THE HERZBERG INSTITUTE OF ASTROPHYSICS

A PLAN FOR 1989/90 THROUGH 1991/92

SUBMITTED TO THE NRC MANAGEMENT COMMITTEE

FOR THE ANNUAL PROGRAMME REVIEW

Respectfully submitted this seventeenth day of February, the year of our Lord
Nineteen Hundred and Eighty-nine

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THE HERZBERG INSTITUTE OF ASTROPHYSICS

Plans for 1989/90 through 1991/92

Director: D.C. Morton Assistant Director: B.H. Andrew

PREAMBLE

The Herzberg Institute of Astrophysics was started as an NRC division in 1975 by combining the Space Physics and Spectroscopy Sections from Physics with the Planetary Sciences Section, the Radio Astronomy Section, the Algonquin Radio Observatory, the Dominion Astrophysical Observatory and the Dominion Radio Astrophyical Observatory from Electrical Engineering. (Both the DAO and DRAO had come into the Division of Electrical Engineering from the Department of Energy, Mines and Resources in 1970.) The High Energy Physics Section was transferred from Physics in 1987.

There are now five research fields in which the HIA is involved - optical astronomy, radio astronomy, solar system physics, molecular spectroscopy, and high energy physics.

Nowadays, most of the research of concern to HIA requires large facilities and teams of scientists that cannot be supplied by a single Canadian university. Furthermore, to study a particular phenomenon, a scientist often requires a variety of measurements covering wide ranges of particle energies and/or frequencies in the electromagnetic spectrum. Collaborative projects and the use of facilities in other countries are now common practice in astrophysics, space physics, and high energy physics.

In response to its objectives the HIA is providing Canadian scientists with the facilities, infrastructure and expertise to work at the frontiers of research, including participation in leading international projects. The laboratory and administrative infrastructure of NRC make the operation of facilities, both national and international, a most appropriate role for the Council. The facilities are open on a competitive basis to all Canadian researchers, and to foreign scientists as well, thus ensuring Canadian access to foreign facilities which complement our own.

With such a mandate to provide expertise and facilities for Canadian science, it is imperative that HIA has first-class scientists and supporting technical staff. We must maintain our reputation as research leaders to have the confidence of the people we are trying to help, and the international groups with whom we wish to collaborate. Furthermore, to be familiar with the latest techniques and to keep our facilities competitive, we ourselves must use both our own and other facilities for front-line science.

As is the normal practice worldwide, NRC does not levy user fees for its facilities. The work usually has no immediate commercial value and charges to university users would only result in a transfer of funds from NSERC to NRC. Moreover, Canadian scientists benefit immensely from being able to use facilities in other countries on the same basis.

STRATEGIC OBJECTIVES

1. Within the domain of NRC's responsibilities, to support the operation of National Scientific Facilities for the benefit of the Canadian scientific community, and

2. As a complement to the support of National Scientific Facilities, to maintain a core of excellence in fields such as astrophysics, solar-system physics, molecular spectroscopy and high-energy physics.

HERZBERG INSTITUTE OF ASTROPHYSICS

The Institute has 104 professional, 60 technical, and 23 support positions for a staff target of 187 on 1 April 1989. There are also 5½ VP term employees. The necessary budget for 1989/90 is $3209K operational, $724K minor capital and $190K major capital.

1. ACTIVITIES

The activities of HIA are described in detail in the operational plans for each planning unit. This section gives a short summary of the principal facilities now supported by HIA or being considered.

1.1 OPTICAL ASTRONOMY (including infrared and ultraviolet wavelengths)

1.1.1 CANADA-FRANCE-HAWAII TELESCOPE (CFHT): This telescope with a 3.6 m mirror on Mauna Kea, Hawaii is suitable for optical and infrared astronomy from 0.3 to 20 µm. The operating costs currently are shared 44.8% by Canada, 44.8% by France, and 10.4% by Hawaii, with the Canadian contribution and the funds for three staff astronomers coming from NRC's Office of National Facilities. HIA provides scientific and technical support, including instrument development.

1.1.2 DOMINION ASTROPHYSICAL OBSERVATORY (DAO): The facilities in Victoria include 1.8 and 1.2 m telescopes, each with modern instrumentation, a precision microdensitometer for measuring photographic plates, an instrument development laboratory, a major computing centre for data analysis, and a Data Centre to distribute archival data from space astronomy.

1.1.3 PROPOSED LYMAN FAR ULTRAVIOLET SATELLITE EXPLORER: This is a NASA satellite to obtain far ultraviolet spectra of stars, galaxies and QSO's with a resolution of $3x10^4$, particularly in the wavelength range 910 to 1150 Å. These wavelengths contain important transitions of D I, H_2, HD, and O VI, which will not be accessible with any other satellite. HIA scientists are involved in NASA's phase A study and the Space Division has indicated that Canada would participate with about $20M in hardware if the mission were selected.

1.1.4 PROPOSED LARGE TELESCOPE COLLABORATION: Telescope technology now seems able to construct and mount mirrors 8 to 10 m in diameter. Already a California consortium is building a 10 m telescope in Hawaii, and the European Southern Observatory has funds to build four 8 m telescopes together in Chile. Such telescopes will be the leading instruments for ground-based astronomy beginning in the early 1990's. Thus Canadian astronomers, with the help of NRC, are searching for possible partners in a large telescope.

One such collaboration could be with the U.S. National Optical Astronomy Observatory, which is seeking funds to build one 8-m telescope on Mauna Kea, and a second in Chile. HIA has been discussing with NAE possible wind-tunnel tests of various enclosures that might be used for such a telescope.

The heads of the science agencies of Canada, France, Germany, Italy, Japan, the United Kingdom and the United States meet annually to discuss common problems. Canada is represented by Dr. L. Kerwin of NRC. At the May 1988 meeting in Venice they formed a Joint Working Group on Ground Based Astronomy to consider possible cooperative projects. This Working Group, which includes the Director of HIA, is preparing a report for consideration by the agency heads in Oxford on 5 May 1989. It is expected that this report will recommend that international collaboration in the construction and operation of a large optical telescope would be particularly appropriate.

1.2 RADIO ASTRONOMY

1.2.1 JAMES CLERK MAXWELL TELESCOPE (JCMT): This 15 m dish, also on Mauna Kea, Hawaii, is optimised for wavelengths from 3 to 0.3 mm to study molecules in space. The operating costs are shared 55% by the United Kingdom, 25% by Canada, and 20% by the Netherlands. The University of Hawaii is allocated 10% of the observing time in return for providing the site. Canada's participation in the JCMT, including a laboratory for instrument development and five NRC staff posted overseas, is the responsibility of the Radio Astronomy Section in Ottawa.

The low atmospheric absorption and outstanding image quality at 4200 m on Mauna Kea make this one of the world's best astronomical sites. Canada's participation there permits our astronomers to be research leaders in many aspects of optical, infrared and radio astronomy.

1.2.2 DOMINION RADIO ASTROPHYSICAL OBSERVATORY: The facilities in Penticton include an aperture-synthesis telescope consisting of four 9-m antennas, being upgraded to seven, a 26-m telescope, an instrumentation laboratory and a major computer system for data analysis.

1.2.3 PROPOSED RADIOASTRON SATELLITE: This Soviet satellite would supplement ground-based radio telescopes to extend the baselines available for interferometers and produce maps of cosmic radio sources with resolutions as small as 36 microarcsec. HIA scientists are participating in the initial discussions and the Space Division has indicated that Canada could provide recording terminals and correlators to be used on the ground to acquire and process the data.

1.3 SOLAR SYSTEM PHYSICS

1.3.1 SPACECRAFT: HIA staff in both the Planetary Sciences and Solar-Terrestrial Physics Sections are collaborating with Canadian university researchers on several space missions, providing specific expertise and making teams large enough to permit Canada to have a significant role in these projects. They include the auroral imager on the Viking satellite flown in 1986, for which data analysis is continuing; a second auroral imager to be flown on the Russian Interball satellite in 1990; the Oedipus rockets with tethered instruments to study the auroral ionosphere in 1989 and 1991; WINDII (Wind Imaging Interferometer) on the UARS satellite for 1991; and WAMDII (Wide Angle Michelson Doppler Imaging Interferometer) on the NASA shuttle for 1992.

1.3.2 CANOPUS: This is an array of instruments at 15 stations in northern and western Canada and a computer system in Ottawa operated by HIA and the Space Division for scientists in six universities to study aurora from the ground. The equipment consists of radars, photometers, all-sky imagers, magnetometers, riometers (to measure absorption of the radio noise background), and tellurometers (to measure earth currents induced by the aurora). The Space Division of NRC is providing project management for procurement, installation, and operational support while HIA has the overall scientific responsibility for the facility and contributes much technical support. HIA and several universities divide specific responsibilities for the various component parts.

1.4 MOLECULAR SPECTROSCOPY

This group maintains excellent laboratory facilities, which are used by external researchers as well as NRC staff members. Much of the work relates directly to astrophysics or atmospheric physics.

1.5 ELEMENTARY PARTICLE PHYSICS

1.5.1 OMNI-PURPOSE APPARATUS FOR LEP (OPAL): This detector for the large electron-positron (LEP) collider at CERN in Geneva will investigate elementary particles at energies up to 200 GeV. Canada covers 9% of the OPAL costs and 8 other countries share the remainder. By participating in the construction and operation of this detector, Canadian scientists will have a part in experiments with one of the world's leading facilities in particle physics without the high cost of being a member of CERN.

1.5.2 PROPOSED SUDBURY NEUTRINO OBSERVATORY (SNO): A consortium of 28 scientists from six Canadian institutions including NRC, three universities from the United States and one from the United Kingdom has proposed placing 1000 tonnes of heavy water and an array of photomultipliers 6800 feet deep in a Sudbury mine to detect cosmic neutrinos.

The facility would provide critical information regarding the serious discrepancy between models of solar energy generation and the neutrinos recorded by existing detectors in the United States and Japan. The SNO instrument would be exceptional because of its ability to detect different types of neutrinos and measure temporal changes in the neutrino flux. The facility would cost some $48M over five years, and would make use of $300M worth of heavy water to be lent by AECL.

2. FUTURE DIRECTIONS AND PRIORITIES

In all Sections of HIA there will be much emphasis on providing facilities and instruments for research and expertise and leadership in the community. These objectives require that each Section maintains a core of active researchers.

2.1 OPTICAL ASTRONOMY

- CFHT users will meet in May 1989 to discuss future instrumentation. It is expected that they will recommend that additional capital funds be provided for certain critical enhancements to the Telescope's capabilities.

- HIA will continue discussions with the U.S. National Observatory regarding collaboration on large optical telescopes. We anticipate a plan including funds for new CFHT instrumentation as well as a share in the proposed 8 m facilities will be submitted to the Canadian Astronomical Society in June 1989. If this plan is accepted it will form the basis of requesting the necessary funds from the Government.

- DAO will give priority to the operation of its telescopes and the Canadian Astronomy Data Centre and to the development of advanced instrumentation, particularly for the CFHT. Funds are requested so that DAO can obtain an infrared array detector.

- If NASA selects the Lyman Satellite for flight, HIA will coordinate the scientific aspects of Canada's participation.

2.2 RADIO ASTRONOMY

- The Radio Astronomy Section in Ottawa will concentrate on the construction of sensitive receivers for the JCMT. This work will include the development of array receivers in collaboration with the University of Alberta.

- DRAO will give priority to the completion and operation of the seven-antenna synthesis array.

- DRAO also will design and build two correlators for the Radioastron project, if participation in this space interferometry experiment is approved.

- HIA will encourage Canadian radio astronomers to consider the relative benefits of future radio astronomy projects such as the proposed 100-antenna array at Penticton for imaging diffuse extended structures at centimetric wavelengths, or submillimetre interferometry on Mauna Kea, or possible successors to the <u>Radioastron</u> missions.

2.3 SOLAR SYSTEM PHYSICS

- The two HIA Sections will make the <u>Canopus</u> network fully operational as soon as possible.

- The Sections also will honour their commitments to international rocket and satellite missions.

2.4 MOLECULAR SPECTROSCOPY

- The Section will continue its investigations of molecules, including species relevant to JCMT and atmospheric research, and will provide spectroscopic facilities for external scientists.

2.5 ELEMENTARY PARTICLE PHYSICS

- The HEP Section will give priority to operating the OPAL detector at CERN, and obtaining significant scientific results ahead of the competing detectors.
- If the funds are allocated, the HEP Section also will continue investigations relating to the Sudbury Neutrino Observatory, with the goal of taking a leading role.

3. HIGHLIGHTS FROM THE PAST YEAR 1988/89

For the second year in a row, an HIA scientist has been elected a Fellow of the Royal Society of London. This year it was Dr. Sidney van den Bergh of the DAO.

3.1 OPTICAL ASTRONOMY

- The DAO occupied its extended and refurbished building.

- The Canadian Astronomy Data Centre has become operational and has been received enthusiastically by a growing number of users.

- The DAO has entered into three instrumentation projects, two with the University of Montreal to design a High Resolution Camera for the CFHT and a High Resolution Telescope, and one with the CFHT to build a multi-object spectrograph. This spectrograph will be the first CFHT instrument with major contributions from both Canada and France.

- With support from the President's Fund, DAO is adding an astrometry capability to its precision microdensitometer.

3.2 RADIO ASTRONOMY

- The Radio Astronomy Section has delivered its first instrument to the JCMT. This acousto-optical spectrometer is the only reliable spectral analyzer at the telescope, and has demonstrated the capability of the Ottawa group to the international partners.

- Canadian use of the JCMT has increased each semester the telescope has been scheduled, and in the latest round, Canadian users received, through the competitive allocation process, an amount of telescope time that exceeds Canada's nominal share. Many of these users come from outside the traditional Canadian radio astronomy community.

- At DRAO, the continuum correlator, one of the most complex sub-systems for the upgraded telescope, has been contracted to industry. The array has been recabled, and by the end of FY 88/89 antennas 6 and 7 will be mounted and mechanically steerable.

3.3 SOLAR SYSTEM PHYSICS

- The Canopus system is now operating under the new data-collection software written by HIA staff to replace the unsatisfactory code from the contractor.

- One Oedipus and two ERRRIS rockets were launched from Norway and Sweden to provide direct measurements of the plasma associated with parallel electric fields and radio aurorae respectively.

- The EXOS-D satellite was launched by Japan carrying an ion mass spectrometer provided by HIA.

3.4 MOLECULAR SPECTROSCOPY

- Bomem Inc. is incorporating an NRC modification into its spectrometer to produce a new higher-resolution model.

3.5 HIGH ENERGY PHYSICS

- The zed and vertex chambers of the OPAL detector were completed and tested at CERN. The OPAL detector is the only one of the four LEP detectors that is on schedule, on budget, and meeting specifications.

- The SNO proposal was reviewed by an international panel, and given the highest recommendation for funding.

4. SITUATION ANALYSIS

Issue 1. Level of resources

While HIA continues to have several notable successes each year, the present state of equilibrium is inherently unstable.

HIA is responsive to and is part of the facility-using community, and that community exerts constant pressure for new or improved facilities and greater services. Meanwhile the budget is constrained and the staff complement continues to decrease. In addition, HIA's flexibility to respond is restricted because so much of its distribution of resources is determined by international commitments such as the JCMT, OPAL, and space payloads. Already HIA has dropped all activities not directly related to our objectives. There are no further resources to be found within HIA without reducing the services expected by the community.

The financial resources available to HIA, including some supplements by the Space Division, are barely sufficient, and staff members are stretched to their limits in several areas. Cracks are bound to appear. In every area the story is the same, as the detailed operational plans show. The Section Heads all have the same complaint, barely enough or not enough money, and too few staff members to cope with the work load.

So the real issue is this. How is NRC going to fulfill its mandate in national facilities for science, given the rising expectations of the client community? That community is increasingly ready to sidestep NRC and deal with the government through NSERC, seeking resources to operate national facilities through university consortia. How does HIA present itself as a credible alternative if it has insufficient resources to respond to community needs?

Issue 2. Long term future

What will be the shape of HIA in ten years? The present grouping of disciplines and their geographical distribution were determined largely by the conglomerate nature of HIA's formation. Nobody would have designed a division that way from scratch. Yet none of the sections would now fit well into any other division in the new NRC. They are related in their studies of basic physics and astrophysics and in their provision of facilities and expertise for university scientists.

There are problems in almost every area, some of which might be solved by a realignment of resources, but these realignments are difficult because of commitments and because of the geographically scattered nature of the division.

The problems are particularly acute in radio astronomy, solar system physics, and elementary particle physics.

Radio Astronomy: The question of the long-term role that DRAO will play in radio astronomy will have to be considered. The expanded synthesis telescope will have a productive life of about a decade, but the Observatory will need a new direction after the turn of the century. There is a proposal for a new aperture-synthesis telescope to be constructed at Penticton, but this could only proceed if it receives the support of the Canadian astronomical community. The Observatory could, however, continue in an instrumentation support role for radio astronomy, even in the absence of an operational on-site telescope. There is some urgency in defining, as best as can be foreseen at the moment, the long-term future of the Observatory since decisions will soon have to be made regarding the long-overdue extension to the DRAO office and laboratory building. The group at DRAO is enthusiastic, motivated, competent and effective, and their efforts should be directed into areas best supporting the radio astronomy community. Moreover, DRAO has a highly visible presence in the interior of British Columbia that is consistent with the government's decentralization policy.

The long-term future of the Radio Astronomy Section in Ottawa seems assured through its association with the JCMT, though the past responsibility for ARO continues to haunt it. Although there would appear to be some scientific benefit in bringing the two radio astronomy groups into physical proximity at one location, there are practical reasons why this should not be done, at least immediately. Both the Radio Astronomy group and the DRAO group are fully committed at the moment and disruptions could be costly. Moreover, a rapid move from Ottawa could impact on the fragile morale of the Radio Astronomy Section. But the situation might be different in the longer term, when DRAO will be looking for new challenges. For example, it could make sense to combine the groups with the JCMT as the basic instrument and submillimeter interferometry as a central research technique. Any changeover in location, or organization, would have to be gradual and bridging resources would be necessary.

Should the solar radio group also move to Penticton or remain in Ottawa isolated from the rest of the Division's radio expertise? The answer depends on what happens at ARO and whether the solar interferometer can be kept operating.

Solar System Physics: Despite the fact that the government has provided modest but dependable funding for space science research as part of its industry-oriented space program, the future of most aspects of solar system physics in Canada is in doubt simply because few young scientists are choosing the subject and universities are not making appointments in this field. Should HIA try to fill the gap or follow the trend?

In these circumstances Space Division funding could be diverted to space astronomy, where the demand is growing, and some of the HIA space expertise could be shifted in this direction too. However, there remains some basic level of space physics activity in Canada which ought to be maintained by the government because of Canada's unique geographic position close to the north magnetic pole and the auroral zone.

The challenge will be to determine the appropriate size of this activity, and to allow the two HIA groups to evolve to it without interrupting existing services or taking on commitments that will last longer than they can or should be supported.

Elementary Particle Physics: In elementary particle physics, the problem is that of scale. The group could have a solid future as a centre of instrumentation expertise for Canadian particle physics, but it is too small to be credible in that role at the moment.

Issue 3. The future of the Algonquin Radio Observatory

After the resurfacing of the ARO 46 m telescope was cancelled, NRC, on the community's advice, diverted the ARO funding to the JCMT. A low level of funding was guaranteed for three years to keep ARO viable while a search was made for an agency willing to take over or pay for the operation of this still useful centimeter telescope. The funding comes from the HIA budget, and HIA cannot afford to maintain it beyond the deadline of 1990 March 31.

The search for paying clients has so far been unsuccessful. The likeliest candidate to date is the NASA program to search for extraterrestrial intelligence (SETI), which has a strong interest in using the ARO 46 m, but is as yet unfunded.

The Department of Energy, Mines, and Resources, along with York University, still uses the telescope occasionally for geophysical long-baseline interferometry, and is anxious to continue to do so, but is unable to provide the necessary funding to support the full operation of the telescope.

Meanwhile, HIA continues to monitor the solar radio flux at ARO with the solar patrol dish and the solar interferometer. These observations are distributed worldwide and are used extensively for geophysics. If ARO closed, the solar patrol could be moved to Ottawa, but the interferometer would have to be closed down.

A committee representing university, NRC, government, and industry interests has been set up to recommend a plan for the future use of ARO to the Vice President (Science).

It is probable that the question of NASA-SETI funding will not be resolved by the end of the period of guaranteed support. NRC would then have to decide whether to continue some basic level of interim support until the question could be settled. If no client can be found, NRC will have to decide whether to close down ARO permanently and face the costs of dismantling the telescopes and building. The observatory grounds revert to the province if they are not being used by NRC, and it is unlikely that the province would be content to have the telescopes mouldering in a Provincial Park like some Mayan ruin. However, NRC has no legal obligation to restore the site to its natural condition.

Issue 4. The eventual shape of HIA

Does it make sense to keep HIA in the scattered condition that history has bequeathed it? Should the Division, or most of it, be brought together in the same place? While the virtues of relocation are sometimes overstated, few would maintain that HIA's present configuration is designed to maximise effectiveness.

If there were to be some centralization, where should it be? Ottawa seems to be excluded by government policy. Victoria might be a good choice, being the site of the biggest non-Ottawa section, and a moderately sized city where local services are available. However, if Victoria were to be the site, why amalgamate the two radio astronomy groups in Penticton? And if the Radio Astronomy Section moved to Victoria, what would happen to Penticton if it had no new telescope to follow the synthesis array?

Finally, if there were to be a consolidation, which parts of HIA should come together, and which remain as they are? Should it all take place quickly, or gradually over ten years? How could it be handled without a major disruption of the work of HIA?

HIA is discussing these long-range questions with the communities it serves and with NRC management.

5. ADDITIONAL RESOURCES REQUESTED

Staff

HIA has adhered to the position controls assigned to it as a result of the cuts to the NRC budget. As a consequence of these decreasing staff levels, a number of critical needs have developed. The requirements are given according to category (temporary, bridging, continuing) but the priorities given are ranked independently of category.

Temporary PY's

a) Extending the terms of the two OPAL RA's through FY 90/91 and FY 91/92. The RA's are needed to make the best scientific use of the detector when it starts operations. NRC has a duty to provide a scientific reward for the time they have invested in developing the equipment. The RA's will have to commit themselves to other appointments now if their terms cannot be extended beyond the fall of 1989. (Priority 1)

b) Programmer for DAO. A programmer is needed for 2½ years beginning 1 October 1989 to help the CADC through the initial crucial period when it begins to handle Space Telescope data. (Priority 4)

c) Telescope Operator for DRAO. A 2-year term is needed immediately to take over the duties of the present telescope operator while she prepares essential software for the operation of the full array. (Priority 3)

Temporary needs therefore are

FY 89/90	FY 90/91	FY 91/92
2.5 PY	4 PY	3 PY

Bridging PY's

a) Computer Manager for DRAO. HIA can provide the continuing position when the present manager retires, but a bridying PY is needed for FY 89/90 to ensure a smooth transition by bringing in the replacement early to learn the job. (Priority 5)

Bridging needs therefore are

FY 89/90
1 PY

Continuing PY's

a) Computer Manager for DAO. DAO desperately needs a manager to take over the operation of its computer systems so that scientists are freed to apply their expertise to data analysis software. (Priority 2)

This need could also be met through a contract with a local company if funds were made available.

b) Secretary at Sussex Drive. The secretary HIA supplied to the Office of National Facilities was replaced by a secretary whose term expires in March 1990. HIA administrative support is at dangerously low levels and the loss of this position would severely damage administrative operations. (Priority 6)

Continuing needs therefore are	FY 89/90	FY 90/91 and onwards
	1 PY	2 PY

The total high priority PY needs in HIA are therefore

FY 89/90	FY 90/91	FY 91/92	FY 92/93 and onwards
4.5 PY	6 PY	5 PY	2 PY

Additional staff needs are noted in the Section reports.

Financial

HIA cannot meet its basic commitments with the budget initially allocated in FY 88/89 and now again in FY 89/90. Only the supplements to the FY 88/89 budget allowed it to survive.

Table B lists the survival levels for each Section, without any allowance for contingencies. These levels are, if one combines operations and minor capital, $3641K in FY 89/90, and $3551K in FY 90/91. The shortfalls inherent in the present allocation are as follows

	FY 89/90	FY 90/91
Amount by which the present allocation is short of the minimum requirement	$144K	$104K
Amount by which the present allocation is short of the minimum requirement plus an 8% contingency	$436K	$388K

In addition, funds are needed to operate and upgrade the DAO Data Centre and other DAO computers. About $25K per year in operations is needed for maintenance contracts, and minor capital of $225K is needed in FY 89/90 and FY 90/91 to complete the conversion to distributed work stations.

Another $75K to $150K a year is needed to purchase computer support services if no NRC PY's are available (see staffing priorities 2 and 4 above).

The highest priorities for new projects are

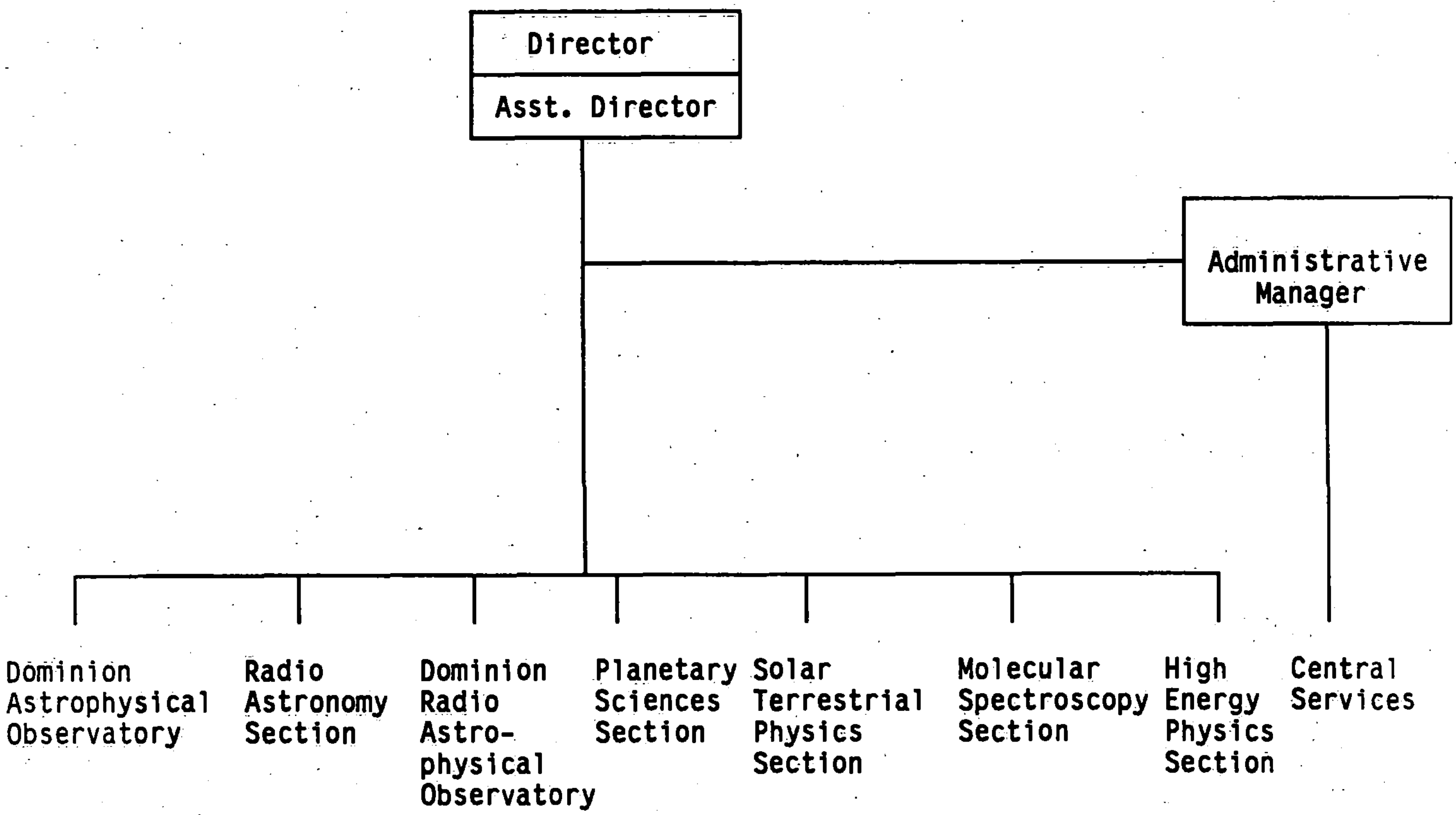
1. IR Array Detector: $190K in operations and $40K in minor capital over the next three years to obtain detector chips and build a system.

2. Sudbury Neutrino Observatory: $211K in operations and $294K in minor capital are needed over the next two years to continue the development of this important project.

The high priority financial needs are therefore

	FY 89/90	FY 90/91
Minimum shortfall	$144K	$104K
Shortfall plus 8% contingency	$436K	$388K
Computer maintenance	$ 25K	$ 25K
Distributed work stations	$225K	$225K
Computer support services	$ 75K	$150K
IR array detector	$ 90K	$ 70K
Sudbury Neutrino Observatory	$300K	$205K

5. DIVISIONAL STRUCTURE



HIA STAFF LEVELS ON 1 APRIL AT EACH FISCAL YEAR
(14 Feb 1989 for FY 88/89)

	1988/89 HIA+VP CY	1989/90 HIA+VP CY+1	1990/91 HIA+VP CY+2	1991/92 HIA+VP CY+3	1992/93 HIA+VP CY+4
Director's Office	3	3	3	3	3
National Facilities	3	3	3	2	2
DAO (3 RA)	42+1	40+1.5	40+1	39	39
Radio Astronomy (1 RA)	24½+4	24+4	23	23	23
DRAO (1 RA)	24	24	22	21	21
Planetary Sciences (1 RA)	19	18	17	17	17
Solar-Terr. Physics(1 RA)	18½	18	18	18	18
Spectroscopy (6 RA)	20	20	21	21	21
G. Herzberg	3	3	3	3	3
High Energy Physics (2 → 0 RA)	13	12	10	10	10
Central Services	21	22	21	21	21
TOTAL = TARGET	191+5	187+5.5	181+1	178	178
Additional Staff Required:					
HEP RA's for OPAL			2	2	
DAO Computer Manager		1	1	1	1
DAO Programmer		½	1	1	
DRAO Computer Manager		1			
DRAO Telescope Operator		1			
Sussex Secretary			1	1	1

89-02-20

89 Feb 10
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TABLE B - SUMMARY OF HIA REQUIREMENTS 1989 JAN 1 DOLLARS

	1988/89			1989/90			1990/91			1991/92			1992/93 and later years		
	OP $K	CAP $K CY	M.CAP CONTR. $K	OP $K	CAP $K CY+1	M.CAP CONTR. $K	OP $K	CAP $K CY+2	M.CAP CONTR. $K	OP $K	CAP $K CY+3	M.CAP CONTR. $K	OP $K	CAP $K CY+3	M.CAP CONTR. $K
Director's Office	76	3		65	7		65	7		65	7		65	7	
Administration	234	26		230	30		230	25		230	25		230	25	
Supplies	184			180			180			180			180		
Travel Overcommitment	20														
DAO Base	652	392		655	120		655	120		655	120		655	120	
Radio Astronomy Base	392*	223		190	60		190	60		190	60		190	60	
JCMT Contribution			770			900			950			950			950
Solar Studies				50	10		50	10		50	10		50	10	
ARO Maintenance				125	10										
DRAO Base + Antennas 6 & 7	304	80	50	320	140	190	310	150	500	330	160		340	170	
Planetary Sciences	155	35		175	35		175	35		175	35		175	35	
Solar-Terrestrial Physics	257	45		250	50		250	50		250	50		250	50	
Spectroscopy	240	140		225	155		225	155		225	155		225	155	
G. Herzberg	14	3		15	3		15	3		15	3		15	3	
High Energy Physics†	421	47		491	50		491	100		491	100		491	100	
Total	2949	994		2971	670		2836	715		2856	725		2866	735	
Reserve 8%				238	54		227	57		228	58		229	59	
TOTAL	2949	994		3209	724		3063	772		3084	783		3095	794	
Initial Allocation				2800	697		2750	697		2750	697		2750	697	
Shortfall				-409	-27		-313	-75		-334	-86		-345	-97	
Extra Resources Requested															
Radio Ast. Relocations							100			100			100		
DAO Data Center & Computers				100	225		175	225		175			125		
DAO IR Array Detector				70	20		60	10		60	10				
SNO Developments				100	200		111	94							
Major Capital project															
DRAO Building						300			2400			1600	20		

*Includes 19K for 1 partial salary at ARO.
†These figures reflect the expected $100K/yr increase for HEP beginning 1989/90.

HERZBERG INSTITUTE OF ASTROPHYSICS

TABLE 1 Divisional Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	187	181	178	178
VP Terms	5½	1		
Expenditures ($K)				
• Operations	3209	3063	3084	3095
• Minor Capital	724	772	783	794
• Major Capital	190	500		
• Grants & Contributions				
• Shortfall	-436	-388	-420	-442
• Total Expenditures	3687	3947	3447	3447
Monies-In ($K)				
• Joint Research Projects	646	42		
• Contracts-In	5	5	5	5
• Financial Arrangements	120	120	120	120
• Grants & Contributions				
• Computer Usage	108	150	150	150
• Rent	15	15	15	15
• Total Monies-In	894	332	290	290

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets	3½	5	5	2
Expenditures ($K)				
• Operations	270	446	335	225
• Minor Capital	445	329	10	
• Major Capital				
• Total Expenditures	715	775	345	225
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

HERZBERG INSTITUTE OF ASTROPHYSICS

TABLE 2 Divisional Summary by Planning Unit

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

Expenditures & Staff	89/90 $K	89/90 ST	90/91 $K	90/91 ST	91/92 $K	91/92 ST	92/93 $K	92/93 ST
• DAO*	775	41½	775	41	775	39	775	39
• Radio Astronomy*	445	28	310	23	310	23	310	23
• DRAO	650	24	960	22	490	21	510	21
• Planetary Sciences	210	18	210	17	210	17	210	17
• Solar-Terr. Physics	300	18	300	18	300	18	300	18
• Spectroscopy	398	23	398	24	398	24	398	24
• High Energy Physics	541	12	591	10	591	10	591	10
• Director's Office	512	28	507	27	507	26	507	26
• Reserve 8%	292	0	284	0	286	0	288	0
• Shortfall	-436	0	-388	0	-420	0	-442	0
• Total Expenditures	3687	192½	3947	182	3447	178	3447	178

* Includes VP Term Positions

Monies-In ($K)	89/90 $K	89/90 ST	90/91 $K	90/91 ST	91/92 $K	91/92 ST	92/93 $K	92/93 ST
• DAO	140		47		5		5	
• Radio Astronomy	521		10		10		10	
• DRAO	5		5		5		5	
• Planetary Sciences								
• Solar-Terr. Physics								
• Spectroscopy								
• High Energy Physics	108		150		150		150	
• Director's Office	120		120		120		120	
• Reserve 8%								
• Shortfall								
• Total Monies-In	894		332		290		290	

* Includes VP Term Position

HERZBERG INSTITUTE OF ASTROPHYSICS

TABLE 2 (cont'd) <u>Divisional Summary by Planning Unit</u>

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90		90/91		91/92		92/93	
	$K	ST	$K	ST	$K	ST	$K	ST
Expenditures & Staff								
• DAO	415	1½	470	2	245	2	125	1
• Radio Astronomy			100		100		100	
• DRAO		2						
• Planetary Sciences								
• Solar-Terr. Physics								
• Spectroscopy								
• High Energy Physics	300		205	2		2		
• Director's Office				1		1		1
• Total Expenditures	715	3½	775	5	345	5	225	2
Monies-In ($K)								
• DAO								
• Radio Astronomy								
• DRAO								
• Planetary Sciences								
• Solar-Terr. Physics								
• Spectroscopy								
• High Energy Physics								
• Director's Office								
• Total Monies-In								

SUPPORT OF OPTICAL ASTRONOMY

PREAMBLE

Astronomy differs from other physical sciences in several important respects:

- The combinations of temperatures, densities and pressures in the objects being studied span a range far greater than those which can be produced in any terrestrial laboratory.

- Astronomers cannot experiment on their objects; they must often wait years or decades to observe natural changes which can give clues to the nature of the underlying physics.

- With ongoing improvements to their ancillary instrumentation, optical telescopes can have productive lifetimes approaching a century.

- Observing objects through the earth's atmosphere severely limits the angular resolution and energy or wavelength range observable. The development of space-based observatories has greatly expanded our knowledge of the universe and increased the need for ground-based telescopes to provide supporting data.

- These space facilities, as well as the construction of large ground-based telescopes, have turned astronomy into big science.

- The Canadian astronomy community is dispersed across the country in a number of university groups of 1 to 20 scientists. Competitive Canadian participation in modern astronomy would be difficult without the expertise and support which can only be provided by national facilities.

- Astronomy has remained one of Canada's pre-eminent sciences since 1918 when the world's largest telescope at the time was opened in Victoria.

- Optical telescopes also are useful for infrared astronomy and many optical techniques are appropriate for ultraviolet astronomy from space. Thus, most IR and UV astronomers consider themselves part of the optical community.

- The only HIA section dedicated to supporting optical astronomy and the related areas of infrared and ultraviolet astronomy is the Dominion Astrophysical Observatory located in Victoria, B.C.

OBJECTIVES

To provide expertise and support for optical, infrared, and ultraviolet astronomy in Canada by:

- operating telescopes and facilities for use by the community;
- designing and developing telescopes and their instrumentation to meet the needs of the astronomy community;
- developing computer systems and programs for data processing and analysis, and for the collection and distribution of archival data,
- maintaining a core of influential scientific and engineering expertise; and
- supporting the scientific infrastructure, and providing public information.

DOMINION ASTROPHYSICAL OBSERVATORY (DAO)

Section Head: J.E. Hesser

This group consists of 25 professional, 9 technical, and 6 support positions for a staff target of 40 on 1 April 1989. In addition there are 1½ VP term positions in this group, one of which is a revenue PY.

1. ACTIVITIES

Each of the activities of the DAO corresponds to one of the objectives. The activities are National Facilities (subdivided into telescopes, the data centre, measuring instruments, and the library), Instrumentation, Computing Systems and Data Analysis, Scientific Research, and Support of the Scientific Infrastructure.

1.1 NATIONAL FACILITIES (8.7 professional, 6.9 technical, 2.6 support, ½ VP term, $310K)

To meet its objectives in this area, the DAO

- operates two telescopes, of 1.2 m and 1.8 m diameters,

- is developing an archival astronomy data centre,

- provides specialized measuring instruments,

- houses the largest collection of astronomy-related books and periodicals in Canada.

During 1988 working visits to DAO were made by 48 scientists, including extended visits by 11 sabbatical and summer researchers.

1.1.1 TELESCOPES: More than half the available telescope time at DAO is used by Canadian and foreign visiting scientists, including many graduate students. These telescopes complement the CFHT, and are used for programs which:

- are not suitable for the CFHT, or do not require a large aperture; or

- involve the development and testing of instrumentation for the CFHT.

To facilitate university faculty research, DAO staff also provide service observing, in which the requested observations are made when external users cannot travel to Victoria.

The telescopes and other facilities are frequently used by foreign astronomers (principally from the US), thus helping Canadian scientists to gain access to facilities in other countries on a quid pro quo basis.

1.1.2 CANADIAN ASTRONOMY DATA CENTRE (CADC): This Centre is being developed to provide Canadian astronomers with access to data from space-based observatories (none of which is Canadian) as well as the CFHT, and advice on processing these data.

The major data file will be from the Hubble Space Telescope, which is expected to be launched in December 1989. For this mission, the Space Division has agreed to cover the cost to NASA of making a copy for Canada. This is the first copy NASA has agreed to release to a country not contributing to the hardware development.

1.1.3 MEASURING INSTRUMENTS: Photographic plates remain an extremely effective medium for collecting astronomical data, because a large plate has many more sensitive elements than any electronic detector. Computerized analysis of plate information requires first converting it to digital form.

- DAO has a collection of over 100,000 astronomical spectrograms which are frequently consulted and re-analyzed, and a complete collection of the major sky survey photographs on glass plates.

- DAO operates one of Canada's two precision astronomical microdensitometers, which are necessary to convert the photographic information into analogue form.

1.1.4 LIBRARY: Because DAO has been in existence for 70 years, its library has an unusually complete collection of books, journals, and sky survey atlases. This collection is frequently consulted by astronomers in Canada and the northwestern USA.

1.2 INSTRUMENTATION (6.0 professional, 1.6 technical, 1.4 support, 1 VP term, $115K)

Because astronomical instrumentation is very specialized, it is not normally available commercially, so in most cases it is designed and produced by observatory and university groups. To meet its objectives, DAO has developed expertise at an internationally recognized level in:

- optical, mechanical, and electronic design; and
- mechanical and electronic fabrication.

1.3 COMPUTING SYSTEMS AND DATA ANALYSIS (1.2 professional, 0.5 technical, 0.6 support, $215K)

DAO must support a broad range of computer services because they are now essential for all of the Observatory's objectives. These services include:

- design and engineering of optical systems and instrumentation,
- reduction and interpretation of data,
- acquisition, retrieval and transmission of data from archives, and
- astrophysical modelling.

1.4 SCIENTIFIC RESEARCH (8.1 professional, 1.2 support, $120K)

Original scientific and technical research is the basis of DAO's excellent international reputation and is central to achieving its service objectives. DAO staff members publish more than 60 research papers annually.

The breadth and depth of scientific interests enables DAO to provide leadership and guidance in areas of astronomy ranging from stellar astrophysics to massive black holes, and to respond to community needs for innovative instrumentation and analytical techniques. For example, DAO staff astronomers have distributed widely software written for sophisticated data reduction tasks first tackled in their research.

1.5 SCIENTIFIC INFRASTRUCTURE (1.0 professional, 0.2 support, $15K)

DAO staff members serve on the executive and editorial boards of most major national and international scientific bodies. These include the International Astronomical Union, the Canadian Astronomical Society, the Royal Society, the Royal Astronomical Society of Canada, the American Astronomical Society, and the Astronomical Society of the Pacific.

DAO staff members also support a vigorous public information program in Victoria and respond to numerous official and unofficial inquiries for astronomical data.

2. FUTURE DIRECTIONS AND PRIORITIES

DAO priorities and directions reflect advice from the NRC Associate Committee on Astronomy and the Canadian Astronomical Society. A User's Committee covering all aspects of DAO activities and reporting to the Director of HIA will be established early in 1989.

Listed below are the primary projects for the next few years.

2.1 NATIONAL FACILITIES

FY 89/90

- Complete the conversion of the 1.8 m telescope and dome to computer control, and install a larger control room with greatly improved thermal insulation, and a roof which will facilitate maintenance of the telescope.

- Explore the optical design of a polarimeter system for the coudé spectrographs of the DAO and CFHT with the Universities of Western Ontario, and Montreal, and Brandon University.

- Participate in the prelaunch system tests for the Hubble Space Telescope in preparation for the acquisition, cataloging, storage and distribution of HST data.

- Implement the archiving system for CCD images from the CFH Telescope.
- Acquire and install additional catalogs, such as the NASA Catalog of IR observations, within the CADC system.
- Learn and develop methods of analysis of HST data, so that DAO may assist Canadian astronomers in processing these data.
- Complete the installation of the DAO stellar photometry software within the main HST data analysis system, and develop algorithms suitable for treatment of undersampled images.
- Conduct a workshop on CADC services at the 1989 CASCA meeting at the University of Montreal.
- Complete and distribute to the scientific community the first edition of a DAO/CADC Facilities Manual.

Longer Term:

- If the requested additional funds become available, operate the Astronomy Data Centre so that Canadian astronomers have access to all archival data from the HST through computer networks.

2.2 INSTRUMENTATION

FY 89/90

- Under contract to the CFHT, continue the design and fabrication and project management of the multi-object spectrograph (MOS) in collaboration with French scientists and engineers.
- Participate with NASA and Canadian industries in engineering studies for the Lyman satellite.

Longer Term

- Contribute significantly to the design of the next generation optical telescope for Canada and assist in the development of other proposals for new optical facilities.
- If the requested additional funds are provided, construct detectors to enhance DAO expertise and to extend significantly the spectral range and data collection efficiency of the DAO telescopes.

Highest priority will be given to a 1-2.5 micron infrared array for use on the 1.8-m telescope. Implementation of an IR array at DAO would: (1) foster research in some of the most rapidly developing areas of modern astronomy; (2) enhance productivity by offering a unique survey capability unaffected by bright moonlight; and (3) develop instrumentation expertise at DAO. The DAO has been invited to join a U.S. university consortium which is negotiating for the latest technology chips from the developer, Rockwell International Inc. The consortium's program is expected to deliver to each participant one array in FY 1989/90 and one four times as large in FY 1990/91.

- As a second priority DAO proposes to build a large-format (2048 x 2048 pixel) low-noise CCD system that would more than quadruple the efficiency with which the Victoria telescopes can record spectral information for faint objects. The engineering experience would be useful in developing a mosaic of large-format CCDs for imaging at the CFHT.

The IR array and large CCD would keep the DAO telescopes performing at internationally recognized standards of excellence.

2.3 COMPUTING SYSTEMS AND DATA ANALYSIS

FY 89/90 and 90/91

- Continue the conversion of the VAX VMS-based computer system to a distributed workstation configuration based primarily on Unix machines. This conversion began in FY 1988/89 with a special year-end Vice-Presidential allocation, and requires the remaining $450K.

2.4 SCIENTIFIC RESEARCH

- Continue research on topics including the distribution and physical characteristics of quasars, distances to nearby galaxies, properties of star clusters in galaxies, multiple star systems, and publication of the 8th Edition of the "Catalogue of the Orbits of Spectroscopic Binary Stars", which is a critical compilation of data for over 1400 systeme.

2.5 SCIENTIFIC INFRASTRUCTURE

FY 89/90

- Plan and host the 1989 "Kingston Meeting" on theoretical astrophysics, and the Northwest Regional Astronomy Conference (on active galaxies).

3. RESULTS FROM THE PAST YEAR 1988/89

An office building extension started in 1987 August was officially opened in 1988 July by the Minister. The extension approximately doubled the floor space to provide needed accommodation for the library, computers, electronics and photographic laboratories, as well as offices for visiting scientists. This ended more than a decade of severe crowding and is enabling DAO to attract an increasing number of visiting scholars.

3.1 NATIONAL FACILITIES

- Major modifications to the dome of the 1.8-m telescope will be complete in 1988/89, and will enable the final stages of computer control to be implemented.
- The CADC became operational and now has 85 users outside DAO (equivalent to 25% of the CASCA membership). CADC's proposal to archive digital images from the CFHT's CCD detectors was approved by the CFHT Board of Directors.
- CADC staff demonstrated remote access to its facilities during the CASCA meeting at Trent University. They also organized at DAO a workshop on the IRAF software environment which was attended by some 40 astronomers from across Canada.
- For the third year in a row, an open house was held in the fall for new students at area universities to acquaint them with DAO facilities.

3.2 INSTRUMENTATION

- In collaboration with the University of Montreal, and with partial financial support from CFHT, an experimental Very High Resolution Camera was developed to explore how to improve further the angular resolution of CFHT images. Two successful observing runs at CFHT (including visitor use) have led to suggestions for minor improvements to the apparatus which will be completed in 1988/89. These runs confirmed that further adjustments of the CFHT optics are now necessary.
- A new, specialized multi-object spectrograph, for the Cassegrain focus of the CFHT was begun as a joint effort by Canada and France. The DAO is responsible for overall project management, mechanical design and fabrication of the multi-object portion of the instrument, and electronic control. The spectrograph should be commissioned in 1990.
- Special studies for the proposed High Resolution Telescope were made for the University of Montreal.
- Investigations of the detectors and the optical design of the Lyman satellite telescope were performed for the ESA study.
- DAO assisted scientists at Laval University, NASA, Simon Fraser University, the University of British Columbia, the University of Calgary, the University of Illinois, the University of Montreal and the University of Toronto with optical design work.

3.3 COMPUTER SYSTEMS AND DATA ANALYSIS

- Four Sun workstations were ordered using funds made available from the Vice President's reserve, for the first phase of DAO's computer development plan.

- With funding from the Division of Informatics, DAO joined BCNet, which provides access to the very large US networks.

3.4 SCIENTIFIC RESEARCH

- Discovery of a significant range in the ages of the oldest star clusters of the Milky Way galaxy that challenges long-held assumptions that these clusters were formed at the same epoch;
- Evidence for a possible supermassive black hole in the nucleus of the relatively nearby Sombrero Galaxy;
- Observations which support the concept that many of the properties of the most luminous galaxies result from mergers between galaxies;
- Analysis of a statistically complete sample of quasars which shows that while some clustering is evident, the distribution is remarkably smooth, in contrast to the spatial distributions of galaxies;
- Lack of any obvious concentration of luminous spiral galaxies in survey in the direction of the proposed enormous mass concentration called "Great Attractor", thereby casting doubt on the interpretation of the velocity data from which the existence of the mass was inferred.
- Prestigious national and international awards that honoured two DAO staff astronomers, including one who was elected a Fellow of the Royal Society, London.

3.5 SCIENTIFIC INFRASTRUCTURE

- A major contribution to Canadian computer networking was made by CADC staff through the NRCNET initiative.
- Canada was represented by DAO staff members at various meetings aimed at exploring possible collaborations with Russian, American, European and Japanese space astronomers.
- Under PRIS management a professional team designed a new public display gallery for the dome of the 1.8 m telescope. The display should be in place in FY 1988/89 and will describe NRC as well as HIA and DAO activities. In FY 1987/88 9000 of the 25,000 people to visit the Observatory were given personally conducted tours by Observatory staff, largely on volunteered time.

4. SITUATION ANALYSIS

Staffing concerns represent the single biggest issue at DAO. Over the past two years concerted efforts have ensured that each section member's efforts are focussed on the highest priority tasks. Many redeployments have been necessary. Furthermore, the APR objectives served as the focus of the interviews for the Personal Performance Reviews conducted at DAO in December 1988 and January 1989. Nevertheless, the options are limited. The Observatory is understaffed for what the community and the Council expect of it.

The shortage of staff is particularly serious at the Canadian Astronomy Data Centre, now that the Hubble Space Telescope has the definite launch date of 11 December 1989.

The formal proposal for the "Space Telescope Canadian Data Analysis Facility" was submitted to NRC's Program Selection Committee in 1984-85. This proposal called for resource levels of 7 PY's (including 2 RA's at the Space Telescope Science Institute in Baltimore), an operations budget of $160K/yr, a minor capital budget of $25K/yr, and major capital acquisitions of $750K for computing facilities and $500K for additional accommodation. It was noted that the costs of acquiring HST data were highly uncertain, but these were estimated at $100-200K/yr.

This proposal received an A rating from the PSC, but the NRC Council later took the unusual action of overriding the PSC recommendation, and raised the rating to A+. The Canadian Astronomical Society and the Joint Subcommittee on Space Astronomy have maintained their strong support for this project.

The resources actually provided were the major capital for hardware acquisition, and accommodation in the new DAO building extension. If the Space Division funds the HST data acquisition, the DAO budget can probably accommodate other CADC operations costs excluding equipment maintenance contracts. However, of the 7 PY's required, NRC has provided only 2, plus a term position for a programmer which runs out on 30 September 1989. Experience shows that the original PY estimate was close to the real needs. Already DAO has provided about 1.8 PY's. Some additional help is needed, particularly with computer expertise that cannot be found by reassigning additional people now on the DAO staff. The most needed positions are a computer system manager and two programmers. Without these extra staff there is the very serious risk that the DAO will fail to provide the basic services Canadian astronomers are expecting in their use of HST data, and that we shall lose the excellent reputation we now enjoy with the U.S. Space Telescope Science Institute.

Another consequence of the staff shortages at DAO is an accelerating decrease in scientific research upon which DAO's ability to meet its service objectives ultimately rests.

There is considerable pressure on the financial side too. In FY 88/89, the DAO met its essential expenses only by converting some minor capital to operations, and by eliminating its computer hardware and software maintenance contracts. Similar measures will be taken in 1989/90, but cannot continue much longer if we are to have reliable and up-to-date facilities.

5. ADDITIONAL RESOURCES REQUESTED

5.1 NATIONAL FACILITIES

Staffing

The highest priorities for additional staff relate to the CADC and the Observatory's computers.

a) In FY 1989/90 a professional systems manager for the networked computers.

b) Beginning 1 October 1989, a term programmer for at least 2½ years while the CADC becomes operational.

c) Beginning in FY 1990/91 another computer programmer for the CADC.

Alternatively, many of these services could be obtained from private-sector contracts if funds were available. For this purpose we are requesting additional operating funds of $75K in FY 1989/90 and $150K in the next two years and then $100K/yr.

Financial

DAO's computer communication costs have been rising as CADC services become more popular. DAO will probably have to make CADC users pay, although in the US NASA and the NSF are providing free communication to scientific groups.

5.2 INSTRUMENTATION

Staffing

Critical contributions by a designer, a machinist and an electronics technician at present are being covered by casual appointments, and a revenue position with costs recovered from the CFHT and the HRT design contracts. One more HIA position would give more stability to the instrument efforts.

Longer term goals include a continuing position in three years or so to succeed the present interim leader of the Instrumentation Group.

Financial

Exploitation of the opportunity to join the U.S. consortium developing new IR arrays with Rockwell (see 2.2, above) will require approx. $70K additional operations money and $20K minor capital in FY 1989/90 and $60K and $10K, respectively, in FY 1990/91 and FY 1991/92.

5.3 COMPUTER SYSTEMS AND DATA ANALYSIS

Staffing

See Section 5.1.

Financial

Towards the end of FY 88/89 the Vice President allocated $155K in minor capital to initiate the major computer system upgrade. The balance of the request ($450K) is necessary over the next two years.

DAO needs at least $25K per year to restore some of the cancelled maintenance contracts during FY 89/90 and to take out basic maintenance on software for the Sun work stations.

5.4 SCIENTIFIC INFRASTRUCTURE

Staffing

In 1989 DAO will lose one of its most recognized younger scientists to a foreign university; the loss exacerbates the decline in scientific effort referred to in Section 4. A replacement is extremely important.

DOMINION ASTROPHYSICAL OBSERVATORY

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	40	40	39	39
VP Terms	1.5	1	-	-
Expenditures ($K)				
• Operations	655	655	655	655
• Minor Capital	120	120	120	120
• Major Capital				
• Total Expenditures	775	775	775	775
Monies-In ($K)				
• Joint Research Project	135	42		
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Rent	5	5	5	5
• Total Monies-In	140	47	5	5

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets	1½	2	2	1
Expenditures ($K)				
• Operations	170	235	235	125
• Minor Capital	245	235	10	
• Major Capital				
• Total Expenditures	415	470	245	125
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

DOMINION ASTROPHYSICAL OBSRVATORY

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
10000	10½	195	10		205	5			5
15000	15	250	50		300				
16000	6	100	55		155				
17000	10	110	5		115	135			135
TOTAL	*41½	655	120		775	140			140

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
10000									
15000									
16000	1½	100	225		325				
17000		70	20		90				
TOTAL		170	245		415				

10000 DAO Research in Astronomy [Activity I, Application 1] (scientific research, scientific infrastructure)

15000 DAO National Facility [Activity IV, Application 1] (telescope measuring instruments,library, computer systems, data analysis)

16000 Canadian Astronomy Data Centre (CADC) [Activity IV, Application 1]

17000 Instrumentation [Activity IV, Application 1] (DAO, CFHT, University of Montreal)

*Includes 1.5 VP PY's.

SUPPORT OF RADIO ASTRONOMY

PREAMBLE

Radio astronomy is a generic term that describes observations of natural electromagnetic emissions from the universe at wavelengths from more than 10 m to less than 1 mm, a range approaching 10^5. The instrumentation problem is quite different from that of ground-based optical and infrared astronomy, which only has to cope with a wavelength range less than 10^2. Radio telescopes come in a variety of shapes, sizes, and configurations that reflect different compromises with the limitations imposed by mechanical feasibility. There is a much greater tendency for radio telescopes to be optimised for specific purposes, particular types of observations, or certain ranges of wavelength. A modern radio telescope typically costs tens of millions of dollars.

Because of the cost and variety of telescopes, much radio astronomy is carried out on an international scale, with each active country contributing to the world pool of instrumentation according to its ability and predominant interests.

Radio telescopes come in two basic types, single dish parabolic reflectors and aperture synthesis arrays. The technologies and signal processing techniques associated with the two types are quite different, as are the techniques associated with different wavelength regimes.

Canadian radio astronomers have a strong interest in galactic astronomy, so the national observatories reflect that interest. Canadian extragalactic astronomers are served by foreign observatories just as foreign astronomers have access to Canadian telescopes in the unofficial quid pro quo that is prevalent internationally.

There are two HIA sections which support and operate national facilities for the radio astronomy community. Both sections have identical objectives, but the application and interpretation of these objectives reflect different scientific interests and are based on different technologies.

The Radio Astronomy Section is located in Ottawa. The research community it supports and participates in has as its main interest molecular astronomy, i.e. the physics and chemistry of molecules in space. Such astronomy is best served by single dish antennas operating at the high frequencies where most of the molecular line emissions occur. The Section provides telescopes, instrumentation, and data systems for this field.

The Radio Astronomy Section also operates the Ottawa River Solar Observatory, and two solar radio telescopes at the Algonquin Radio Observatory (Lake Traverse, Ontario) that have been providing basic solar data for several decades.

The Dominion Radio Astrophysical Observatory (DRAO) is located near Penticton, B.C. The users served by this national facility are mainly interested in the physical processes in the diffuse interstellar medium as evidenced by synchrotron continuum radiation from electrons orbiting in magnetic fields, by thermal continuum emission from regions of ionised hydrogen, and by line emission from the electron spin-flip in atomic hydrogen. These emissions occur at relatively low frequencies, so that aperture synthesis techniques are needed for acceptable angular resolution.

DRAO's main instrument is an aperture synthesis telescope that is uniquely suited to studies of the low density interstellar medium. DRAO is a centre of expertise in the aperture synthesis technique.

The Observatory also has a 26 m diameter antenna that observes radio spectral lines at decimeter wavelengths. In addition, DRAO extends the daily coverage of the solar flux monitor with a solar radio telescope identical to one at ARO.

OBJECTIVES

To support radio astronomy in Canada by

- operating radio telescopes and facilities for use by the astronomy community
- developing instrumentation and systems for signal detection and processing
- developing computer systems and software for data processing and analysis
- designing and developing new or improved telescopes to meet the evolving needs of the community
- maintaining a core of scientific and engineering expertise
- supporting the scientific infrastructure and providing public information.

RADIO ASTRONOMY SECTION

Section Head: J. M. MacLeod

This group consists of 15 professional and 9 technical positions, for a staff target of 24 on 1 April 1989. In addition there are 4 VP term positions ending on 31 March 1990 for the maintenance of ARO.

1. ACTIVITIES

Each activity corresponds to one of the objectives. The activities are operating telescopes and facilities, developing instrumentation, developing new or improved telescopes, conducting scientific research, and supporting the science infrastructure.

1.1 TELESCOPES AND FACILITIES: (2.5 professional, 2.0 technical, $10K*)

Canada is a partner with the United Kingdom and the Netherlands in operating the world's largest submillimeter telescope, the 15-m diameter James Clerk Maxwell Telescope on Mauna Kea, Hawaii. The costs are shared 55% from the UK, 25% from Canada, and 20% from the Netherlands. Available observing time is allocated in the same proportions, on average.

The Radio Astronomy Section supports the JCMT as a National Facility for Canadian astronomers. Four members of the Section have been posted to Hawaii to provide on-site operational support, and one has been posted to Edinburgh, the headquarters of the facility. Several members of the Section participate in various committees related to the telescope.

1.2 INSTRUMENTATION: (5 professional, 3 technical, $55K*)

As part of the JCMT Agreement, HIA maintains a well-found lab to develop and test receiving systems and instrumentation for the JCMT. Construction costs and some development costs are borne by the JCMT Development Fund. HIA bears the cost of the well-found lab.

1.3 NEW OR IMPROVED TELESCOPE SYSTEMS: (0.1 professional)

The Section played a significant role in the ESA study of the orbiting radio telescope Quasat and will have a small part in the similar Soviet Radioastron.

*In addition, there is an annual contribution to the JCMT organization of 25% of operating costs (about $750K) and 25% of the Development Fund (about $250K).

1.4 SCIENTIFIC RESEARCH: (5.4 professional, $185K)

The Section carries out active research in radio astronomy to keep up with scientific and technical progress in the field and to maintain its credibility with its international partners and the community it serves. Section astronomers specialize in research on the chemistry and physics of interstellar molecular clouds and benefit from laboratory information provided by the HIA Spectrocscopy Section.

The Ottawa River Solar Observatory at Shirley's Bay is an advanced optical facility which is used for studying dynamic phenomena on the surface of the Sun and their relationship to the 11-year cycle of solar activity.

1.5 SCIENTIFIC INFRASTRUCTURE: (2 professionals, 4 technical, 4 VP Terms, $195K)

Daily radio observations of the sun at 10.7 cm wavelength have been made with a 1.8 m diameter telescope for over 40 years. These observations constitute the longest continuous record of the solar radio flux and are recognised as the best indicator of solar activity. For the past 20 years these measurements have been augmented by high resolution observations with the ARO solar interferometer that locate active regions on the sun. These data are of considerable use in assessing solar effects on radio communications, space missions, geophysical exploration, and long distance power transmission. The information is transmitted daily to the Department of Energy, Mines, and Resources in Ottawa and to the National Geophysical Data Centre of NOAA in Boulder, Colorado, which redistributes it to many international users. The Section also mails monthly solar reports to 90 users in Canada and abroad.

The time of sunrise or sunset at a particular location and date often is required for a court case or for another government agency. During 1988, there were approximately 400 requests from 100 separate agencies for information of this nature.

The 46-m telescope at ARO has been mothballed since 1987 April 1 while its future is considered. A staff of four at the observatory carries out mechanical and electrical maintenance on the telescope, which is still used occasionally for geophysical very-long-baseline interferometry. The four positions have been guaranteed only until 1990 March 31.

2. FUTURE DIRECTIONS AND PRIORITIES

2.1 TELESCOPES AND FACILITIES

The section has an ongoing commitment to provide the best possible service to meet the needs of Canadian JCMT users. However, the operation of the telescope is the responsibility of the Royal Observatory, Edinburgh, so that operational objectives cannot be determined for the telescope by the section alone.

2.2 INSTRUMENTATION

Very sensitive receivers are required for the JCMT. The Section will provide a receiver using a high performance superconductor-insulator-superconductor (SIS) mixer for the important band between 330 and 375 GHz. The initial effort will concentrate on a single-beam receiver, to be followed by a multi-beam receiver.

FY 89/90

- 345 GHz SIS RECEIVER: The Section has entered into a collaboration with the University of Kent and the Rutherford Appleton Laboratory (RAL) in the UK, to build a single-beam SIS receiver for the JCMT. Kent will supply lead-alloy SIS junctions to RAL for integration into waveguide mixer blocks and installation into a prototype receiver, which will be tested on the JCMT before the end of 1989/90. Meanwhile, the RA Section will build a phase-locked local oscillator system for 330-360 GHz which will be incorporated in the prototype along with a higher frequency mixer from Kent and RAL, with telescope tests expected in early 1990.

- SIS JUNCTIONS AND PLANAR ARRAYS: A second collaboration involving the Radio Astronomy Section, the University of Alberta, and the DAO has begun research on the construction of niobium nitride SIS mixers, which appear to be more rugged than lead alloy devices and operate at much higher frequencies. The primary goal is to incorporate a NbN mixer and an IF amplifier on the same substrate as a wideband planar antenna.

  Goals for 1989/90 will be to measure the current-voltage characteristics of the NbN junctions at microwave frequencies, to construct scaled-up models of high efficiency planar feeds, and to determine the optimum design.

Longer Term

- 345 GHz SIS RECEIVER: The longer term goal of this project at HIA is to produce a receiver of standardized JCMT design for the frequency range of 330-375 GHz. The first test observations should occur in late 1991.

- PLANAR ARRAY PROJECT: The goal is to construct planar arrays of NbN SIS junctions, perhaps 8 x 8 elements, along with the planar feeds to permit using these arrays on the JCMT as submillimeter cameras. Observations of extended sources of submillimeter emission will be possible in a fraction of the time presently required. The timescale envisioned for this project is 5 to 6 years.

2.3 NEW OR IMPROVED TELESCOPE SYSTEMS

- Study the requirements for using the JCMT as one element of a submillimeter VLBI array in the mid-1990's.

2.4 SCIENTIFIC RESEARCH

FY 89/90

- The spectrum of the dense gas clouds associated with IRC +10216 will be observed with the JCMT from 223 GHz to 270 GHz to attempt identification of the numerous lines expected. The excitation of a number of species in the molecular envelope of this carbon star should then be understandable.

- During 1989/90 a large number of asteroids will be observed at 5 wavelengths with the JCMT, and for the brighter ones information will be obtained at different phases of their rotations. It may well be possible to determine which asteroids are metallic.

- The dynamics of a cloud of gas which appears to be falling into the nucleus of the peculiar galaxy Centaurus A will be studied with the Very Large Array in New Mexico, using radio emissions from OH and formaldehyde.

2.5 SCIENTIFIC INFRASTRUCTURE

FY 89/90

- A major modification and upgrade of the solar radio telescopes is concentrating on replacing the ARO control computer in early 1989 and completing the installation of a dual-horn system for absolute calibrations.

- In the past, sunrise-sunset information has been provided free of charge. A decision has been taken to charge users for the service. A fee scale will be worked out in early 1989.

Longer Term

- The receiving systems at the ARO solar flux monitor and the interferometer will be replaced with modern equipment. The DRAO solar flux monitor will have its receiver replaced, and will have a new control computer, identical to the ARO computer. Absolute calibration of the solar flux will be carried out on a routine basis, using the new dual-horn calibration system.

2.6 MAINTENANCE OF THE ALGONQUIN RADIO OBSERVATORY

FY 89/90

- The goal will be to maintain the 46-m telescope in such a condition that it can be used for irregular geophysical very-long-baseline observations when required.

Longer Term

- The goal is to find one or more outside agencies which will pay enough for the use of the Algonquin Radio Observatory to keep it working. Two candidates at present are the NASA program to search for signs of extraterrestrial intelligence (SETI) and the French Vesta space probe project. The Department of Energy, Mines, and Resources would continue to be a partial user of the 46 m telescope.

3. RESULTS FROM THE PAST YEAR 1988/89

3.1 TELESCOPES AND FACILITIES

Since JCMT operations began in 1987 September, the Canadian participation has grown dramatically. The percentage of available time granted to Canadian programs on a competitive basis has increased from 12% to 29%, and the number of Canadian proposals per semester has gone from 15 to 36. New users, mostly young astronomers, are coming to the JCMT from universities all across the country, and from outside the traditional groups of Canadian radio astronomers.

- The full complement of four staff members stationed in Hawaii was achieved. Section members working in Hilo for the JCMT are now considered a key part of the operation and maintenance team.

3.2 INSTRUMENTATION

- AOS-C: The Canadian acousto-optical spectrometer was delivered to Hawaii in August, and installed on the JCMT in November. It has greatly improved the quality of spectra, and is now the only reliable spectrometer on the telescope.

- Phase-Locked Local Oscillator for 330-360 GHz: All the required components for this system were ordered, and a computer program to remotely control it has been written.

- Planar Antennas for SIS Arrays: A scale model of a very efficient, extremely broad-band planar antenna has been constructed and tested. The interactions among several such antennas mounted together have been studied.

3.3 NEW OR IMPROVED TELESCOPE SYSTEMS

- QUASAT, a proposal to launch a satellite for very-long-baseline interferometry was not selected by the European Space Agency. Nevertheless, the work done by the RA Section and a private contractor supported by the Space Division left ESA with a very favourable view of Canadian capabilities. Discussions have begun with Soviet astronomers on the similar Radioastron.

3.4 SCIENTIFIC RESEARCH

- The proposal to survey the submillimeter spectrum of the envelope of the carbon star IRC +10216 has achieved long-term status on the JCMT. Approximately 8% of the spectrum has been surveyed and several unidentified lines have been detected.

- The nebula L723, which initially appeared to be quadrupolar, has been shown to be a bipolar nebula with a very large opening angle for its outflow lobes.

- Initial observations of asteroids with the JCMT have detected 11 objects, and spectra of several have been observed at five different wavelengths, including 350 microns, the shortest radio wavelength at which asteroids have been detected.

- The nearness of the large radio galaxy Centaurus A has made it possible for details of the spatial distribution of its molecular gas to be studied with the Very Large Array. A cloud of gas which is falling into the nucleus has been shown to be internal to the galaxy.

- A new system was installed on the ORSO photoheliograph for measuring the positions of solar events and for automatically acquiring preselected target areas on the sun. Software developed for the solar image-processing system is now making possible 2-dimensional spectroscopy of solar flares photographed at ORSO.

3.5 SCIENTIFIC INFRASTRUCTURE

- A new computer control and data logging system for the solar radio flux monitor was installed at ARO.

- An additional index of solar activity has been developed by combining observations from the flux monitor and the 32-element interferometer to eliminate the bright compact sources and provide a better measure of the widely distributed thermal activity.

4. <u>SITUATION ANALYSIS</u>

4.1 TELESCOPES AND FACILITIES

The high cost of posting Section members to Hawaii and Edinburgh has now been paid for the present three year cycle. However, in FY 90/91, additional funds will be required to move four people from Hawaii to Ottawa and a further four from Ottawa to Hawaii. Attempts will be made to spread out the postings over several years.

After 1½ years of operation, the JCMT is still not performing as well as it might, primarily because of a lack of low-noise receivers. If the SIS prototype receiver being built by HIA, Kent and RAL is successful, the most important frequency range will be covered with a competitive instrument.

4.2 INSTRUMENTATION

Proposals for new instrumentation for the JCMT are initiated in each of the three contributing countries, channeled through two committees of the JCMT, and then approved by the JCMT Board, before money from the Development Fund is finally granted. The six-month cycle of this process causes delays in obtaining approval and financing for instruments.

4.3 SCIENTIFIC INFRASTRUCTURE

The future of the solar radio program is tied closely to the future of ARO. If ARO continues to operate beyond March 31, 1990, as the result of outside financial support, it is expected that the solar radio telescopes will remain based at ARO and DRAO. If, however, ARO is permanently closed down, the solar flux monitor will have to be moved to a new location close to Ottawa, and the interferometer probably will be closed.

At present, there are four VP term positions to cover maintenance of the observatory until 1990 March 31. A committee with representatives from NRC, U. of Toronto, York U., EMR, and other Canadian institutions is exploring options for the future of ARO beyond this deadline.

5. ADDITIONAL RESOURCES REQUESTED

5.1 TELESCOPES AND FACILITIES

Financial

The requirement to move four families between Ottawa and Hawaii every three years, on the average, and to move one family between Ottawa and Edinburgh every three years, will cost approximately 10 x $30K = $300K for a three year cycle, or about $100K per year above the regular Section budget.

5.2 INSTRUMENTATION

Staffing

The highest priority staffing requirement in the Section is a continuing position for an electronics technologist to build electronic circuits for the JCMT.

Financial

$50K in minor capital to finish equipping the Section as a well-found laboratory for the JCMT.

5.3 SCIENTIFIC INFRASTRUCTURE

Staffing

- A one year term position in 1989/90 for a technologist who will have primary responsibility for the maintenance of the solar radio telescopes.

Financial

An additional $30K of minor capital is required for the solar astronomy budget for 1989/90 in order to purchase critical components for the solar radio upgrade (receiver components) and to purchase components for a mirror stabilization system for ORSO which will enable useful data to be taken on windy days.

- A client agency willing to pay the operating costs of ARO beyond 31 March 1990.

RADIO ASTRONOMY SECTION

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	24	23	23	23
VP Terms	4			
Expenditures ($K)				
• Operations	365	240	240	240
• Minor Capital	80	70	70	70
• Major Capital				
• Total Expenditures	445	310	310	310
Monies-In ($K)				
• Joint Research Projects	511			
• Contracts-In	5	5	5	5
• Financial Arrangements				
• Grants & Contributions				
• Rent	5	5	5	5
• Total Monies-In	521	10	10	10

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets				
Expenditures ($K)				
• Operations		100	100	100
• Minor Capital				
• Major Capital				
• Total Expenditures		100	100	100
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

RADIO ASTRONOMY SECTION

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
70000	5.5	155	30		185	5			5
71000	6	50	10		60				
75000	4	125	10		135	5			5
76000	8	25	30		55	511			511
77000	4.5	10	-		10				
TOTAL	28	365	80		445	521			521

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
70000									
71000									
75000									
76000									
77000									
TOTAL									

70000 Ottawa Research in Radio Astronomy [Activity I, Application 1] (new or improved telescope systems, scientific research)
71000 Solar Astronomy [Activity I, Application 1] (scientific infrastructure)
75000 ARO Maintenance [Activity IV, Application 1] (part of scientific infrastructure)
76000 JCMT Instrumentation [Activity IV, Application 1] (instrumentation)
77000 JCMT Support [Activity IV, Application 1] (telescopes and facilities)

DOMINION RADIO ASTROPHYSICAL OBSERVATORY

Section Head: L.A. Higgs

This group consists of 13 professional, 7 technical, and 4 support positions for a staff target of 24 on 1 April 1989.

1. ACTIVITIES

Each activity corresponds to one of the objectives. The activities are operating telescopes and facilities, developing instrumentation, implementing computing systems and data analysis, developing new or improved telescopes, conducting scientific research, and supporting the science infrastructure.

1.1 TELESCOPES AND FACILITIES (5.3 professional, 3.5 technical, 2.0 support, $200K)

DRAO is a National Facility for research in radio astronomy. Its principal instrument is an aperture synthesis telescope which now operates with four 9-m antennas on a 600-m east-west baseline, at two continuum frequencies (408 and 1420 MHz) and at 128 spectral-line frequencies around 1420 MHz.

The 26-m antenna of the Observatory serves as a complementary instrument for the synthesis array, providing information on the largest angular scales, to which the array is insensitive.

The present synthesis array is a unique facility for hydrogen-line spectroscopy and the study of low-brightness, extended regions of radio emission. It complements larger arrays, such as the U.S. Very Large Array, which do not provide information on spatial structures in the 0.1 to 3-degree scales to which the DRAO instrument is sensitive.

DRAO also operates a solar patrol telescope that makes daily observations at 10.7 GHz, as part of the HIA effort in monitoring the radio flux from the sun.

1.2 INSTRUMENTATION (0.8 professional, $50K)

Aside from the development work related to the synthesis telescope (1.4), Observatory staff are continually improving the instrumentation of the facility by adding new capabilities, or designing and developing better components and techniques. DRAO is a centre of expertise in aperture-synthesis techniques, radio-frequency and antenna engineering, correlation techniques, and the detection of weak signals. In FY 89/90, DRAO will start the development of correlators for the Radioastron project of the USSR, if the necessary resources are provided by the Space Division of NRC.

1.3 COMPUTING SYSTEMS AND DATA ANALYSIS (1.5 professional, 0.8 technical, 0.2 support, $120K)

Aperture synthesis requires major computer resources for image formation, image reconstruction (converting the observed image to that which would have resulted from a completely filled aperture), and image processing. DRAO provides expertise and software tools to users for all phases of the analysis.

1.4 NEW OR IMPROVED TELESCOPES (1.7 professional, 2.7 technical, 0.2 support, $190K)

DRAO staff members are in the process of expanding the synthesis telescope from four to seven antennas and to two polarizations. The expansion should be completed by 1991. The upgraded telescope will cut the time of an observation from 35 days to 12 days, double the sensitivity, and increase the dynamic range by a factor of at least ten.

Part of the work is being carried out in collaboration with universities (particularly the University of Alberta), which welcome the opportunity to provide graduate students with real problems and experience in modern technology.

1.5 SCIENTIFIC RESEARCH (2.7 professional, 1.4 support, $80K)

DRAO staff members have an active program of research in the areas particularly suited to the DRAO instrument, and have made substantial contributions to galactic astronomy.

1.6 SCIENCE INFRASTRUCTURE (1.0 professional, 0.2 support, $10K)

DRAO staff members participate broadly in professional affairs, serving as committee members of professional societies, acting as referees and editors, and organizing symposia.

As a visible NRC facility in a tourist area, the Observatory presents a modest public information program highlighting the role that NRC plays in supporting astronomical research in Canada.

2. FUTURE DIRECTIONS AND PRIORITIES

For the next two years, the first priority for DRAO will be the completion of the expansion of the synthesis array from four antennas to seven. During this period, the telescope will be kept operational but at a somewhat reduced level of activity. The second priority, over the next three years, will be the design and construction of a building addition that will provide laboratory, library and office space adequate for the requirements of the observatory for the next decade. The challenge in 1989/90 will be to arrive at a final design which meets DRAO's needs, especially that of maintaining a radio-quiet environment.

Growth of the DRAO radio-astronomy instrumentation laboratories, in close collaboration with Canadian universities, will be a goal for the next decade. The research in instrumentation carried out at DRAO is an important complement to the research in astronomy itself, in that both are necessary if a National Facility is to be kept at the research forefront.

As part of the instrumentation effort, DRAO is expecting to undertake a collaborative project with the Institute for Space and Terrestrial Science (ISTS) at York University to provide recording terminals and correlators for the Soviet Radioastron project that will put a radio telescope in earth orbit to be used with ground-based telescopes for interferometry. Canadian participation will be funded by the Space Division of NRC. The signing of an agreement between the Soviet Union and Canada covering many areas of co-operation in space research, approval by the Space Division, and a contractual agreement between the Soviet Institute of Space Research and DRAO+ISTS are prerequisites for this project to proceed.

In the decade following 1990, the expanded synthesis array will be used to its fullest potential in serving the user community, including mapping in a systematic way the northern Galactic plane.

During FY 89/90, detailed plans for a successor to the synthesis telescope will be finalized. The current design consists of 100 steerable 12 m dishes on fixed mounts spread over an area 2 km in diameter. The instrument's wide field of view and sensitivity to large-scale structure would fill the gap between the Very Large Array in the United States and single large dishes. The goal is to construct the new instrument over a 5-year period beginning in 1995.

The DRAO Users Committee established in 1988 will be a strong influence in determining future priorities.

Specific goals in the short and longer terms are:-

2.1 TELESCOPES AND FACILITIES

1989/90:

- shut down the four antenna array in December 1989 to prepare for the start of five-antenna observations in April 1990;
- construct and test the continuum correlator for the five-antenna synthesis array;
- complete the delay system for the seven-antenna array;
- connect the RF signals from the last two antennas to the telescope control building;
- design the prototype of the new ASIC-based spectral correlators;

- accept delivery of a new automated solar patrol telescope from the Radio Astronomy Section in Ottawa by March 1990;

- upgrade the motor control system of the 26-m telescope.

Longer Term:

- maintain regular operation of a reliable, well calibrated, facility for aperture-synthesis observations during the current expansion phase, now in its fifth year;

- maintain the 26-m radio telescope to complement the synthesis telescope;

- maintain an observational capability on the 26-m telescope for OH and H I lines;

- expand the synthesis array to seven antennas by installing three new antennas, along with new continuum and spectral correlators and all the other associated electronics; and

- bring the synthesis telescope into operation again as a fully functioning system. This will require the installation of greatly expanded computing facilities, consisting of a network of workstations clustered with a central node.

2.2 INSTRUMENTATION

FY 89/90

- design and construct a combined 18 cm and 21 cm receiver box with a wide-band feed for the 26-m telescope;

- complete agreements between NRC and IKI (Moscow), and between DRAO and ISTS on Radioastron;

- prepare new trailer accommodations and shielded laboratory space for three staff members of the Radioastron project; and

- hire new staff members for Radioastron.

Longer Term

- produce two correlators for Radioastron, one to be used in the Soviet Union, the other to be established in Canada as a facility for Canadian scientists using the instrument. The target for delivery of the correlators is early in 1993 for a launch in 1995.

The project must be fully funded by the Space Division, except for 0.5 PY which DRAO will contribute from its ongoing staff to this project.

2.3 COMPUTING SYSTEMS AND DATA ANALYSIS

FY 89/90

- study the feasibility of incorporating the large body of DRAO software into a standard, widely used software skeleton, such as AIPS or IRAF;
- install a powerful new UNIX workstation; and
- place an order for a new main computer for DRAO, for delivery early in FY 90/91.

Longer Term

- maintain and improve the user-friendly data reduction system.

2.4 SCIENTIFIC RESEARCH

- continue an active research program in the general area of the physics of the interstellar medium; and
- systematically map the northern Galactic plane, providing a database for future research. In the coming three years, two to three fields per year are targetted for publication, with the remainder of the 24 field survey being completed when the seven-antenna array is available.

2.5 NEW OR IMPROVED TELESCOPES

FY 89/90

- hold an international workshop to investigate the scientific potential and engineering problems of the proposed major new synthesis telescope.

Longer Term

- study the best tradeoff between scientific performance and engineering costs for a proposed new synthesis telescope for Canada, and lay the groundwork for initial feasibility studies.

3. RESULTS FROM THE PAST YEAR 1988/89

One of the largest problems facing DRAO staff over the past decade has been a critical shortage of laboratory, library and office space. With the approval of an expenditure of about $4.3M on a building addition, this difficulty finally has been addressed.

3.1 TELESCOPES AND FACILITIES

- Two of the operational targets noted in the last APR have been attained: (i) the array has been recabled and the construction of the continuum correlator has been contracted to industry; (ii) by the end of the current fiscal year antennas six and seven will be mounted and mechanically steerable.

- The 26-m telescope is now nearing 30 years of use and several sub-systems are in need of upgrading. In the past year, the computer control system has been replaced.

3.2 INSTRUMENTATION

- Most instrumentation effort has been devoted to the expansion of the synthesis telescope (3.5). In addition, a new broad band feed for the 26-m telescope was designed and developed.

3.3 COMPUTER SYSTEMS AND DATA ANALYSIS

- A software system for screen editing of synthesis telescope data was implemented on the VS 2000 workstation, and enhanced graphics software for the presentation of astronomical data was developed.

3.4 SCIENTIFIC RESEARCH

- Research programs continue to yield exciting new discoveries, facilitated mainly by the wide-field 408 MHz observations. In the past year, an extremely bright flaring radio source was detected in the Cygnus X radio complex, and two new morphological types of radio source were found in the same general region from follow-up observations made using the U.S. Very Large Array. One probably is the result of a stellar wind and the other may represent a supernova remnant with a bipolar structure.

- In 1985, the staff of DRAO began a long range program of systematic observations of the northern Galactic plane, involving 408 MHz and 1420 MHz observations at 24 field centres. To date, four of these have been observed and two papers are in press.

4. SITUATION ANALYSIS

The major factor affecting the planning and operation of DRAO, especially the development of the observational National Facility, is still the lack of adequate staff. The effective operation of the existing four-antenna array requires at least two additional permanent staff members and the expanded array will probably require a further two. The provision of two, two-year term positions starting in 1988 has improved the manpower situation during the building phase but the staffing situation must still be described as critical.

The research effort of the Observatory is increasingly being eroded by commitments to the operation and upgrade to the Facility. A balance must be found that keeps the scientific staff active in research while providing the required services to the telescope users.

The protection of the radio quiet environment of DRAO will be greatly enhanced if the land transaction, now in the final stages of contract negotiation, comes about. This will prevent development in the major portion of the White Lake Basin.

5. ADDITIONAL RESOURCES REQUIRED

5.1 TELESCOPES AND FACILITIES

Staffing

April 1989: A telescope operator/computer analyst. A second telescope operator is urgently needed to provide back-up to the current operator/analyst to allow continuous telescope operation with ongoing software development. A person is currently filling this role in a 4-month casual position. Although an ongoing position is needed, even a one-year term would speed the upgrade. (Priority 1)

April 1990: An electronic/electrical technologist. The Observatory is critically short of technologists in all areas of expertise. The most urgent need is someone for general electronics and electrical work to ensure smooth operation of the facility and adequate receiver maintenance. (Priority 2)

April 1990: A digital engineer. An engineer on a two-year term appointment is currently taking a large portion of the development load in the area of digital electronics but there will be a continuing need for an engineer after the telescope enters into its operational phase. (Priority 3)

Financial:

A careful analysis of the funding requirements for a national facility of the complexity of DRAO indicates that effective operation of the seven-antenna array is impossible below a funding level of $380K for operations and $190K for minor capital beginning in FY 92/93. Leading to this level state, the following funds are needed to complete and commission the array:

	FY 89/90	FY 90/91	FY 91/92	FY 92/93
Operations	$350K	350K	360K	380K
Minor capital	175K	175K	180K	190K

A survival status, that does not take full advantage of the investment in the expanded array, can be maintained with

Operations	$320K	310K	330K	340K
Minor capital	140K	150K	160K	170K

5.2 INSTRUMENTATION

Staffing

April 1990: A digital technologist. A two-year term position for a digital technologist has eased somewhat the serious manpower problem in the area of digital electronics, but a synthesis telescope depends upon complex digital instrumentation. There is an ongoing requirement for at least one (and probably two) digital technologists. (Priority 2)

5.3 COMPUTING SYSTEMS AND DATA ANALYSIS

Staffing

April 1989: A computer analyst. The present manager of the DRAO computer systems will reach retirement age in April 1990. We would like to hire his replacement with one year of overlap to maintain continuity. This is a very important position in the DRAO organization and great care must be taken in the selection of a successor. Consequently a bridging position for one year is requested. (Priority 1)

DOMINION RADIO ASTROPHYSICAL OBSERVATORY

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	24	22	21	21
Expenditures ($K)				
• Operations	320	310	330	340
• Minor Capital	140	150	160	170
• Major Capital	190	500		
• Total Expenditures	650	960	490	510
Monies-In ($K)				
• Joint Research Project				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Rent	5	5	5	5
• Total Monies-In	5	5	5	5

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets	2			
Expenditures ($K)				
• Operations				
• Minor Capital				
• Major Capital				
• Total Expenditures				
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

DOMINION RADIO ASTROPHYSICAL OBSERVATORY

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

		EXPENDITURES				RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
20000	5.3	80	10		90				
25000	18.2	240	130	190	560	5			5
26000	.5								
TOTAL	24	320	140	190	650	5			5

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

		EXPENDITURES				RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
20000									
25000	2								
26000									
TOTAL	2								

20000 DRAO Research in Astronomy [Activity I, Application 1]
(scientific research and scientific infrastructure)

25000 DRAO a National Facility [Activity IV, Application 1]
(telescopes and facilities, instrumentation, computing systems, data analysis and new or improved telescopes)

26000 DRAO Radioastron Correlator [Activity IV, Application 1]
(part of instrumentation)

SUPPORT OF SOLAR-SYSTEM PHYSICS

PREAMBLE

Charged particles and magnetic fields ejected from the sun interact with the earth's upper atmosphere to cause aurorae and magnetic storms. These interactions are particularly intense in the auroral oval which is located about 20° from the north magnetic pole and stretches across Canada from the Yukon to Newfoundland.

Rockets, satellites and ground based measurements are used to study these effects. Now that the rocket range at Churchill has been closed, Canadian scientists are totally dependent on international collaborations for all space missions, except for a few rocket flights in which Canada has paid for the launch costs at a foreign range. Typically a satellite experiment takes 10 to 15 years from conception to publication of the data, and a rocket experiment 4 years, while ground-based arrays have a useful life in excess of 10 years.

The research community in Canada consists of some ten small groups in universities across the country, plus the two Sections now in HIA. These HIA Sections have made major contributions to Canada's reputation for science in space, and have collaborated extensively with university researchers in assembling teams of sufficient size to participate in large international projects.

The planning for space science in Canada, the funds for industrial contracts to design and build the hardware, and the management of projects is provided by the NRC Space Division under the terms of the government's Space Plan. A central core of scientific expertise is provided by HIA.

The two Sections in HIA often work together on the same project, but the nature of the phenomena between the earth and the sun, and the differing techniques used to study them have led to different emphases.

The Solar-Terrestrial Physics Section studies the more distant interplanetary medium and magnetosphere where measurements can be made in situ with satellites.

The Planetary Sciences Section studies the upper atmosphere nearer the earth, which is not directly accessible to satellites. Here, remote sensing techniques and rocket experiments are very effective.

The ionosphere which lies between is naturally the subject of joint study by the two sections because it is the boundary layer that couples the two regions.

Both sections are located on Sussex Dr. in Ottawa.

OBJECTIVES

- To provide scientific and technical support to facilities maintained by NRC for university scientists studying solar-terrestrial and upper atmospheric phenomena;

- To provide a core of federal government expertise in a field of national importance;

- To provide access to international space research through joint participation with foreign laboratories in international programs;

- To provide expertise to Canadian industry in the development of instrumentation for space science;

- To provide a national centre of expertise in solar-terrestrial and upper atmosphere physics, whose staff can maintain continuity and join with university groups in teams large enough to participate in major projects.

PLANETARY SCIENCES SECTION

Section Head: A.G. McNamara

This group consists of 9 professional, 9 technical, for a staff target of 18 on 1 April 1989.

1. ACTIVITIES

1.1 OPTICAL AURORA, AIRGLOW, AND MAGNETOSPHERIC PROCESSES (4 professional, 4.5 technical, $100K)

1.1.1 CANOPUS: The Canopus ground network is part of the Canadian Space Program. It will be used on many international projects, including the International Solar-Terrestrial Physics (ISTP) program in which NASA, ESA, Japan and the Soviet Union will launch satellites from 1992 to 1996. This will be the most important study of the magnetosphere to date and the major effort of the next decade. The data from ground based arrays are crucial in the full interpretation of multi-satellite observations.

Section staff are part of the University/NRC/EMR science team responsible for the science planning of Canopus. One Section member is the overall Project Scientist and three others have major responsibilities for BARS (Bistatic Auroral Radar System), MPA (Meridian Photometer Array), DCS (Data Collection System), and for the interpretation and monitoring of the incoming data streams.

1.1.2 SONDRESTROM RADAR/OPTICAL GROUND CAMPAIGN: This project is based on the incoherent scatter radar facility at Sondre Stromfjord in Greenland and its associated optical observatory. The Section has been involved with a joint program of optical observations with the University of Michigan since 1983.

1.1.3 SATELLITE AURORAL IMAGERS: The Section has played an important role in the development of UV satellite cameras with fast time resolution for two magnetospheric satellites. The first was the Swedish scientific satellite, Viking, which flew in 1986 and the second is the Soviet Interball polar mission to be launched in 1991. The Space Division has given preliminary approval for a similar camera to be flown on the Swedish satellite, Freja, designed to give more direct correlation between the fine structure of the aurorae and the incoming particle streams. These are joint projects with Canadian university scientists.

1.1.4 WINDII - a wind imaging interferometer - is designed to fly on the NASA UARS satellite in 1991, which will obtain simultaneous measurements of key atmospheric parameters including wind, temperature, and composition over a wide range of altitudes. WINDII will provide the data for the upper end of the altitude range.

1.1.5 WAMDII - a wide angle Michelson Doppler imaging interferometer - is designed to fly on the Shuttle in 1991. It will measure atmospheric winds, temperatures, and emission intensities over a period of a few days with very high spatial and temporal resolution to study both large and small scale features in the mesosphere.

1.1.6 GEMINI is a new component of our continuing aeronomy program. The name for this rocket has been derived from the basic objectives, the study of General Excitation Mechanisms in NIghtglow. The Science Team involves personnel from the Universities of Saskatchewan and California at Berkeley, with HIA in the lead role. The major funding for the program will be provided by the NRC Space Division, leading to a launch from White Sands in the fall of 1992.

The Gemini experiment is intended to develop a rocket instrument for high resolution airglow and auroral spectroscopic imaging and to use that technology to further our understanding of the chemistry of the quiet, terrestrial lower thermosphere, and improve our capability to provide imaging detectors for orbital flights.

1.2 IONOSPHERIC PLASMA MICROSTRUCTURE AND INSTABILITIES' AND IONOSPHERIC-MAGNETOSPHERIC COUPLING (3.5 professional, 4.5 technical, $80K)

Plasma instabilities in the ionosphere are driven by electric fields and current flows. These instabilities generate micro-scale irregularities ranging from centimeters to meters in the electron density.

1.2.1 BARS (Bistatic Auroral Radar System) consists of two unattended, computer controlled,continuously operating radars located at Nipawin, Saskatchewan, and Red Lake, Ontario. Each radar measures the position and Doppler shift of the auroral scattering centres in its beams. The data result in a high resolution (20 km x 20 km) map of ionospheric-magnetospheric electric fields over an area of nearly 200,000 square km at intervals of 30 seconds.

The major objective is to map electric fields for correlative studies with spacecraft observations. Another goal is to understand the complex plasma mechanisms causing the auroral scattering in the E-region.

1.2.2 ROCKETS: Plasma probes in rockets have been built for the direct measurement of plasma density fluctuations. These experiments are carried in NASA payloads called ERRRIS for launches in Sweden in 1988 and 1989. The project is designed specially for radar aurora studies and is supported by simultaneous coherent and incoherent radars operated by Cornell University and by EISCAT.

Similar plasma probes have been built for the Canadian Oedipus-A and -B rockets each consisting of a 1 km tethered double probe to measure natural and artificial stimulation of the plasma medium. These will be launched in Norway in 1989 and 1991.

1.2.3 Ultra-low-frequency (ULF) waves are hydromagnetic waves in the ionosphere-magnetosphere system which transmit significant amounts of energy from the magnetosphereic cavity to the ionosphere where it is dissipated in Joule heating. The purpose of these studies is to understand this mechanism of energy flow as a part of the solar-terrestrial energy budget. Both theoretical and observational work is underway in collaboration with DSIR New Zealand, and Canadian colleagues.

1.2.4 WISP/HF - This is a waves-in-space-plasmas instrument, built for NRC by Canadian Astronautics Limited, and will be launched on the Shuttle as part of the test of the Orbital Maneuvering Vehicle in 1995.

1.3 COMETS AND METEORS (1.5 professional, $30K)

The overall scientific objective is to understand the significance of the smaller members of the solar system, particularly comets and asteroids. There is increasing evidence that their interactions with the earth have had a crucial effect on the origin and development of life on earth.

1.3.1 COMETS: The objective of this program is to determine the physical properties of comets from high-resolution CCD images recorded with the Canada-France-Hawaii Telescope. Direct analysis, modelling, and correlation with ground-based and spacecraft data are employed to deduce the morphology, kinematics, and production rates of gas and dust.

1.3.2 ASTEROIDS: This recent program in collaboration with the Radio Astronomy Section is a JCMT study of the surface properties of asteroids, particularly their thermal properties and mechanical conditions. It complements our studies of large meteoritic bodies since asteroids are recognized as the parent bodies of meteorites.

1.3.3 METEORS AND METEORITES: Debris from comets and asteroids is observable on the Earth as meteorites and meteors, particularly meteor showers. Physical properties and statistics of occurrence are determined.

2. FUTURE DIRECTIONS AND PRIORITIES

Collaboration with foreign scientists is essential if Canadians are to participate in space missions and to have access to the diverse array of sophisticated instruments required to study complex geophysical phenomena. Therefore, first priority must go to keeping our existing international commitments to both the schedules and the performance of the equipment we provide.

The international agreements include the Interball and Freja Imagers, the ERRRIS and Oedipus and Gemini rockets, the shuttle flights of WINDII and WAMDII, and the data analysis for Viking.

The Section's support of Canopus also must continue; it represents a commitment to a large group of Canadian university scientists, as well as being an essential component of all the international solar-terrestrial satellite programs in which Canada is participating.

The current projects occupying a major portion of the staff and financial resources are (1) Canopus, (2) Viking+Interball+Freja, and (3) the rocket payloads ERRRIS, Oedipus and Gemini. Canopus and Viking+Interball+Freja have about 10 year lifespans and ERRRIS and Oedipus about two or three years. All of these are cooperative projects with Canadian universities and/or foreign countries. As the shuttle launches of WINDII, WAMDII, and WISP approach, some effort will return to writing software for operations and data analysis.

Active accumulation of meteor data has been terminated and some final comet observations are being made at the CFHT. These areas of research will be phased out over the next five years as the analysis and publication of the results are completed.

At present the only new project undertaken is an imaging spectrograph to observe airglow on the Gemini mission.

2.1 OPTICAL AURORAE

FY 89/90

- High priority will be given in 1989 to completing the installation of the Canopus instruments, and acquisition of data from all sites. Field calibration of the Canopus photometers is to be undertaken to ensure that the measured intensities are accurate. Cooperative measurements will be made with the Japanese satellite EXOS-D which will be launched in February 1989 and will be viewing the northern polar cap in the fall of 1989.

  The Canopus DCS software must be converted to run under Version 5 of the operating system.

- Construction of the Interball imager is well under way by the prime contractor, Canadian Astronautics Ltd.

- The Gemini imager optics will be optimized and mechanical and electronic designs will be completed. Some of the fabrication work will be submitted to the HIA machine shop. Additionally, long-lead-time components will be ordered as funds become available. Some imager assembly could occur and development of the science instrument software will begin.

2.2 IONOSPHERIC PLASMA

FY 89/90

- The BARS radars have been operational in the standard background mode for nearly two years. During 1989, particular effort will be directed toward achieving improved reliability for the EXOS-D campaign period.

- Digitized data from the 1988 cooperative radar campaign with the University of Saskatchewan will be used to study the radar frequency dependence of the Doppler shift of type III echoes.

- Using Canopus BARS data, we will study events having a range-time-intensity signature which suggests a relationship with ULF waves.

- The second ERRRIS rocket campaign for the study of radar aurorae, will be conducted in Sweden with two payload launches during February and March 1989. Data analysis will commence as soon as the digital telemetry tapes are received from NASA - probably in early summer.

- The Oedipus-A launch is scheduled from Norway during January 1989. Analysis of the data will start as soon as possible because any modifications seen to be necessary for the Oedipus-B launch in 1991 must be known early in the schedule.

2.3 COMETS AND METEORS

FY 89/90

- CFHT data obtained on comets will be analyzed in four areas: the onset of coma development in Comet Halley, Comet Halley near opposition in November 1985, dust in Giacobini-Zinner, Comet Halley at large heliocentric distances, both pre- and post-perihelion. Other studies will include our observations of several faint comets covering a wide range of activities near the cometary nucleus.

- More observations of asteroids are scheduled in 1989 using the JCMT at millimeter wavelength.

- Analysis of the MORP fireball data from 1971-1985 will continue. Theoretical calculations and computer modelling of comet streams is in progress in cooperation with several Czechoslovakian and Canadian institutions.

3. RESULTS FROM THE PAST YEAR 1988/89

3.1 OPTICAL AURORAE

- The full complement of four meridian scanning photometers of the Canopus array were in operation during the past year and data were collected via satellite telemetry. Much of the software development during the year was concerned with data from a single station. The concepts for the expansion to merged multi-station data and some associated code were developed.

- The contractor's DCS software proved to be unsatisfactory, so that a new program with enhancements to the monitoring capability was written by HIA staff.

- In the analysis of Viking results steady progress has been made in developing software for quantitative interpretation of the image pairs from the two cameras. The comparison between visible region spectral ratios observed from the ground with Canopus photometers and the ratios in the signals from the two cameras has made for two good ground-satellite simultaneous observations.

- The Viking camera design was analysed to determine the best choice of photocathode and filter for use in the Interball imager and recommendations were made to the contractor.

3.2 IONOSPHERIC PLASMA

- BARS was operating well during the first half of 1988. In June, a severe lightning strike on the power line at the Red Lake radar did a lot of damage to the equipment, and partial operation was not restored until September. An intermittent problem still continues in the VAX computer on site.

  A number of papers on the radar scattering characteristics have resulted from the analyses of BARS and of campaign data by scientists at HIA, the University of Saskatchewan, and the University of Western Ontario.

- Our cooperative radar campaign in August 1988 in Manitoba was carried out and digitization of the data is now under way at the University of Saskatchewan.

  Three manuscripts reporting results obtained during previous CW radar campaigns have been submitted for publication and one is now in press.

- One paper on the ULF work is now in press and another will be soon.

- Preliminary analysis of plasma probe data from the 1988 ERRRIS rocket flight is nearly completed in cooperation with the NASA project scientist. Instruments for the second ERRRIS campaign were built and have been shipped to Sweden. The Oedipus-A plasma probe experiemnt was also built and sent to Norway.

- An on-board imager was built for the Oedipus payload. It employs an intensified CID TV camera mounted on the aft payload. This TV experiment may lead to the use of a relatively inexpensive means of determining aspect of sounding rockets.

3.3 COMETS AND METEORS

- The CFHT database obtained on Comets Halley, Giacobini-Zinner and others is now being analyzed. Progress has been made on calibration and reduction of the images.

- In August 1988, five asteroids were observed at 1 mm wavelength using the JCMT with useful results.

- Analysis of the large data base on meteor fireballs has revealed that a high proportion of meteorites are from recognizable asteroids.

  Three papers were published in 1988 and five more are in press for 1989.

4. SITUATION ANALYSIS

The Section's current and future projects are clustered around two major themes: the optical studies of upper atmospheric emissions, and the electromagnetic studies of the auroral and magnetospheric plasma. There are four scientists working on optical auroral projects and four, including an RA, on auroral plasmas.

The sizes of these groups are barely adequate for the tasks of simultaneously managing the facilities and maintaining scientific credibility through active scientific research. The current staff levels must be maintained in these areas, and proper credit must be given to individuals who sacrifice personal publications in order to support the facilities.

Although the presently available resources roughly balance the Section's commitments, significant swings are likely in the future. Because of both the hazardous nature of space flights and the erratic scheduling and funding of space ventures, all planning contains major elements of uncertainty.

Since Canada has no launch capability of its own, Canadian scientists are almost totally dependent on the whims and budgets of their international partners. To ensure a lively future for Canadian space science, the Section must respond to all appropriate missions by joining science planning groups and working on several design teams knowing that very few will result in flights.

4.1 OPTICAL AURORAE

- Canopus continues to be a major load for the four scientists involved in the daily monitoring of the health of the MPA and BARS instruments and the integrity of the data. The greatest load is in the development and maintanance of Canopus software.

- There is a potential shortage of scientific manpower in Canopus. Section scientists associated with the MPA and BARS are working almost exclusively writing software, overseeing data collection and archiving. When the relevant satellite projects reach the data taking stage, full participation in the magnetospheric-ionospheric science will require a group of scientists with available time.

- The staff needed to analyse the results from the Viking imager is not sufficient. Consequently, the initial financial and scientific investment in the program is unlikely to provide the return to NRC which could be realized. Proper use of the Viking results demands the efforts of at least two research associates dedicated to interpretation of the images.

- Before submitting the Gemini proposal, an extensive analysis was made of the impact of the proposal on the Section's resources. The main requirement was for technical officers, of which we had an adequate number with the appropriate skills. The Space Division is buying the hardware. The additional travel can be handled within the present sectional budget. GEMINI will use five Technical Officer PY's and between one-half and one Research Officer PY in 1989.

4.2 COMETS AND METEORS

The Section recognized some four years ago that it would have to discontinue its meteor work in order to give priority to space activities. First the meteor radar and optical observations were terminated and the Shiels and Springhill sites closed. Then the prairie meteorite network (MORP) of 12 stations was closed.

Currently, the equivalent of 1.5 scientists are making the final observations of comets with CFHT, and are analyzing the large libraries of meteor and MORP data. Recently one of the meteor scientists has been spending a large fraction of his time with the Canopus project.

5. ADDITIONAL RESOURCES REQUESTED

The most urgent future problem is that four of the eight scientists will probably be retiring within the next five years. Replacements must be planned. It takes time to fill a vacated position with a recruit of the desired quality. What is needed is the flexibility to anticipate a vacancy by hiring a good recruit if one becomes available.

A related problem is the need to get young scientists into the Section to provide the stimulus and vigor of youth. The youngest permanent scientist in the Section is now 51 years old! The situation should be remedied with the replacement of retiring staff in the next few years.

The current level of financial support appears to be adequate for all sectional activities. Additional RA PYs are desirable as noted below.

5.1 OPTICAL AURORAE

Two new Research Associates to add to the present four Research Officers.

5.2 IONOSPHERIC PLASMA

One new Research Officer to add to the present three Research Officers and one Research Associate.

PLANETARY SCIENCES SECTION

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	18	17	17	17
Expenditures ($K)				
• Operations	175	175	175	175
• Minor Capital	35	35	35	35
• Major Capital				
• Total Expenditures	210	210	210	210
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets				
Expenditures ($K)				
• Operations				
• Minor Capital				
• Major Capital				
• Total Expenditures				
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

PLANETARY SCIENCES SECTION

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
80000	18	175	35		210				
TOTAL	18	175	35		210				

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
TOTAL									

80000 Planetary Science Research [Activity I, Application 1]

SOLAR TERRESTRIAL PHYSICS SECTION

Section Head: J.R. Burrows

This group consists of 12 professional, 6 technical, for a staff target of 18 on 1 April 1989.

1. ACTIVITIES

1.1 GLOBAL MAGNETOSPHERIC PHENOMENA (6.1 professional, 2.7 technical, $170K)

1.1.1 MAGNETOSPHERIC ION COMPOSITION: A study of the sources, energization and transport of magnetospheric plasma inferred from satellite measurements of ion composition, energy spectra, and flux anisotropies, particularly at middle and high latitudes.

These investigations depend on data from NASA's Dynamics Explorer 1 satellite, the NRC Suprathermal Ion Mass Spectrometer (SMS) launched in February 1989 on the Japanese EXOS-D satellite, and a proposed Cold Plasma Analyser for the Swedish Freja satellite to be launched in 1992.

1.1.2 ELECTRIC CURRENTS IN THE MAGNETOSPHERE: A study of the large scale electrodynamical coupling of the magnetosphere and ionosphere by currents at auroral and polar latitudes, inferred from magnetic field measurements made in situ by satellites, and remotely by the Canopus array of ground instrumentation.

1.2 SMALL-SCALE PROCESSES IN THE IONOSPHERE AND MAGNETOSPHERE (1.6 professional, 0.7 technical, $30K)

1.2.1 COUPLING PROCESSES: A study of the interface region between the ionospheric and magnetospheric plasmas by in situ measurements from sounding rockets, to determine the role of electric fields and plasma wave instabilities in coupling the two plasmas at the interface. This study consists of two NRC rocket campaigns in Norway, named Oedipus A and B, in 1989 and 1991.

1.2.2 E REGION INSTABILITIES: A study of wave-particle interactions between intense meter-scale plasma waves and ambient and precipitating ions and electrons in the upper electrojet region (110-120 km), by in situ measurements from sounding rockets, and remote radar measurements. This study, named ERRRIS, consists of two NASA campaigns in Sweden, in 1988 and 1989.

1.3 COSMIC RAYS OF GALACTIC AND SOLAR ORIGIN (4.3 professional, 2.6 technical, $100K)

1.3.1 HELIOSPHERIC MODULATION: A study of how cosmic rays from galactic sources are affected by the interplanetary magnetic field as they propogate through the heliosphere to the earth's orbit. Measurements spanning several solar cycles continue with neutron monitors at three Canadian sites, and since 1976 with a horizontal muon hodoscope in Ottawa.

1.3.2 THE THREE-DIMENSIONAL HELIOSPHERE: An NRC instrument in the Ulysses spacecraft will measure the propogation and acceleration of solar cosmic rays during a five year mission, out to Jupiter and over the poles of the sun, where no spacecraft has been before.

1.3.3 ACCELERATION MECHANISMS IN SOLAR FLARES: A joint NRC and University of Chicago instrument will measure the isotopic composition and energy spectrum of solar cosmic rays, using the TIROS-I satellite in a low altitude, polar, geocentric orbit. Variations in the isotopic abundance will be used to infer properties of the solar flare sites and acceleration processes. The three year mission will be launched in late 1990 or early 1991.

2. FUTURE DIRECTIONS AND PRIORITIES

The Section's future direction and priorities are: (1) to maintain and enhance viable research groups in each of the three areas of solar-terrestrial research where the section currently has internationally recognized expertise; and (2) to maintain a balance between participation in international collaborations and purely Canadian projects.

The rationale and implications of these goals are discussed more fully in the Situation Analysis, section 4.

2.1 GLOBAL MAGNETOSPHERIC PHENOMENA

FY 89/90

- Studies of magnetospheric ion composition will give priority to the EXOS-D satellite while studies with the older Dynamics Explorer data will continue as manpower permits. Nearly a year will be needed to shake down data processing and achieve a good understanding of the SMS instrument's measurements.

- During FY 89/90, the Section will complete the design phase of the proposed Cold Plasma Analyzer for the Swedish Freja satellite.

- In the Section's support of the Canopus array, the priority item is completing fabrication, calibration and deployment of magnetometers to the twelve sites. Anomalies in the operation of the riometers and tellurometers must also be resolved. All instrumentation must be operational to support correlative studies with the EXOS-D satellite in the fall of 1989.

- Planning for the proposed Focus mission with the US Air Force Geophysical Laboratory (AFGL) will continue at a low level. Focus is a small satellite for magnetospheric studies at high latitudes. If approved by NASA, AFGL and NRC, it likely will follow the Freja mission.

Longer Term

- Analysis of EXOS-D data will continue for about three years after the 1989-91 operational phase is completed.

- The launch of the Freja satellite is currently scheduled in 1992. This activity will demand more of the section's staff during the 1989-91 period.

- Further correlative studies between CANOPUS and the EXOS-D and Freja missions are projected for 1990-1993, and with satellites in the International Solar-Terrestrial Program during 1993-96.

2.2 SMALL-SCALE PROCESSES IN THE IONOSPHERE AND MAGNETOSPHERE

FY 89/90

- The main emphasis will be on analysis of data from the ERRRIS and Oedipus-A rockets during 1988 and 1989. Work will start on instrumentation for the Oedipus B 1991 rocket campaign.

2.3 COSMIC RAYS OF GALACTIC AND SOLAR ORIGIN

FY 89/90

- A prime goal is to maintain the quality of data from the three remaining neutron monitor stations at Goose Bay, Inuvik, and particularly from the Deep River site, since its data are sent monthly to the World Data Center A for Solar-Terrestrial Physics for publication and global distribution.

  As soon as manpower is available, a design will be developed and prototyped for a data-readout based on a micro-computer to replace the twenty-five year old punch paper tape. The planned system includes telephoned data transmission directly to a computer in Ottawa, which will significantly reduce manpower requirements for data processing in future.

  Consultations with DOE/AES will be undertaken for the permanent closing and dismantling of the Alert station site.

- Preflight preparations for the Ulysses mission will continue in Europe and will consume about one person-year of effort.

- Calibration, spacecraft integration tests and software development are the principal activities planned for the TIROS-I solar flare particle experiment during 1989-90. These will require about a two PY effort.

- Work on the Sudbury Neutrino Observatory is expected to continue at a low level during 1989-90. The section's contribution is in the planning of quality control and background radioactivity in project materials. Project activity beyond 1990 is uncertain.

- In order to check the effects seen during the past solar cycle operation and analysis of data from the horizontal muon hodoscope for galactic cosmic ray measurements will continue at a 0.2 PY level until the end of FY 1995/96, beyond the next reversal of the solar magnetic field. Dr. Bercovitch will continue to supervise its operation and do the data analysis as a guest worker after his retirement.

Longer Term

Following the scheduled October 1990 launch of Ulysses, data processing and scientific analysis should proceed at a level of two PY/year for the five year duration of the mission, in order to obtain a significant scientific yield from this project, to which NRC has been committed since 1977. However, it is unlikely that more than one person-year/per year can be allocated from the section's present staff.

Following launch of the TIROS-I satellite in 1990 or 1991, operations and scientific analysis will require about one PY/per year for the three year mission and one year post-mission period.

3. RESULTS FROM THE PAST YEAR 1988/89

3.1 GLOBAL MAGNETOSPHERIC PHENOMENA

- The Suprathermal Ion Mass Spectrometer (SMS) was completed, flight qualified, calibrated and integrated into the Japanese EXOS-D satellite for launch in early 1989.

- Mission planning and instrument definition studies of the proposed joint Focus mission were continued by staff in HIA, the Space Division, and Canadian universities.

- A proposal to provide a cold plasma analyzer for the Swedish Freja satellite was prepared jointly by HIA and the University of Saskatchewan staff and submitted through the Space Division to the Swedish Space Corporation. It has accepted the proposal, subject to final mission approval. Instrument design studies are underway.

- Four magnetometers have been installed at Canopus sites during 1988 and software for data analysis continues to be developed.

3.2 SMALL-SCALE PROCESSES IN THE IONOSPHERE AND MAGNETOSPHERE

- All instrumentation was completed and integrated into the rocket for the Oedipus A campaign of January 1989.

- All instrumentation was completed and integrated into the two rockets for the ERRRIS campaign of February, 1989.

- Preliminary analysis of the data from the 1988 ERRRIS sounding rocket has been completed in co-operation with co-investigators from NASA and Cornell University.

3.3 COSMIC RAYS OF GALACTIC AND SOLAR ORIGIN

- The flight spare unit of the cosmic ray experiment for the Ulysses mission was reassembled and tested, following extensive rework of its Data Processing Unit. Requalification of the unit and integration into the engineering model spacecraft is scheduled for March, 1989.

- Design, construction and calibration of the prototype detector system for the TIROS-I satellite have been successfully completed. Some flight hardware has been delivered to the University of Chicago and the remainder is scheduled for early 1989.

- Data processing for the neutron monitor at Alert was suspended in August, 1988, due to a lack of personnel to cope with equipment malfunctions at the station.

4. SITUATION ANALYSIS

The Section's work has been driven strongly by four negative and one positive factor. The negative factors are

1) the complete absence of any Canadian programmatic framework for conducting solar-terrestrial research in space from the takeover of DRB/DRTE by DOC in 1969 until the formation of the Canada Centre for Space Science (CCSS) in 1980.

2) the closure of the Churchill Research Range in 1984 which seriously disrupted independent Canadian research of the upper atmosphere and near space environment at auroral and polar latitudes;

3) the Challenger space shuttle accident in January, 1986, which has delayed the launch of the Ulysses mission, and is still causing uncertainty in NASA's planning of various future international programs in which the section might participate;

4) the staff attrition which has hampered work efficiency, contributed to serious work overload and resulted in considerable staff stress and symptoms of burnout.

The one positive factor is the establishment of the CCSS, which later became part of the Space Division; it has permitted new planning initiatives and the gradual build-up of new research projects to the point where scientific productivity and publication should start to grow in the next two years.

Finding Room for Science

During the past four years, STP staff have been almost entirely occupied in preparing instrumentation for three international satellite missions and three bilateral rocket campaigns, and in implementing the instrumentation and software components of the Canopus network. Work on the ground-based cosmic ray equipment has been restricted to a bare minimum of maintenance and routine data processing. Only a small amount of the staff's time has been available for data analysis and scientific interpretation.

Balancing International and Domestic Projects

A suitable balance between international and domestic projects is an important factor in planning viable research for the Section. Most programs for study of the space environment require international collaborations, because there is no domestic capability for launching satellites or sounding rockets. Consequently, it is essential to have critically sized groups that can maintain a world-class capability, both scientifically and technologically, in those areas of space research which the section has developed during the past two decades.

However, domestic projects are also important because greater control is possible in selecting research objectives, in scheduling projects and in committing resources. One such major project is the Canopus network, maintained by NRC for university and government scientists studying solar-terrestrial phenomena. The Section provides scientific and technical support to some of the facilities. Other smaller projects are the horizontal muon hodoscope and the ground-based neutron monitoring stations.

Staff Concerns

The average age of the Section's 17 continuing staff has decreased slightly from 50.0 one year ago, to 49.7 at 1 June 1989, but 10 staff are aged 50 to 57. This situation has implications for the planning of future research, when projects typically have a time scale of 10 years. This age distribution already is resulting in an increased incidence of physical impairments, which limit the type of work assignments and decrease working efficiency.

During the past few years, work requirements have resulted in a number of staff deferring or limiting vacation leave. At present, five of the staff have more than 50 days of leave credits with an aggregate total of over 400 days. This situation will tend to constrain the capability of the Section to respond to any further emergency situations related to project deadlines.

5. ADDITIONAL RESOURCES REQUESTED

The team of NRC/HIA laboratory personnel engaged in the technical and scientific development of space instrumentation is of a sub-critical size, compared to similar laboratory groups in other countries. In order to maintain the momentum of current initiatives, two additional continuing positions are needed in the group; the first for a technical officer and the second for an engineer.

Solar-terrestrial research requires instrumentation carried on satellites and sounding rockets which is never available commercially. An in-depth capability is needed in-house for considerable development before contracting out flight hardware construction to Canadian firms.

A wide variety of special problems must be solved in designing a scientific instrument to function in the space environment and within a particular spacecraft. The present small team of scientists and technologists cannot maintain adequate expertise in all of the areas, and at the same time cope with the extreme peaks in work loading that occur as the result of the rigid demands of the spacecraft schedules.

The firms who undertake instrumentation contracts cannot provide an adequate core of basic expertise because of their endemic staff turnover problem. An adequate core of technological expertise must be maintained within the NRC laboratories if a viable activity in space instrumentation is contemplated for the long term.

SOLAR-TERRESTRIAL PHYSICS SECTION

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	18	18	18	18
Expenditures ($K)				
• Operations	250	250	250	250
• Minor Capital	50	50	50	50
• Major Capital				
• Total Expenditures	300	300	300	300
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets				
Expenditures ($K)				
• Operations				
• Minor Capital				
• Major Capital				
• Total Expenditures				
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

SOLAR-TERRESTRIAL PHYSICS SECTION

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
50000	18	250	50		300				
TOTAL	18	250	50		300				

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
TOTAL									

50000 Research in STP [Activity I, Application 1]

SUPPORT OF MOLECULAR SPECTROSCOPY

PREAMBLE

The interpretation of observations of stars, the interstellar medium, planets and the atmosphere of the earth all depend heavily on the basic understanding of the spectroscopy of the gaseous species present. Similarly, many industrial and environmental applications and university research projects depend on the spectroscopy of gases.

During the past 50 years NRC has developed an outstanding expertise in the spectroscopy of molecules and molecular ions, which continues to enhance the Council's international reputation and has external applications as well as relevance to other HIA activities, in particular the participation in the James Clerk Maxwell Telescope.

Research and instrumentation on molecular spectroscopy change on time scales of one to five years so that longer term planning may require significant revision.

The only HIA section dedicated to providing support and expertise in molecular spectroscopy is the Spectroscopy Section located in Ottawa.

OBJECTIVES

The objectives are

- to provide spectroscopic expertise and laboratory facilities in support of research in molecular structure, astrophysics, and atmospheric physics;

- to provide expertise and state-of-the-art instrumentation in support of the Canadian spectroscopic community;

- to collaborate with Canadian manufacturers of spectroscopic instrumentation as required to improve their products; and

- to conduct front line research in order to maintain credibility in the above endeavours.

SPECTROSCOPY SECTION

Section Head: J.W.C. Johns

This group consists of 13 professional and 7 technical positions, plus 2 professional and 1 support position in the Office of the Distinguished Research Scientist, for a staff target of 23 on 1 April 1989.

1. ACTIVITIES

The section's activities are readily divided into sub-projects on the basis of experimental techniques, as follows:-

1.1 MICROWAVE AND SUB-MILLIMETER WAVE SPECTROSCOPY (3 professional, 1 technical, $110K)

Study of rotational spectra of simple molecular species likely to be of astrophysical interest and in particular to maintain a laboratory facility closely matched in capability to the JCM Telescope.

1.2 INFRARED SPECTROSCOPY (5 professional, 2 technical, $110K)

Study of vibration-rotation spectra simple molecular species (including ions and dimers) likely to be of interest to astrophysics and atmospheric physics.

1.3 VISIBLE AND ULTRAVIOLET SPECTROSCOPY (5 professional, 3 technical, 1 support, $110K)

Study of electronic spectra of simple molecular species (including ions and excimers).

1.4 ELECTRON SPECTROSCOPY (2 professional, 1 technical, $68K)

Study of energy levels of negative ions, neutrals and positive ions of atoms and simple molecules by electron impact.

THEORETICAL SPECTROSCOPY: Two theoreticians have been included in the above numbers. As need arises they give support to any of the sub-projects 1.1-1.4.

2. FUTURE DIRECTIONS AND PRIORITIES

The section will continue to place strong emphasis on:

- the study of the spectra of small, relatively light, molecules, simple clusters (dimers), radicals and molecular ions, which are of importance in astrophysics and in the atmospheres of planets including the earth;

- maintaining state-of-the-art experimental facilities;

- theoretical studies aimed at understanding observed energy levels and transition intensities as well as predicting new spectra of interest for experimental study.

2.1 MICROWAVE AND SUB-MILLIMETER WAVE SPECTROSCOPY

- The spectrometer has been modified to reach 370 GHz, the region of greatest interest for the JCM telescope. However, coverage is still not as complete as we would like, so we will add one or two klystrons in FY 89/90.

2.2 INFRARED SPECTROSCOPY

- The difference frequency laser and diode laser spectrometers are still amongst the most sensitive instruments available for detecting and characterizing new molecular or ionic species. The work is very fruitful and will be continued.

  A quadrupole mass spectrometer will be added in FY 89/90 to allow *in situ* monitoring of ion concentrations.

- The modified ultra-high resolution Bomem spectrometer has now been in operation for about one year. Some small problems remain which seem to be connected with the very high resolution attained. We will work closely with Bomem Inc. in order to find solutions.

  Another, unrelated, problem is that the cooled 50 cm base path absorption cell is not long enough for the study of some dimer molecules. A new 2-m cell (capable of attaining a path of 80 m) has been designed. Construction should be completed in FY 89/90.

- Two very long path cold cells already in use for much of the dimer work are interfaced to a medium resolution Bomem interferometer. Some of the experiments planned for this apparatus can make use of higher resolution. We hope to upgrade the interferometer during FY 89/90.

2.3 VISIBLE AND ULTRAVIOLET SPECTROSCOPY

- This region is covered by a high resolution interferometer and the large 10-m vacuum grating spectrograph. No major changes for these instruments are planned.

- Development of sources will continue, emphasizing the use of free jet expansions to obtain very low temperatures.

  In addition, we plan in FY 89/90 to develop a new laser induced plasma source for the generation of strong very short wavelength continua necessary for the observation of absorption spectra.

2.4 ELECTRON SPECTROSCOPY

- The loss of an order of magnitude in the observed signal-to-noise ratio was traced to increased cooling-water temperatures during the summer months.

  A refrigeration system will be installed to enable year-round data collection.

3. RESULTS FROM THE PAST YEAR 1988/89

The spectroscopic equipment operated by the Section continues to be in demand by collaborators from all over the world. In 1988, eleven projects involved partners at Canadian universities and twenty-four projects involved researchers from foreign institutions.

3.1 MICROWAVE AND SUB-MILLIMETER WAVE SPECTROSCOPY

- The frequency range of the spectrometer has been extended up to 280 GHz, and to 370 GHz under favorable conditions by utilizing the fourth harmonic from the tripler).

- Two new free radicals have been detected: one is probably NS_2 and the other has been shown to contain C, S and N.

3.2 INFRARED SPECTROSCOPY

Science Results:

- Emission spectra observed from the hot spots of Jupiter were assigned to the $2\nu_2 - \nu_2$ and possibly the $3\nu_2 - \nu_2$ vibration-rotation bands of H_3^+.

- Hydrogen dimers were shown last year to be important in the interpretation of spectra of the atmospheres of Jupiter and Saturn. Spectra of most of the possible isotopermers have now been obtained.

- Laboratory low temperature long path spectra of N_2 cast doubt on previous speculation that oceans of liquid N_2 may exist on Triton.

- An extensive far-infrared spectrum of the HCl dimer has been observed. The analysis led to the identification of one of the low frequency intermolecular modes at 160 cm^{-1}.

- Two new ions of astrophysical signficance, $HOSi^+$ and H_2COH^+, were positively identified by infrared spectroscopy, using a difference-frequency laser.

Commercial Applications:

- The modified ultra-high-resolution Bomem Fourier transform spectrometer proved to be better than the original instrument, even when operated at moderate resolution. Originally Bomem Inc. (Quebec) decided not to market a high resolution option for their spectrometers, but the loss of several sales during 1988 to Bruker (West Germany) has prompted them to change their mind. Bomem is now negotiating to buy the drawings from NRC in order to provide its customers with our modification.

3.3 VISIBLE AND ULTRAVIOLET SPECTROSCOPY

Science Results:

- Spectra obtained from a free jet expansion source allowed analysis of the Herman infrared quintet band system ($C'' \, ^5\Pi_u$ - $A' \, ^5\Sigma^+g$) of N_2 for the first time. The A' state is particularly important for the understanding of recombination of ground state nitrogen atoms and is also believed to be involved in the Lewis-Rayleigh afterglow.

New Techniques:

- A new emission source has been developed for the excitation of spectra by Penning ionization. It consists of a supersonic jet of metastable atoms crossed by a similar jet of molecules to be excited.

  The source is particularly suited to Fourier transform spectrometers since there is none of the sputtering or sparking typical of conventional hollow cathode lamps.

  Cool (about room temperature) spectra of several ions (CO_2^+, CS_2^+, CS^+ and H_2O^+) have already been obtained.

3.4 ELECTRON SPECTROSCOPY

- Work on improving the spectrometer continues. In particular, high voltage drivers for the quadrupole mass spectrometer are nearly complete.

- In the meantime, work on Xenon has resulted in a new understanding of the mechanism of excitation by electron impact and in the way negative ions, excited states of the neutral species and positive ions are produced.

4. SITUATION ANALYSIS

The most pressing problem is matching the skills of the technical officers with the needs of the experimental scientists. Some of the TO's who have been with the Council for many years are not skilled with modern electronics, computers or lasers. Consequently, one of the leading scientists in the Section still does not have the TO support that he deserves.

SPECTROSCOPY SECTION

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	23	24	24	24
Expenditures ($K)				
• Operations	240	240	240	240
• Minor Capital	158	158	158	158
• Major Capital				
• Total Expenditures	398	398	398	398
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets				
Expenditures ($K)				
• Operations				
• Minor Capital				
• Major Capital				
• Total Expenditures				
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

SPECTROSCOPY SECTION

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
40000	23	240	158		398				
TOTAL	23	240	158		398				

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

EXPENDITURES						RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
TOTAL									

40000 Research in Spectroscopy [Activity I, Application 1]

SUPPORT OF ELEMENTARY PARTICLE PHYSICS

PREAMBLE

The general objective of research in high-energy physics or elementary-particle physics is to understand the building blocks of nature and the forces that hold them together to form the familiar protons, neutrons, and atoms. At present we think that the elementary particles are quarks (up, down, strange, charm, etc.) and leptons (electrons, muons, tauons, and their associated neutrinos). The binding forces are caused by the exchange of the photon, the W^+, W^- and Z^0 bosons, and the gluons. These particles and their forces are all tied together through a comprehensive theory called the Standard Model. Work in this field is extremely active and is making remarkable progress in understanding the fundamental nature of matter and energy.

Front-line research in high energy physics requires large and expensive facilities such as the Large Electron-Positron (LEP) accelerator nearing completion at CERN ($1B) and the Superconducting Super Collider proposed for the United States ($6B). The experiments on these accelerators are carried out by large teams of up to 500 physicists over 10 to 20 years. The apparatus for these experiments is large, sophisticated and expensive; a typical detector may cost $100M.

The experimental community in Canadian universities is relatively small, being made up of groups at McGill, Montreal, Carleton, Toronto, York, UBC, and Victoria amounting to a total of about 80 physicists. In addition there are more than 100 theorists also working in the field but scattered over more universities. The support for this community is also small by world standards, being about $8M/yr.

The overall program in Canada is very highly regarded and recent results from initiatives involving Canadian groups have been very successful. Currently, Canada is involved in new projects which are at the frontiers of high energy physics, so that one can expect the Canadian contribution to continue to be of high quality.

University experimenters have many responsibilities besides their research, and their graduate students have to complete their degrees on a time scale short compared with the length of these projects. Therefore the universities require a dedicated infrastructure to carry out the necessary engineering, technical, and management work to participate in this field. This infrastructure requires professional staff working full time on the projects. It is in this area that the current NRC group plays a major role and where additional resources would strengthen the Canadian contribution in the field.

Another aspect of the field is that Canada is using the large facilities and programs in other countries in a parasitic mode. The USA spends about $600M/yr on elementary-particle physics and has at least four large laboratories working on it. Canada has had free access to these facilities and has therefore received very good treatment from the host countries.

There has been some criticism since most of our money goes directly to the experiments and almost none to supporting the facilities.

NRC support for high energy physics is supplied by the HIA High Energy Physics Section, which is housed in the Physics Department of Carleton University, Ottawa. The HEP Section has a very close working relationship with the Carleton High Energy Physics group.

OBJECTIVES

The objectives of the High Energy Physics Section are:

- To assist the Canadian community by providing the infrastructure necessary to carry out research programs in elementary-particle physics at large international facilities.
- To provide a full-time professional staff to give the continuity and stable base necessary to carry out a Canadian program.
- To provide the community with an advanced instrumentation group to help in the construction of hardware and provide expert technical advice.
- To maintain a high quality staff by carrying out research in elementary particle physics.
- To provide a source of information and advice on developments in particle physics to assist the Federal Government in formulating policy in this field.

HIGH ENERGY PHYSICS SECTION

Section Head: C.K. Hargrove

This group consists of 10 professional and 2 technical positions for a staff target of 12 on 1 April 1989.

1. ACTIVITIES

1.1 OPAL (7.4 professional, 1.5 technical, $541K)

The European community is constructing a Large Electron-Positron (LEP) collider at CERN in Geneva. This ring with a 27 km circumference will be operated initially at or close to the mass of the Z^0 particle where it will produce about one Z^0 per second as opposed to previous accelerators which produce a few a year.

The Omni-Purpose Apparatus for LEP (OPAL) is one of four detectors to look at the decay products of these particles. It is being constructed by a collaboration of 22 institutions from nine countries.

NRC has led Carleton University and the University of Montreal into this collaboration, the Canadian component of which now involves 23 physicists from these institutions and 11 graduate students. Canada's direct contribution, in addition to salaries, is about $9M, or approximately 10% of the total cost of the detector, and is being funded by NRC and NSERC.

Canada is responsible for a pressure chamber 8 m long by 4 m diameter, 24 zed chambers, the vertex chambers, and some of the data acquisition hardware. The zed chambers are attached to the inside wall of the pressure chamber where they measure particle positions in the axial or z direction, and the vertex chamber is at the centre of the detector, enclosing the collision area.

1.2 TAGGED PHOTON SPECTROMETER

The Section provided specialized data acquisition software to a collaboration of scientists from Carleton University and the University of Toronto and their American colleagues who used a Tagged Photon Spectrometer at Fermilab in Illinois. This experiment measured the production and decay processes of mesons and hadrons which contain the higher mass charmed quarks.

1.3 SUDBURY NEUTRINO OBSERVATORY (SNO) (2.6 professional, .5 technical)

A collaboration of 28 scientists in seven Canadian and five U.S. and U.K. institutions has developed a proposal to study neutrinos from the sun and from supernovae in the low background environment of a deep Canadian mine. Neutrinos of various energies should reach the earth from several steps in the chain of nuclear reactions which power the sun.

Past measurements of the electron neutrinos from the decay of ^{8}B in the sun indicated the arrival of, at most, a third of the number expected by the theory of stellar structure. The proposed Cerenkov detector containing 1000 tonnes of heavy water, 6800 feet deep in the Creighton mine near Sudbury, Ontario will be able to detect various types of neutrinos with high sensitivity and hence tell whether the neutrinos have changed enroute to the earth, as suggested by some theories. The continued absence of neutrinos would have the most profound implications for either our models of solar energy generation or our understanding of the physics of neutrinos.

The detector also should be sensitive enough to detect realtime changes in the neutrino flux from either solar variations or galactic supernovae.

2. FUTURE DIRECTIONS AND PRIORITIES

The top priority of the Section over the next five years must be the commissioning and operation of the OPAL detector at CERN. NRC has commitments to Canadian university scientists and the international consortium that must be honoured.

To fulfill its mandate to the Canadian high energy physics community, the Section must perform research in new instrumentation techniques for particle physics, and keep aware of new opportunities in high energy physics.

The Section has made a commitment and a very significant contribution to the SNO collaboration, which should be continued when final approval and funding for the experiment is received.

2.1 OPAL

FY 89/90

The Canadian equipment and software for OPAL are on schedule for the planned turn on of LEP on 17 July 1989. As soon as useful data are available some physics must be extracted quickly, since OPAL is in competition with the other three LEP experiments.

Longer Term

The OPAL experiment will remain the top priority for the Section. This facility will take data at or around the energy of the Z^0 for at least five years beginning in 1989. Around 1995 it is expected that the LEP machine will be upgraded in energy to nearly double its 100 GeV limit so that the W^+ and W^- bosons can be produced. The study of the decays of this boson would require at least another five years. Therefore, the exploitation of OPAL is very likely to continue to the year 2000 or beyond. During this time the HEP Section will be expected to participate in operations, maintenance, the extraction of the physics, and possible upgrades to the hardware required by new technological developments.

2.2 TAGGED PHOTON SPECTROMETER

FY 89/90

The Section is in the process of concluding this experiment. This will be the last year of serious data analysis, and the final results will be published in FY 89/90 and FY 90/91.

2.3 SNO

FY 89/90

If funds are provided, the Section will continue development work on the final detector. We will investigate the water purification system, and the feasibility of using reflectors and discrete neutron detection methods.

We plan to build a medium sized test detector and use it to calibrate the Monte Carlo programs, as well as use it as a testbed for the selection of the final components of SNO.

Longer Term

It is hoped that SNO will be funded fully within the next year. Since NRC has a responsibility for national facilities, it would be a natural extension for the Section to take responsibility for the infrastructure for this project if the Canadian collaborators agree and the resources of the Section are increased accordingly.

3. RESULTS FROM THE PAST YEAR 1988/89

3.1 OPAL DETECTOR

The 24 zed chambers, the vertex chamber and the pressure vessel were tested and installed at CERN in preparation for the start of data taking in the third quarter of 1989.

The programs to analyze the data from the OPAL detector are now written and are being debugged and improved. All the Canadian items have met their specifications and are on schedule.

3.2 TAGGED PHOTON EXPERIMENT

The past year has seen a sustained analysis effort for Fermilab Experiment E691, a study of charmed-particle photo-production at the Tagged Photon Spectrometer. The high statistical accuracy of the charm samples collected by E691 have provided many opportunities to study the detailed physics of heavy quark systems.

For example, lifetimes of the D^0, D^+ and $D(s)^+$ mesons have been published which are more precise than the average of all previous measurements combined. A study of D^0-D^0 mixing has set an upper limit of 0.5% and E691 was among the first experiments to observe the charmed baryon Sigma(c).

Other physics topics that have either been published or are under investigation include Cabibbo-suppressed and semi-leptonic D decays, excited charm mesons and the dynamics of charm photo-production.

3.3 SNO FEASIBILITY

The SNO proposal received a strong endorsement from a high-level international committee. While awaiting a decision on the funding, the collaboration is continuing studies towards a final design.

NRC staff have run Monte Carlo simulations on the effect of the timing accuracy of the photomultiplier tubes, have investigated their response to light at various incidence angles, and have searched for a reflecting material that will not deteriorate in water.

4. SITUATION ANALYSIS

OPAL Staffing

The original proposal for OPAL to the Program Selection Committee of NRC stated that the Section staff required an increase of 4 PYs for the life of the project. To date NRC management has provided one 4-year, two 3-year- and one 2-year position, all research associates. Two RAs are now in positions which disappear on 31 March 1990.

The HEP Section has done everything possible to provide the additional support for OPAL, first by using its one retirement for a permanent position for a third RA, and secondly by stationing more permanent staff from Ottawa in Geneva. However, two serious problems remain:

a) two RAs, who have worked extremely hard on the OPAL equipment, must leave at the start of the operational phase just when NRC needs their experience on the project, and before they receive any scientific return for their efforts; and

b) in order to keep the equipment operating 24 hours a day, NRC's commitment to OPAL requires a minimum staff of four based at CERN.

To meet the minimum requirement for OPAL, HEP still needs at least two of the four originally requested PYs to continue beyond 1 April 1990. The present two RA's could be extended to their 5-year limits, and then new ones recruited.

OPAL Vertex Detector

Although the vertex chamber delivered to OPAL meets its specifications, the intense radiation so close to the LEP collision volume greatly increases the risk of failure. Since so much time is needed to disassemble and reassemble the complete OPAL detector during the scheduled shutdowns of LEP, any major repair of the vertex chamber would be impossible. Consequently, funds are needed from NRC and NSERC to construct a replacement chamber. The new chamber also will include modifications that can increase its resolution significantly.

SNO Staffing

At present the Section has one full-time permanent professional working on SNO and two professionals who have committed 30% of their time to the project. The project has been given one additional full-time permanent position, which will be filled in FY 89/90. The Section will reallocate the equivalent of one technician to the project.

To be able to accomplish the work that we feel that NRC should do as a minimum, the project will require one research associate as soon as possible, a technician starting in FY 1989/90, and an additional professional physicist starting in FY 1990/91. The additional staff will be required throughout the 4-year construction period and the 2 or more years of data taking.

Pending the decision on funding the complete SNO project, some resources were obtained from the general HEP budget and from the National Facilities budget in 1988/89, but these have not been sufficient for any progress on the medium size test detector.

This situation cannot persist in the new fiscal year, without affecting NRC's position in the project. Thus, a substantial budget request has been submitted to construct a pilot plant for the water purification and monitoring system, to construct and operate the medium test detector (MTD) at the NRC Linac, and to continue further participation in the project. The budget does not include funds for any final detector components.

Continued Support for Canadian Particle Physics

The development of instrumentation for new experiments must be receive a higher priority once OPAL becomes operational.

If NRC accepts that the role of the HEP Section is to provide instrumentation, coordination, and continuity for particle physics in Canada, it must give serious consideration to at least doubling the size of the group, even for the present level of community activity. At the current size of seven permanent professionals, the group is too small to carry out its role.

The Superconducting Super Collider

The Superconducting Super Collider (SSC) is in the final stages of approval. Its site in Texas has now been selected. With a circumference of 80 km this accelerator will be the largest single instrument ever built. It is expected to cost $US6B to construct and have an annual operating budget of $US250M.

The project is so large that the U.S. Department of Energy (DOE) has asked other countries, including Canada, to participate in its construction up to about 25% of the total. When completed it will be the major facility in high energy physics and at the cutting edge of this field for the forseeable future.

The presence of the SSC will have a major impact on particle physics in Canada, regardless of our mode of participation. However, the infrasturcture to cope with a major SSC project does not exist in the university community.

If NRC is to contribute to this infrastructure, the HEP Section would have to grow to at least 20 professionals to be credible. An alternative would be to establish a fully equipped particle physics institute to provide a focal point for the university community.

5. ADDITIONAL RESOURCE REQUIREMENTS

5.1 OPAL

Staffing

As indicated above, the Section requires the extension of two RA positions from 1 April 1990 until the end of OPAL in order to meet its commitments to the operation of the detector.

Financial

The estimated costs to NRC to construct the replacement vertex chamber are an additional $50K in FY 89/90 and $150K in FY 90/91, all in operations.

5.2 SNO

Staffing

The Section requires an additional RA position for the SNO project, an additional technician starting in FY 89/90 and an additional professional starting in FY 90/91.

Financial

The Section needs substantial funding for the SNO project to get the NRC effort back on track within the collaboration. The estimates are $211K, for operations and $294K for minor capital spread over FY 89/90 and FY 90/91. These costs assume that the effort expands some, that we will be performing development work in the water purification system, and that the MTD will be designed and built.

HIGH ENERGY PHYSICS SECTION

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	12	10	10	10
Expenditures ($K)				
• Operations	491	491	491	491
• Minor Capital	50	100	100	100
• Major Capital				
• Total Expenditures	541	591	591	591
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Computer Usage	108	150	150	150
• Total Monies-In	108	150	150	150

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets		2	2	
Expenditures ($K)				
• Operations	100	111		
• Minor Capital	200	94		
• Major Capital				
• Total Expenditures	300	205		
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

HIGH ENERGY PHYSICS SECTION

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	EXPENDITURES					RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue*	Fin. Arrang.	G&C	Total
30000	8.9	491	50		541	108			108
31000	3.1								
TOTAL	12	491	50		541	108			108

*Computer usage by Carleton University

(B) PROJECTIONS FOR PROPOSED NEW PROJECTS

	EXPENDITURES					RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
30000									
31000		100	200		300				
TOTAL		100	200		300				

30000 HEP, OPAL [Activity IV, Application 1]
31000 HEP, SNO [Activity IV, Application 1]

MANAGEMENT, ADMINISTRATION, AND CENTRAL SERVICES

Director: D.C. Morton, Assistant Director: B.H. Andrew
Administrative Manager: M.C. Storr

This group consists of 5 professional, 11 technical, and 12 support positions for a staff target of 28 on 1989 April 1. These totals include 1½ professional and 1 support position assigned to the Office of National Facilities.

MANAGEMENT OBJECTIVES

- To lead the division's planning of programs and budgets and to provide overall direction to program and operational activities.
- To provide overall scientific and technical leadership.
- To consult with the relevant parts of the scientific community.

ADMINISTRATION OBJECTIVES

- To administer and apply divisional policies, practices, and management systems.
- To provide the clerical, administrative, financial, and common technical services necessary to carrying out the mandate of HIA.
- To provide the division with expertise in the regulations that govern its affairs, and in the policies and practices of NRC.
- To provide liaison with NRC central administrative and financial services.

1. ACTIVITIES

1.1 MANAGEMENT AND DIRECTION (2.3 professional, 1.5 support positions, $72K)

The Director and Assistant Director decide upon the overall program definition and balance, and the budgetary allocations that are best suited to the division's pursuit of its objectives within the changing context of Canadian science. They are responsible for the satisfaction of the division's client - the science community of Canada - and for consulting that community in developing plans to serve its present and future needs. In these activities, they are assisted and advised by the division's Section Heads and professional staff members.

The Director and Assistant Director must also advise and assist NRC senior management to approve and provide appropriate responses to the community's needs for facilities, to inform and advise the government, and to apply government policies.

The Director has the ultimate responsibility and authority for all activities carried out by the division, and is specifically concerned with the scientific and technical direction of the division. To these ends the Director must be an active scientist, must keep abreast of the latest scientific and technical development, and must participate in studies of new projects.

The Assistant Director substitutes for the Director in his absence, and also is concerned with the operation of facilities and equipment, liaison with and services to users, and with the division's management and administrative affairs.

1.2 CLERICAL, ADMINISTRATIVE AND FINANCIAL SERVICES (0.4 professional, 10.5 support positions, $400K)

Under the direction of the Administrative Manager, clerical, administrative and financial services staff members supply the division with information, support, and services in the areas of personnel policy, pay and attendance, administrative policies and procedures, travel, and financial systems, payments, and accounting.

They also provide necessary services in the area of purchasing and supplies, and provide secretarial and general clerical support.

Many of these services also must be provided by local staff at DAO and DRAO. (Administrative staff members at these observatories are not included in the totals at the start of this section.)

Administrative staff are expected to keep their counterparts in central administration informed of divisional concerns, and to be informed of NRC policies and procedures as they apply to divisional activities.

1.3 COMMON TECHNICAL SERVICES (0.2 professional, 11 technical positions, $40K)

Under the direction of the Administrative Manager, technical services staff members supply the division with services in mechanical design, drafting, machining, electronic consulting and construction, and instrument construction.

1.4 INDUSTRIAL LIAISON, SAFETY, AND TRAINING (0.1 professional positions, $0K)

The Administrative Manager acts as the divisional Industrial Liaison Officer and supplies advice and expertise on contracting. He also acts as the Divisional Training Officer and Co-chairman of the safety program.

2. FUTURE DIRECTIONS AND PRIORITIES

2.1 MANAGEMENT AND DIRECTION

FY 89/90

- The Director will continue his research including studies of the interstellar gas and quasi-stellar objects, and the compilation of atomic spectral data relevant to these investigations.

- The Director will continue to participate in the studies of new projects, including a large optical telescope on the ground and an ultraviolet telescope in space.

- In order to improve management coordination, HIA is instituting weekly planning and review meetings among the Director, Assistant Director, and Administrative Manager, and frequent meetings among these three and the seven Section Heads.

- The NRC Personal Performance Review will be fully in effect; all staff members will be reviewed.

- The Director, Section Heads, and perhaps some senior staff members will participate in a management training course being organized by the Science Divisions.

- To improve communications, the Director, Assistant Director and Administrative Manager will put into effect a policy that will see each of them visit the Victoria and Penticton sections at least two times per year.

- Following the APR exercise, this document will be used as the basis for preparing flow charts that show the schedules, milestones, outputs, impacts, and objectives of all HIA activities. A common format is being developed by the Science Divisions for these project plans.

Longer Term

- In hiring, HIA will emphasize improvements in its ability to provide services in the French language.

2.2 CLERICAL, ADMINISTRATIVE AND FINANCIAL SERVICES

FY 89/90

- HIA at Sussex will standardize its computer support systems by moving from word processors to a PC-based text system.

- HIA will complete Phase 2 of its Stores computerization program by implementing automated processing of standard forms and documents. This program is compensating for past staff reductions in the Supply Office and Stores.

- The possibility of integrating the Stores of the three divisions that occupy the Sussex building will be studied as part of the NRC plan to modernize the Sussex laboratories.

2.3 COMMON TECHNICAL SERVICES

Longer Term (Sussex Drive)

- The PC's in the text system will be networked.
- HIA will develop a computerized version of its stocked item catalogue.
- HIA will replace its aging milling equipment and electronic instruments.

2.4 INDUSTRIAL LIAISON, SAFETY AND TRAINING

- HIA will explore ways of maintaining and upgrading the expertise of its staff members. One possible vehicle is use of the National Technological University which uses earth satellite transmissions to feed lectures to subscribing institutions with a receiving system.

3. RESULTS FROM THE PAST YEAR 1988/89

3.1 MANAGEMENT AND DIRECTION

- By the end of FY 88/89 we will have completed the rearrangement of space to create an administrative area that incorporates the offices of the Director, Assistant Director and Administrative Manager, the travel and personnel offices, and the secretarial pool. Better coordination and some efficiencies are expected.
- The Assistant Director should achieve C-level bilingual status by the end of FY 88/89. Lunch time refresher courses attended by the Administrative Manager, several Section Heads, and central support staff have been terminated by cutbacks at the language school.
- HIA has accelerated the French language training schedule for Section Heads and senior scientists.
- Two sections of HIA have been instructed in the Personal Performance Review procedures, and the supervisors have completed the first round of interviews.
- A divisional newsletter has been started to encourage a feeling of community among the scattered sections.

3.2 CLERICAL, ADMINISTRATIVE AND FINANCIAL SERVICES

- The computerized inventory control system in Stores is almost complete.

3.3 COMMON TECHNICAL SERVICES

- The Design Service was upgraded by the addition of a state-of-the-art CAD system.
- the Instrument Development Service was introduced to the CAD/CAM process with the addition of a new computer controller for a milling machine. Members were trained in its use.

3.4 INDUSTRIAL LIAISON, SAFETY, AND TRAINING

- Central Services staff members received 300 person-hours of CAD/CAM training and 372 person-hours of French language training.

4. SITUATION ANALYSIS

Thirty-seven percent of the division's staff are located outside Ottawa at Hilo, Hawaii; Victoria, B.C.; Penticton, B.C.; Algonquin Park, Ontario; and Edinburgh, Scotland. Another 7% are located at Carleton University. The main research instruments of many of the staff are in Hawaii, and Geneva, Switzerland and for others research is through collaborative space missions. Travel is essential but causes pressure on the budget and inevitable absences from the home bases. The administrative, communications, and management problems are magnified by these grographically scattered responsibilities.

The division as a whole continues to feel the strain of limited resources, particularly personnel resources, that is common to most parts of NRC. Many staff members work long hours of unpaid overtime to fulfill HIA's numerous commitments and still keep involved in research.

Frustrations often arise from a sense of missed opportunities. There is always a temptation to take on too much. There can also be a latent anxiety caused by not having enough time and money to do the best possible job.

Another cause of frustration is the perception that NRC in particular, and science in general, are not properly recognized by the federal government.

Support staff have to take on additional duties as their numbers decrease. It has been a long time since anyone saw a secretary reading a book in this division.

At the director level there is the common and growing burden of bureaucratic chores imposed both by NRC and externally. Nowadays a director could keep fully occupied dealing with the paper that comes across his desk from outside, without ever undertaking any initiatives of his own.

The problem is exacerbated in HIA because the scattered division and the heavy emphasis on involvement with the science community mean that both the Director and Assistant Director spend considerable time in travel status. In addition, the Assistant Director also serves as Director of the

Office of National Facilities for Science, and so devotes only about half his time to HIA. Also there are no professional officers, other than the Director's research assistant, to assist the Directors or the Administrative Manager, as there are in many other divisions.

Section Heads, too, who are meant to be the working level scientific managers, spend an ever increasing proportion of their time on bureaucratic and administrative chores, to the point that it may be difficult to persuade people to accept these positions in future.

Still, people remain surprisingly cheerful in spite of it all. The Vice-President always seems able to throw us a lifebelt just when it seems we are going to sink. Nevertheless, a major annual planning exercise such as this APR seems largely pointless when the resources in the system permit little more than survival.

On the plus side, there is just enough of a sense of progress in all areas, and enough good results, to keep everyone encouraged. Each section has at least one recent significant success.

The monthly Directors' meetings that were instituted this year for the Science Divisions by the Vice-President (Science) are also proving to be a boon, since they provide a forum for examining common issues, and a means for taking joint actions to resolve problems and explore opportunities.

5. ADDITIONAL RESOURCES REQUESTED

One professional position (to be shared with the Office of National Facilities for Science) and one permanent position for one of the two term positions of the divisional secretarial pool which disappear on 31 March 1989 and 31 March 1991.

DIRECTOR'S OFFICE

TABLE 3 Planning Unit Summary by Financial Classification

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	89/90	90/91	91/92	92/93
• Staff Targets	28	27	26	26
Expenditures ($K)				
• Operations	475	475	475	475
• Minor Capital	37	32	32	32
• Major Capital				
• Total Expenditures	512	507	507	507
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements	120	120	120	120
• Grants & Contributions				
• Total Monies-In	120	120	120	120

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	89/90	90/91	91/92	92/93
• Staff Targets		1	1	1
Expenditures ($K)				
• Operations				
• Minor Capital				
• Major Capital				
• Total Expenditures				
Monies-In ($K)				
• Contracts-In				
• Financial Arrangements				
• Grants & Contributions				
• Total Monies-In				

DIRECTOR'S OFFICE

Table 4 Planning Unit by Projects for 1989/90

(A) PROJECTIONS BASED ON APPROVED RESOURCE LEVELS

	EXPENDITURES					RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
99000	28	475	37		512		120		120
TOTAL	28	475	37		512		120		120

(B) MOST URGENT ADDITIONAL RESOURCES REQUIRED, INCLUDING PROJECTIONS FOR PROPOSED NEW INITIATIVES (Other needs are discussed in the text)

	EXPENDITURES					RECEIPTS			
Project Code	ST	Ops	Minor Cap	Major Cap	Total Exp	Revenue	Fin. Arrang.	G&C	Total
TOTAL									

99000 Director's Office/Administration [Activity I (50%) and Activity IV (50%), Application 1]