into metals, alloys and composites, production processes, paints, coatings and sealants.

### R&D Planning

The laboratory operates within a five year strategic plan that is updated annually. It provides them with an opportunity to be proactive and respond to changing marketing conditions or emerging technologies. The Director of the laboratory reports to a V.P. Technology.

There is an interaction down through the various management levels. Sheritt has people who are specialists in market intelligence who conduct marketing studies. Interactive committees are formed in the early stage of the review process to take account of market developments and business opportunities. " Researchers are involved in the planning process because there has to be a certain amount of technology push, as well as market pull".

Aspects of environmental control are on the agenda of any project being planned, as well as recycleability.

The laboratory serves the business units such as aerospace materials. People from the business units sit on their planning committees, as they sit on theirs, where appropriate.

Market opportunities have an impact on our R&D plans. Identified market niche (e.g. advanced industrial materials) that they can serve based on their position in the market will be targeted (e.g. Canadian one dollar coin).

Sheritt doesn't tie the hands of their researchers; they allow them to conduct strategic basic research to a certain extent. They conduct approximately 10% strategic basic research. The balance between basic and developmental research is determined by the job to be done.

### R&D Funding

Their major source of funding is Sheritt Gordon. Their total budget is \$12 million, of which \$4 million is truly research, the rest quality assurance and testing.

Their research funding level is determined by what they need to do to meet the needs of strategic programs. They hope to get new programs in the area of plastics and polymers.

They do some research in support of the licencing activities of their External Technology Group. They may spot an opportunity for a metal extraction process for which they have not yet developed a process. The laboratory will then develop such a process for licencing. (e.g. in the rare earths)

The can retain 100% of the externally earned funds. "The entire cost of the research operation has been paid for from licence fees earned".

### Personnel Management

All of their managers have been to Queen's or Western Ontario to attend well structured management courses of three weeks or more duration, but not R&D management courses. They have made use of Bob Cooper's New Product Development Course. They are an active member of the Canadian Research Management Association.

Significant R&D achievements are recognized through salary increases. Their whole salary structure is performance related. There is no internal reward system that gives out cash or prizes.

They encourage their people to publish in the traditional journals and literature, and to obtain patents. They are starting to display patents on one of their walls. Their people do win awards from organizations such as the Canadian Institute of Mining and Metallurgy, and the Canadian Institute of Chemistry.

Sheritt has always had a dual promotion ladder system. The top rung is called a Principal Scientist (they have two at the moment). They have never failed to recognize the scientists' contributions. They have had no trouble in operating the ladder.

"The professional growth that a person can see ahead is the motivation [to encourage productivity]. He or she will publish papers and be recognized by peers, attend conferences and make presentations; that in itself is recognition and reward, and job satisfaction".

Researchers do have some freedom, depending on the level of the researcher, to select projects, or change direction if needed to meet objectives. In the case of termination, researchers would prepare a short memo to the Director and senior management recommending termination. "Researcher must have the freedom to think and some freedom to act".

The purpose of attending a conference must be associated with the responsibility of the individual. The person is going either because of a specific technical focus of the conference in his/her area of activity, or he/she is going to look for new areas of research that we might enter and wants to see what other people are doing (e.g. electronic materials). Conference attendance is also seen as part of professional development and an opportunity to receive recognition from peers. "Need to get our

people out to meet their peers".

Individual researchers cannot benefit financially from patents or licences; they are all assigned to the company.

Several actions are taken to maintain the skills of their researchers and prevent technological obsolescence. They are currently recruiting and bringing in new blood, some straight from university at the Ph.D. level. These new people are familiar with the latest analytical techniques. They have training programs and send people on refresher courses as well as back to university for graduate degrees. They expect researchers to work on their own "skunk works" projects for up to 10% of their time. "We recognize that some of the best innovations come from that activity".

They also cycle their researchers out into the plant for a year. They plan to have some of their people lecture at university and have professors on sabbatical and graduate students work in their facilities. They have visiting professors come during summer months. They have an active program of seminars with visitors coming to their facilities to give talks, and their people going to seminars sponsored by the Alberta Research Council.

The Director believes that the scientific ladder definitely permits the incumbent to stay abreast of the state-of-the-art in their field. It gives them the time to use library resources (internal, CISTI, CANSDI, etc.) and meet peers. They utilize their senior scientists as valuable resources.

### R&D Control

They prepare a regular monthly progress report where technical achievements are written up very thoroughly.

R&D projects are monitored through lab reports. Project progress is compared to original objectives.

Individual performance is evaluated during performance appraisals. Internal reports are rated much more highly than published papers. The researcher is measured against their job description and the objectives of the job.

They do not have any direct process to measure the quality of lab management. "The performance of the laboratory would reflect the quality [of management]". They have, from time to time, solicited personal input from researchers about factors that would improve their work situation, or factors that are hindering their progress.

R&D projects are terminated prematurely if objectives are not being achieved and are most likely not going to be achieved, or the market for the end product/process changes.

## Technology Transfer

Technology to be transferred tends to be mineral extractive technology. Many of the requests for this technology come to their door because of their reputation built up over the past 30 years. Internal technology transfer is straightforward (the present manager of production used to be in research). In many cases, the engineer and technicians transfer into production with the technology; some temporarily, some permanently.

Factors or activities that improve the probability of successful technology transfer include:

- temporary transfer of people
- a production staff that is very knowledgeable about technology; all have good technical training and are very capable of receiving the new technology
- very receptive group that needs the new technology because of a market opportunity
- technical support of new technology after transfer

The probability of successful technology transfer has been reduced when, "on occasion we have let the technology go too soon and an unidentified parameter in the process goes out of control or beyond specification". This gives production people problems.

When they were transferring technology to the Philippines, they sent out 13 families for three years, along with some school teachers to look after the children.

They contract out approximately 5% of their R&D to universities such as Alberta, U.B.C., McGill, and Queens where there are specialized people and equipment. Their percentage of contract research is growing as they move into new areas such as polymers, or ceramics where they don't want to reinvent the technology.

They own all the technology and just licence it to users.

## Joint R&D Ventures

They are involved with the WESTAIM program that is designed to encourage the use of advanced industrial materials in firms in Western Canada. Established in April, 1990, the program is an agreement between the federal and provincial governments (I,S&T, ARC, NRC) involving the expenditure of \$140 million over five years.

They look for partners who can bring new technology, cash or market position to Sheritt and both can benefit. These alliances can develop from the normal supplier-customer relationship.

WESTAIM has a program review committee with two representatives each from the federal and provincial governments, and three from Sheritt. Sheritt is the operational manager of the program.

All intellectual property normally belongs to WESTAIM, which is a separate legal entity, wholly owned by Sheritt. If a client puts up the majority of the resources they can get the intellectual property rights.

Miscellaneous Comments"

"We try to give our marketing people an unfair advantage based on technology".

## Noranda Technical Centre

### Background

The Noranda Technical Centre conducts research in the areas of opto-electronics, artificial intelligence, CAD/CAM, robotics, metals, alloys, environmental analysis and treatment, and metal production processes.

They employ approximately 200 full-time staff of whom 120 are researchers.

### R&D Planning

Annually in the Winter and Spring, Noranda develops a strategic plan where they look at what the strategic technologies are for the company based on their business needs. They publish the strategic plan at the end of Spring. Strategy is top-down while research proposals are bottom-up. They consider research proposals from the point of view of: potential return, is the proposal new, will it provide a competitive advantage, is it new technology and what is the probability of success, both technical and commercial.

Senior management at the Technical Centre and senior people in Noranda (operations) are involved in developing the plan. Plans are reviewed with operations to make sure that they are comfortable with them. The plan is communicated to the people at the bottom in hopes that they will put forward proposals for new programs based on the top-down direction.

No outside elements have any major impact on the R&D plans.

There is no formula used in deciding the balance between basic/strategic research and development. They look at the opportunities as they come up. Company does not like to have a fixed percentage devoted to strategic research. At the present time exploratory type research accounts for less than 5% of their research effort while applied more strategic research accounts for 25-30%. Interviewee believes that industry should do more longer range research.

### R&D Funding

The major source of funds is as follows: 70% from operations, 25% from the corporate office, and 5% from government or other sources. Their funding level is \$30 million.

About 5% of their work is funded externally and differs little from regular work. It has to be useful to Noranda. They can retain 100% of externally generated funds.

## Personnel Management

About 60% of their managers have been on R&D type management courses. They have had courses especially designed for them by Peter Richardson and John Gordon (Queen's) on the topic of strategic management (two week course). They also send their people on Peter Richardson's course that is given in EMR.

The interviewee did not believe that they were recognizing R&D achievements well enough. "We need help here, we are not doing enough". They have patent awards that include money and a plaque, and they have a bonus system that can reward people for significant achievements (can be a large amount of money, five figures). Although aware of the R&D 100 awards, they have not been encouraging staff to apply because they were not aware that Canadians were eligible.

They established a dual ladder in 1989. It has three rungs: research scientist, senior scientist and principal scientist. They totally ignore titles in determining compensation. They expect people to move back and forth from one ladder to another and work their way up that way.

Their compensation system and bonus system is each based on performance and everybody has an opportunity to get merit increases.

The researchers are free to recommend anything at any time, in terms of project selection, change, or termination and their recommendations are usually accepted. "I expect the researchers to work within the system, but the system is fairly loose. The researcher must develop a case or rationale to support recommendations for change".

Noranda has no formula or policy concerning conference attendance. Researchers attend conferences where they think they will get benefits, either from training or contacts. Noranda encourages people to give papers, but they don't require it. Most conference attendance is part of trying to achieve some technical objective, and therefore, it would be covered by a project budget. Overhead budgets would be used if a conference assisted in moving Noranda into a new area.

Noranda has a patent award of \$100. on application, and another \$100. and a plaque on issuing. They have not had any spin-off of technology to an employee.

Noranda has a policy of allowing people to obtain and keep up with the skills they want, partly on company time through projects, conferences, etc. and partly on their own personal time. "People won't stay here or get financial rewards if they are technologically obsolete". They do not set up R&D projects just to keep people up in their skills; they expect people to spend some of their time on personal projects without any formal policy being in place (except that project must be of interest to

the company). They have a Discretionary Fund that is used to support new ideas and to encourage people to come up with new ideas. This is relatively hassle-free funding for the researcher to support the first few steps of a project.

Their scientists keep up-to-date by reading, going to conferences, working with other companies and peers, and working on joint projects with competitors in areas such as environmental control.

### R&D Control

At the program level, they have various steering committees from operations that monitor and approve their various programs.

At the project level, each project has well documented objectives and a timetable for delivery, and a budget that must be met.

Each person has a list of objectives for the year that are tied to the project objectives. They negotiate those objectives with their manager and are measured against them. Researchers are evaluated on what they did, their ability to work in a team, their communications skills, their technical ability (e.g., are they keeping up), their leadership ability, creativity, etc.

Lab management is judged on whether they are meeting their objectives. These might be, in addition to technical objectives, a recruiting objective or a downsizing objective. They have decided not to survey their researchers on lab management quality. "I want the managers evaluated based on my evaluation and my direction as opposed to the things that make the staff happy which might be different".

An R&D project will be terminated if there is not a fit between technical and company objectives.

### Technology Transfer

The interviewee believes that Noranda is very good at internal technology transfer. The lab usually (90% of time) has to sell an R&D project to operations before it is started.

The following factors have improved technology transfer:

- strongly encourage people to transfer from lab to operations, and from operations to lab
- researchers spend a lot of time onsite in operations
- direct contact is very important
- provide training on new technologies

- virtually unlimited travel to operations
- very good coupling between lab and operations

The probability of successful technology transfer is reduced when the lab develops something that operations can't handle right away. Sometimes resources in operations (dollars and technical human resources) don't allow them to assimilate the new technologies as fast as the laboratory would like.

There are a lot of temporary transfers of researchers to operations; they encourage them to stay. "One of our roles is to develop technical talent for the operations".

They contract out \$4 million (out of \$30 million) to other companies, universities or government labs when they have facilities and expertise Noranda needs. In the case of universities, they try to help them train the talent they will require later on. Sometimes people from universities or other companies work in their lab.

The Golden Rule applies to ownership of intellectual property that results from conducting R&D for an external client.

#### Joint R&D Ventures

Potential joint ventures tend to be projects that are bigger or longer range than they would like to do on their own. e.g. mine automation projects or common industry problems such as environmental control.

Funding arrangements are usually fairly equitable; equal partnership.

Usually form a committee with people from both groups represented to manage the project.

Since most of these joint ventures are an equal partnership, the intellectual property is usually jointly held with everybody getting the same rights to it.

#### Miscellaneous

Industry can do research much more efficiently and get it into use faster than government. The government is not capable of deciding what are the most important problems to work on for eventual use by industry.

## **Synchrude Canada Limited**

### Background

The laboratory of Synchrude Canada supports the oil shale mining and extraction activities of the company. The laboratory employs approximately 130 people in research and 60 in development.

### R&D Planning

The R&D program is focussed on solving operational problems in the mining and extraction of oil from oil shale and in exploiting opportunities for technical improvements. The R&D program is tied to the strategic direction of the company. About one-third of the R&D program is initiated directly by plant operating problems and the rest by the need for improvements in the plant's operation (e.g. reducing costs).

Senior executives in the laboratory and the company are involved in the planning with operations identifying the technical problems to be addressed. Most of the direction setting is done within R&D itself.

Environmental issues play a role in the setting the R&D plans.

The balance between basic/strategic research and development is arbitrary; all the pressure is to do development work. They need to work hard to do any basic research as the pull from the plant is quite great. i.e. to solve day-to-day technical problems. About 10% of their work can be called strategic research, the rest is development. It is hard to keep the scientists, themselves, on the strategic work because of pressures from the plant.

### R&D Funding

The only source of funding for the lab is the company. They are given a single appropriation each year. Their R&D budget is approximately \$20 million and is determined mainly by the need to have a continuity of effort. They have been able to show that R&D has been cost-effective (e.g. cost savings and improved efficiencies) to the company.

The laboratory does not conduct any R&D for outsiders.

### Personnel Management

Most of the R&D managers have had some general management training, but few have had any explicit R&D management training.

The only recognition for an R&D achievement is having a project or solution implemented in the field. This leads to an emphasis on short term research. There are no in-house prizes and although they recognize patents there are no awards for them. They used to give a financial reward but dropped it. They have not gone after R&D 100 awards.

They hold a seminar series in which their people can present the results of their work and this is considered a source of satisfaction to their research staff.

They have had a technical ladder in place since 1982 but it is not working all that well. Some of the problems they have encountered are using the technical ladder as a dumping ground for failed managers and having difficulty in defining the roles between the technical and management ladder. The technical ladder is utilized throughout the whole company, not just in R&D.

Motivation to encourage productivity comes through the job itself; people meet the plant person with a technical problem and try to solve it. Motivation comes from knowing you can make a significant impact on the operation and meeting a satisfied customer.

Researchers have little freedom to select or modify projects; work is very narrowly directed. Projects must be aimed at plant requirements. It is hard to terminate a project unless there is a better project (to solve the problem) in the wings. Changing research direction is always painful.

Each researcher is supposed to get to one conference a year (U.S. or Canada) but it does not always work out that way. Politics plays a role in conference attendance in that when oil prices are low, conference attendance is lowered to keep a low profile, especially overseas conferences.

Individual researchers cannot benefit financially from their patents.

They are having some difficulty in maintaining the skills of the researchers as they have to cover a broad range of technologies. Groups are often below critical mass. Changing directions is hard. They have in-house tailored courses (2 days/week) from the University of Alberta and they try to keep in contact with the rest of the world. "We have a real danger of building a Not-Invented-Here Syndrome". They have graduate students and post-doctoral student working in their lab. They also have visiting professors for 6-8 months, especially when they are trying to change a research direction. They have not found guest speakers very successful as their talks tend to be superficial. They are trying to set up some joint research projects.

## R&D Control

The output of the laboratory is measured in terms of their impact on the plant operation; how much money have they saved operations.

R&D projects and individual performers are judged as to whether they have solved an operational problem. They do not use external papers published as a criterion. They use internal reports to some extent but application of the results in the field are more important. In the area of basic or strategic research they do not have good measures. They are in the process of moving away from rewarding people for just what they accomplish to adding in a significant component looking at how it was accomplished. "Our former single minded approach to accomplishment actively discouraged people from helping each other. Our working environment was too competitive. e.g. One part of a lab wouldn't share needed information to solve a problem with another part of the laboratory".

Lab management is judged by the same criteria as is used in general line supervision in the plant; not a good system for R&D.

R&D projects are terminated if they are not and are not expected to answer the technical question posed or produce the return envisioned.

## Technology Transfer

The operations side always initiates the R&D projects thus all technology transfer is internal to the plant. They have had examples of both successful and unsuccessful transfer.

The interchange of people between the plant and the lab have improved the probability of technology transfer. They use teams from both the technology producer and receiver units. They have found that the early identification of a customer has enhanced technology transfer.

Technology transfer has been reduced when they have tried to transfer technology via documents only. Problems with transfer to the plant can occur if the person (customer) who agreed with the need for the technology leaves. Another major barrier to technology transfer is the reluctance of people in Edmonton to go to Fort McMurray. They move people back and forth quite a bit.

At the moment only about 10% of their activity is contracted out to firms that have specific expertise. They plan to increase their contracting to universities or government labs in order to grow some needed expertise in these laboratories locally and build bridges with universities.

## Joint R&D Ventures

They look for a partner when a project to be undertaken is too large, in an unfamiliar area and they don't have the needed capability. They also utilized joint projects when they want to quickly catch up with a technical area. Environmental projects are a natural for joint ventures.

Funding arrangements are negotiated individually; there is no fixed formula. One group manages the project, and it is usually them. Can't manage by committee.

They try to keep any joint project in a pre-competitive area so everyone shares the intellectual property. Projects with, for example, AOSTRA, has them obtaining the right to use the resulting technology.

## REVIEW AND SUMMARY OF FINDINGS

### R&D Planning

The R&D planning process in these organizations appears to be very closely tied to their business objectives. The setting of the strategic direction for the laboratories' programs is done at a senior level involving both R&D staff and senior staff from the business or operational side of the organization. Actual project proposals are initiated by the researchers themselves in the light of their strategic plan.

Several of the organizations made use of outside industrial advisory committees to formulate their plans while others such as AECL and Ontario Hydro appeared to have active participation of their direct clients.

With the exception of the U.S. Bureau of Mines, the balance between basic/strategic basic research and more applied work appears to be driven directly by the need to know in order to advance technology. The private sector organizations allocated between 5-10% of their R&D budgets to basic research while the publicly supported laboratories allocated 10-25%. The balance in the U.S. Bureau of Mines appears to be determined more by government (White House) policy.

Both the U.S. Bureau of Mines and CSIRO tend to work on projects that will benefit groups of firms rather than just a single firm.

### R&D Funding

The "government" research laboratories get most of their funds through government appropriations. There is, however, pressure on them to obtain an increasing amount of their funding from the private sector through contract work or joint projects. CSIRO, for example, must obtain 30% of its funds from other than direct government appropriations. In general, the public laboratories are able to retain 100% of any funds earned, less a headquarters service charge.

The services that "government" laboratories contract out do not differ significantly from the R&D they conduct financed by government. The exception to this is AECL which does conduct some non-nuclear research for clients based on expertise developed while working on internal nuclear research.

In the private sector the laboratories are almost completely dependent on their parent companies for their funds. They do very little R&D for outside clients. They can retain 100% of the externally earned fees.

R&D for external clients differs little from internally funded R&D.

## Personnel Management

CSIRO, Ontario Hydro and Noranda reported that many if not all of their managers have attended management courses specific to the R&D setting. The others reported that their supervisors/managers had been on general management courses.

The "government" laboratories had specific internal award programs to reward significant achievements in innovation, publications and technology transfer, in addition to normal promotion rewards. CSIRO has a system of awarding temporary promotions to recognize achievement in a particular year. The private sector laboratories reported greater reliance on their normal salary promotion system without any other form of recognition.

Several interviewees reported that they encourage their staff to go after external awards such as those provided by professional associations or magazines. The magazine award mentioned most often was the R&D 100 sponsored by the American magazine "Research and Development".

R&D management literature points out that just confining rewards to salary increases is not particularly motivating for scientists and engineers.

All respondents reported employing a dual promotion ladder for their scientist and engineers. Dual ladders have been found to be an excellent vehicle for attracting and retaining high performing scientists or engineers who have either no aptitude or interest in pursuing a career in management.

Several respondents believed that the greatest stimulus to R&D productivity was the work itself, and the opportunity to gain recognition from either clients or the professional community.

With one exception, interviewees reported that their researchers had a fair degree of freedom to select and modify their R&D projects, as long as their changes were covered by the business plan of the organization.

Conference attendance was based on the following criteria:

- availability of funds
- relevance of the conference to the person's work
- who else might be at the conference that you want your staff to meet
- gaining recognition through the presentation of papers
- whether attendance would assist in keeping up-to-date
- whether attendance would assist in moving the lab into a new scientific or technological area

CSIRO reported making use of private sector funding to assist their personnel attend overseas conferences.

U.S. Federal Government scientists and engineers, by legislation, can receive up to 15% of the royalties from licencing fees on work they have patented, with the balance retained by the research organization.

Several organizations reported that they pay their staff a cash bonus on filing, and another cash bonus on receiving the patent. Royalty payments have the drawback in that they are based on licence fees and many times patents are taken out as a defensive measure, with no intent to licence.

The laboratories used a mixture of approaches to prevent technological obsolescence among their staff. These included:

- encouraging staff to take or give university courses/seminars
- offering sabbatical leaves
- conference attendance to meet peers
- assignment of challenging projects that force researcher to keep up-to-date in order to solve the problem
- operating a post-doctoral and summer student program that brings in fresh people with new ideas, etc.
- providing libraries in each research division
- allowing researchers to do some personal interest research
- encouraging staff to publish
- bringing in attached staff from other organizations or working with colleagues in other organizations on joint projects
- rotating technical staff into the operations side of the business for a year

AECL reported that they also have an annual peer review of the programs to make sure they are on the frontier of their fields.

Several interviewees mentioned that they have to work hard to maintain their staff's technical expertise.

## R&D Control

Factors reported used to determine the quality and quantity of output at the laboratory level are:

- quality of publications/patents
- quality of research proposals
- effectiveness of technology transfer activities
- quality of service to clients
- cost-benefit analysis of lab outputs versus cost of laboratory operations

At the program or project level the factors used to determine quality or quantity of output are:

- quality of internal reports, products and new ideas
- degree to which projects are meeting previously determined objectives or milestones in terms of timeliness and cost
- effectiveness of technology transfer activities (i.e. implementation of research results)

Individual R&D performers are judged based on:

- number of publications in refereed and non-refereed journals
- innovativeness of their ideas and research approaches (i.e. degree of creativity)
- the degree to which they are up-to-date in their field
- the number and quality of internal reports
- their ability to solve technical problems
- the degree to which they have achieved the objectives agreed to at the beginning of the reporting cycle
- their ability to work in a team
- their communication skills
- their leadership abilities

In general, the lab management is judged on basis of whether the laboratory is meeting the needs of the organization and or clients. Only AECL Research reported using an explicit mechanism to determine the quality of laboratory management (i.e. Upward Feedback)

Factors taken into account when deciding on the early termination of an R&D project are:

- whether projects are meeting their objectives, or are likely to achieve their objectives within the cost and time frame permitted
- whether a researcher has been able to get an external sponsor for the work
- external sponsor or partner unhappy with the project
- level of organizational interest in the project
- the existence of higher priority projects that require the resources
- the level of interest of the researcher in the project
- whether the need for the project is still valid (i.e. the market for the end project/process changes)
- whether project results have been developed elsewhere
- whether the project's technical objectives are still in line with the organization's business objectives

### Technology Transfer

In the case of the private sector firms, most of the technology transfer activities are within their own organization and many of the projects are initiated by clients in the operations side of the firm.

CSIRO, AECL and the U.S. Bureau of Mines have active offices whose job it is to transfer technology developed in their laboratories.

Interviewees reported that the activity that had the greatest impact on improving the probability of successful technology transfer was getting the researchers out of the lab and in direct contact with the potential technology recipients, as early as possible. Several of the respondents reported that they preferred to have the recipients work with their researchers, in a cooperative arrangement, as early as possible in the life of the R&D project. Other activities or situations reported to improve the probability of successful technology transfer are:

- providing initial information on research projects through newsletter type publications to an interested client base
- exhibiting technology at trade shows and conventions
- sponsoring technology transfer seminars and industry briefings in person and via satellite link-up
- early identification of the potential recipient
- having a good understanding of the client's work environment and how they conduct their business
- having people from the recipient organization spending time in the technology developer's laboratory before transfer
- temporary transfer of developers to recipient organization to learn about their operations and problems
- writing technology transfer agreements that benefit both sides
- recipient organization/group having people knowledgeable about technology
- having a very receptive group that needs the new technology
- providing training to handle the new technology during the transfer and technical support after the transfer
- having adequate travel budgets so that researchers can visit the recipient as frequently as necessary

Activities or situations which were reported as lowering the probability of, or being barriers to successful technology transfer are:

- lack of technical expertise in the potential recipient organizations
- developing a technology outside the direct interest of the clients
- having researchers who are reluctant to visit with, or work with external clients
- trying to obtain sole credit for the development of a technology

- being unaware of the pressures on the technology recipient
- trying to transfer technology by reports only
- giving away too much during technology transfer negotiations
- publishing information about technology that could be retained as a trade secret
- transferring the technology prematurely before it is well understood
- lack of resources (human and physical) to assimilate the new technology as quickly as might be possible
- the potential recipient organization having a NIH (Not-Invented-Here) attitude to outside technology
- being overoptimistic about the recipient's ability to utilize the technology
- insufficient resources and time to properly transfer the technology
- not having people who are knowledgeable about technology transfer
- language barriers, especially in the case of international technology transfer

The private sector firms emphasized the two-way flow of personnel between the research laboratory and the operations side of the firm as increasing the probability of effective technology transfer.

All the respondents reported that they allowed their researchers to temporarily transfer to the technology recipient's organization as part of the technology transfer process. A few private sector respondents mentioned that they encourage people to permanently move to the recipients location as they see their laboratory as a training ground for the operations side of their business.

#### Joint R&D Ventures

Potential joint R&D project partners are identified through their external contacts with colleagues and customers. Several lab interviewees mentioned that potential partners have approached them because of their world reputation.

Joint R&D ventures appear to involve R&D projects of large size, in areas unfamiliar to one of the partners, or of general interest to the industry and of a pre-competitive nature such as environmental projects.

Funding arrangements are determined by negotiation with the partner(s).

Generally one of the partners who is either doing most of the work, or whose facilities are being used, manages the project.

Ownership of the resulting intellectual property is also subject to negotiation but appears to be a function of who puts up the most resources.

## **CONCLUSION**

This review of both public and private sector laboratories has shown that while differences in their operations exist, especially in the funding area, they are becoming more alike as the pressures on the public laboratories to be more financially self-sufficient increase.

Interaction between laboratory personnel and their external/internal clients or customers appears to be a major factor in determining the laboratories success in both keeping abreast in their fields, be aware of their client's technical problems and in transferring technology to potential recipients. This would suggest that travel/conference funds for scientists and engineers in federal government laboratories should be generous.

The most interesting management technique noted during this brief survey of R&D management practices was the "Upward Feedback" program of AECL Research which is designed to improve the overall management of their laboratories. This is a management technique that EMR might want to look into for possible adoption.