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RADARSAT STUDY

REPORT ON RESULTS :

DECEMBER 1981 - APRIL 1982

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1. INTRODUCTION

1.1 The Objectives and Conduct of the Study

The objectives of the study have been to identify, evaluate and develop UK interests in the Canadian CCRS Radarsat project. Initially the project tasks were defined as follows:-

1. To provide up-to-date information to the Department of Industry on the progress of the project.

2. To define UK interests in the use of Radarsat data and to ensure that the interests are presented in a form which can be integrated into the work of the Canadian Radarsat Study Team.

3. To identify and define industrial and commercial opportunities for the UK arising from the project.

4. To make recommendations to the Department of Industry on specific areas to be followed up, supported and promoted.

The study period was five months, from December 1981, ending in April 1982 and a mid-term progress report was submitted in February 1982.

The part of the study concerned with liaison has involved visits to Canada for discussions with CCRS, and our associate company Philip A Lapp Ltd. who are contracted to CCRS on aspects of the Phase A study; also with the other prime participants in the Phase A study, Canadian Astronautics Ltd. (CAL), SPAR Aerospace, and MacDonald Dettwiler Associates (MDA). As part of the work we have attended Radarsat Information Standards Committee meetings and a Concept Design Review.

In addition we have had a number of discussions with CCRS team members in the UK and have discussed the relationship of Radarsat and ERS-1 with ESA.

On the subject of user interests we have carried out an extensive survey, the results and conclusions from which are given in Chapter 4. Full details are given in the mid-term report of February 1982 which is included as Annex V.

In identifying and evaluating UK prospects for possible industrial involvement we have had discussions with:-

- British Aerospace, Filton and Stevenage.

- Marconi Space and Defence Systems
- Marconi Research Centre
- Logica
- RAE
- Rutherford-Appleton Laboratory
- The Meteorological Office.

1.2 Progress and Results

Up to date our liaison activities have kept us fully informed of developments and thinking in the Radarsat Project Office, and contacts are continuing with planned activities extending past the end of April.

In the case of user interests we have passed on the results of our survey to the Canadian team but it became evident during the study that because of the highly specialised main application of the Radarsat, specific UK user requirements will not influence the specification of the primary instrument nor the satellite orbit and operations schedule. They could, however, have a bearing on the choice of the secondary instruments, or, rather, they could influence UK propositions for secondary instruments.

Potential UK user requirements for Radarsat are, however, closely bound-up with satellite remote sensing in general and the ESA ERS-1 programme participation in particular. In view of this it has been proposed that the promotion of satellite remote sensing, particularly by microwave sensors is the most effective on-going activity in this area.

A number of distinct possibilities for industrial participation in the Radarsat project have been identified preliminarily, including involvement in the satellite bus programme and in the provision of instruments. Further, possibilities are seen to arise in data handling equipment and services, in this case closely bound up with the broader UK satellite remote sensing strategy.

As an additional item the strategic implications of the Radarsat project have been assessed as these may have a bearing on any UK programme determined.

The whole has enabled us to come up with specific recommendations regarding the development of a UK strategy for collaboration in the Radarsat project. However, during the course of the study the final date of the Phase A studies by CCRS was extended to September 1982 leaving the final specification for the system open with respect to the selection of the bus and the composition of the secondary instrument package. Clearly this affects the UK strategy and, accordingly, it has been proposed that the UK study be continued a further six months to allow the development of UK courses of action based on the final specification. This will also allow the industrial prospects to be further evaluated and promoted for incorporation in the Canadian programme.

2. THE RADARSAT PROGRAMME : CURRENT STATUS

The concept of Radarsat is to provide all-weather sea ice coverage of northern Canada to assist the transport of crude oil and natural gas from the Arctic Fields to the eastern Canadian seaboard. The main element of the ice intelligence system will be a synthetic aperture radar (SAR) aboard the satellite to give frequent coverage of crucial areas of sea ice conditions to enable the year-round operation of heavy ice-breaking tankers on the Arctic Pilot route (Figure 1). The Arctic Pilot Project (Annex I) will be the proving exercise for the shipment of liquified natural gas.

The provisional satellite launch date is in 1990, though commercial sources indicate the Arctic Pilot route could be in operation as early as 1986. In this case airborne radar will provide an interim service, with possible contributions from other radar satellites that might be operating at that time like the ESA ERS series or the Japanese MOS. These in any case will be used to develop the operational system prior to the Radarsat launch. As part of the Phase A studies for Radarsat the cost-effectiveness of satellite versus aircraft mapping radar systems is being assessed. Should Radarsat prove effective it is assumed that it will be the first of an operational series.

Following the project design review meeting in March 1982 it has been determined that the satellite will be in a 99 degree, 1000 km altitude orbit. The SAR instrument will be C-band with a fully-processed resolution capability of 25m. The south-looking electronically steerable swath of 150 km width will give coverage to 78°N. Preferred secondary instruments are, at the moment, a scatterometer or a high resolution visible/infrared multichannel imaging system. The final selection of the secondary instrument package will depend partly on the satellite vehicle or bus chosen and on the prospects of instruments being donated by collaborators in other countries. Negotiations are underway regarding the selection and provision of the bus and the provision of secondary instruments. Specifically CCRS is approaching the United States concerning provision of a launcher, a scatterometer and a NASA-operated read-out station in Alaska. This source is also being considered for a visible/infrared imaging system as an alternative to the scatterometer for the secondary instrument.

Details of the specification as at May 1982 were given in Annex II, compared to ERS-1 specifications.

Being in a high inclination orbit the satellite instruments will be able to cover most of the world at various frequencies of repeat coverage. Because of the south-looking SAR, coverage of the Antarctic will extend to 88°S. Considerable opportunities, therefore, exist for applications of data of various sorts from the instrument package. Radarsat will be, in effect, one of a number of remote sensing satellites in orbit capable of supplying a wide and varied user community. In practice the operation of the other remote sensing satellites like the ESA ERS-1 is seen as complementary rather than competitive.

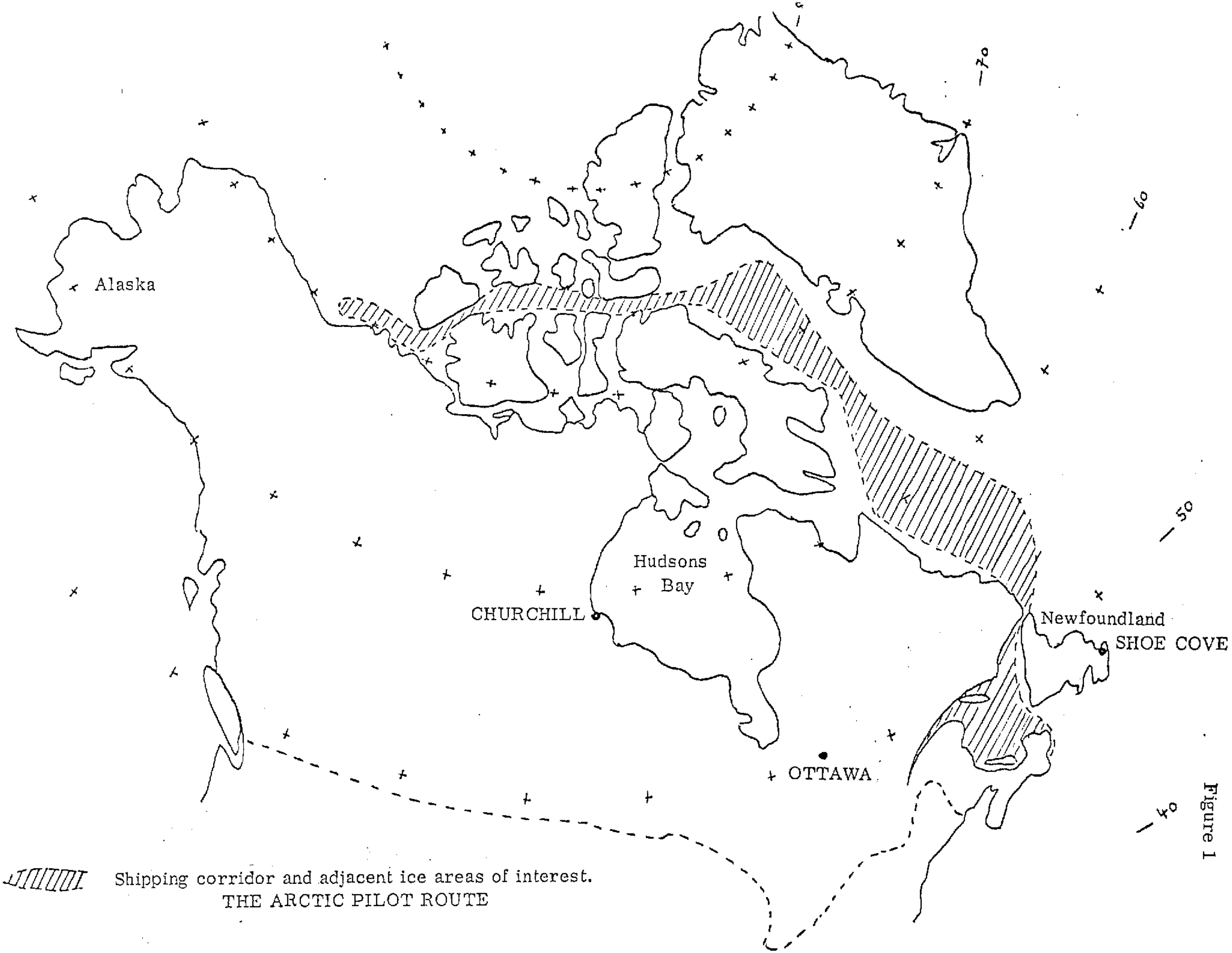
Initially the secondary user package was seen to be dominated mainly by oceanographic and meteorological applications. However, the possible inclusion of a high resolution thematic mapper (visible/infrared imager) reflects the emergence of major Canadian land applications. This instrument is also favoured by some ice mapping interests.

The primary Canadian interests are in the provision of the data services for the ice information system for Canadian waters. There will only be a small amount of on-board data recording and storage and read-out over Canada for the primary SAR instrument. Users elsewhere in the world will have to make their own arrangements for data collection and processing.

The ice data dissemination system, though the concept is not finalised, envisages a limited number of 'Main Processor' stations handling synoptic data at full specification plus other meteorological and oceanographic data. Intermediate Processor stations will handle regional and synoptic data, and also receive processed outputs from the Main Processor stations. Limited capability 'User Processors' are envisaged aboard ships and drilling platforms and these will receive products from the 'Main' and 'Intermediate' processors. Alternatively, it is possible that some ships will carry direct-read-out quick-look type receivers for the SAR, giving a lower resolution (100-150m) product for immediate operational use.

The main satellite data reception stations will be at Churchill and Shoe Cove giving different areas of coverage with data relayed to MPs via communications satellites. For areas outside the line of sight of Churchill there will be a limited data storage capability.

Further details are given in Annex III.



Shipping corridor and adjacent ice areas of interest.

THE ARCTIC PILOT ROUTE

Figure 1

3. THE UK TECHNICAL AND INDUSTRIAL POSITION

With regard to the possible UK technical and industrial advantage in participating in the Radarsat Programme, these are in three distinct areas of possibility:-

- In the provision of the satellite vehicle.
- In the provision of instruments or collaboration in instrument programmes.
- In the provision of data stations and data processing equipment.

3.1 The LSat Position

In the fabrication of Radarsat the arrangement will be almost certainly for Spar Aerospace to have the systems prime, payload and AIT responsibilities, with the basic bus vehicle being brought in from a foreign source. Eight candidate buses have been considered so far by CAL and Spar, including the UK heavy geostationary platform LSat. (Comparisons of specifications are shown in the bus matrix in the interim report). Of these the SPOT bus is probably too small. LSat flight costs could be higher than for some other vehicles but as one of the larger bus candidates, it can accommodate a larger secondary instrument package than some of the smaller buses.

Under an agreement with BAe, Spar are committed to the promotion of LSat in Canada and would use it in national programmes if necessary. Spar have commissioned work by BAe to specify the modifications to the LSat bus necessary for the Radarsat mission. The first review of this work will be in May with the final meeting in June 1982. It is combined with work commissioned by ESA.

BAe would of course be interested in providing LSat platforms for a Radarsat series and the possibility of using it for post ERS-1 missions, reinforces the prospect for multiple sales for remote sensing/radar missions. ESA is funding a study on LSat for this role using the Radarsat specification as its basis, to be completed by July 1982. This work is combined with the BAe work for Spar. In Canada LSat is also a candidate vehicle for the Mobile Satellite (MSat) and the Direct Broadcast Satellite (DBS). The Spar agreement to promote LSat envisages 60 per cent of any work involved being done in Canada, possibly rising to 75 per cent. Ultimately the choice of bus will be political with initial consideration of US and British vehicles. France will be considered if satisfactory solutions do not come from these quarters. NASA views on the project as a whole, which could affect the bus position, are expected in mid-1982, while any UK position should be made clear by autumn 1982. It has been tentatively proposed by Canada that if the UK were to cover non-recurring costs in converting the LSat for the Radarsat mission, Canada could cover recurring costs for possibly 3 spacecraft.

3.2 On-Board Instruments

3.2.1 The Instrument Package

The position on the Radarsat instrument package at the end of March 1982, resulting from the Phase A studies is as follows:

> The primary high resolution SAR instrument will have C band frequency thus allowing close comparability with the ERS-1 SAR system (AMI) and some commonality of equipment. A steerable acquisition swath has been decided upon to improve coverage for the primary ice mapping mission, but this will incidentally be of value to the large number of possible secondary applications.
>
> The secondary instrument will be a wind/wave scatterometer or a thematic mapper. This will be some form of high resolution visible/infrared multi-spectral instrument like the SPOT imager or the Ocean colour monitor (OCM) proposed for ERS-1. Final selection will depend on user requirements and the possibility for the contribution to the CCRS programme of an instrument by a foreign collaborator.

The incorporation of the other recording instruments originally considered, including a radar altimeter and an imaging microwave radiometer, will depend on the selection of the satellite vehicle. A large 'bus like LSat could allow more than one instrument in the secondary package. The programme might be open to instruments not yet considered, particularly if these were to be wholly donated by a collaborator though this might mean additional expense to Canada. Questions of complementarity arise in this case as the radar altimeter is a natural partner for the scatterometer.

Consideration of complementarity also arise if Radarsat is seen as one of a number of remote sensing satellite providing a comprehensive operational service. In this context the inclusion of a visible/infrared imaging instrument could be favoured by the dropping of the Ocean colour monitor from ERS-1.

3.2.2 UK Instrument Interests

There are a number of possibilities for UK contributions to the instrument package either by the supply of a complete instrument or through collaboration in instrument development, provided this is acceptable to the Canadian Government. Several bodies are involved.

Marconi

The group has very substantial experience in the development of military airborne SAR systems and of SAR image processing equipment. It has carried out optimisation studies on the AMI for ESA, which included the integration of the scatterometer with SAR elements. Marconi is to be the prime contractor for the ERS-1 AMI with Thomson CSF providing some of the hardware. They have had discussions with Spar Aerospace about this and clearly there are joint possibilities to be explored with the Radarsat SAR particularly now that a C-band instrument has been specified. As Spar will be doing the IDTHS on ERS-1 they will be working directly with Marconi on this project.

They collaborated with Aerospatiale in the development of the Ocean Colour Monitor (OCM) for ERS-1, (since dropped), with MSDS responsibilities being for the detectors and electronics.

They are working on the star sensor for a filtered attitude determination system (FADS, in combination with BAe) which will be relevant for Radarsat.

Rutherford-Appleton Laboratory

There are a large number of candidate instrument possibilities for the secondary package from this source and tentative contacts have been made regarding radar altimetry.

The laboratory is actively engaged in the development of aircraft radar altimeters to be used by the Scott Polar Research Institute for Arctic ice studies, particularly for the future international MIZEX programme. In the space field it has carried out studies for ESA on ocean and ice applications of altimetry and is working with European groups to obtain improved satellite altimetry through measures including improved position fixing. They are considering the possibility of a low cost altimetry satellites of the type recently initiated by the University of Surrey as an educational service.

The global altimetry programme envisages improving satellite accuracies from the current state of art of 5 - 10 cms to 1 - 2 cms by the end of 1990's. This will involve highly accurate satellite position fixing by; the use of the instrument itself with a network of ground reflectors; radio position fixing including, possibly, the Global Positioning System (GPS) if data from this could be released by the U.S. Navy; laser tracking systems for very fine corrections. The space element will include a number of vehicles, with a requirement for a sun-synchronous remote sensing satellites plus non-synchronous types. (These could include low cost altimetry vehicles).

In the infrared field the laboratory is involved with a proposal for an Along Track Scanning Radiometer (ATSR) for sea surface temperature measurement. This is favoured for inclusion on ERS-1 as a complete instrument funded by the UK. In other contexts it could be engineered as add-on channels to optical instruments of the OCM type.

The laboratory has extensive experience of passive microwave instrumentation (PAM). It has collaborated with Denmark on proposals for ERS PAM instruments, is working with France on an instrument for SPOT 2 and discussing possibilities with India for their IRS-1 vehicle. Similarly to the low-cost altimeter proposition, the idea of a low cost imaging microwave radiometer (IMR) satellite has been considered. Microwave instrumentation will be necessary for the correction of atmospheric refractive index effects on very high precision altimetry.

Other interests include various upper atmosphere interests and the active microwave pressure sounder (AMPS) proposed by the Meteorological Office. In addition they have an instrument accommodation team who have worked on ERS-1 problems and for British Aerospace on LSat.

British Aerospace

The Filton group have specific interests in radar altimeters and have a company-developed breadboard for a system on which they have been collaborating with Rutherford-Appleton Laboratory.

The group has extensive experience with passive microwave instruments in the military sphere and have done studies for the DoI on satellite microwave applications.

Other work which could be of interest to the Radarsat Project is on the filtered attitude determination system (FADS) being developed under a DoI contract with Marconi (star sensor) and Ferranti (gyro). This was intended for ERS-1 and would provide high pointing accuracy for high resolution imaging instruments like the OCM and the SAR where fixed position accuracies if less than 1 km are required.

The Meteorological Office

The Active Microwave Pressure Sounder (AMPS) instrument proposed for ERS-1, with Herriot-Watt University, Jet Propulsion Laboratory and Rutherford-Appleton Laboratory, could be of interest for Radarsat. It was not accepted for ERS-1 but on Radarsat it could provide mutually correcting data with the scatterometer.

The Meteorological Office would only be interested in the instrument, however, if the Radarsat service was operational and capable of providing global coverage. This implies on-board storage and more ground stations, though there would be low-rate stations, possibly combining scatterometer and altimeter data reception. The instrument proposed for ERS-1 would have to be redesigned to take account of the higher orbit of Radarsat.

Other

EMI Varian and AEG have been commissioned to develop power amplifier tubes for the ERS-1 SAR. EMIV are developing a klystron and AEG a TWT. The klystron is likely to be the better solution and it might be of interest for the Radarsat SAR.

MSDS have a high performance stabilised antenna for ship-board use that may be of interest for portable tactical quick-look systems or processed product reception.

Instrument Costs

Rough figures for a number of the instrument options considered have indicated from a number of sources:

OCM (Ocean Colour Monitor) - 100 MAU.	:	£63M
OCI (Ocean Colour Imager)- a simplified lower performance instrument of considerably lower cost.	:	£50M
ERS-1 Altimeter.	:	£12M
Low-cost Altimeter.	:	£3. 5M
ATSR	:	£0. 8M
Low-cost IMR (Imaging Microwave Radiometer) package.	:	£3. 5M

3.3 Data Processing and Data Stations

The UK is well placed in the field of remote sensing data processing in general, though less so with regard to data receiving and pre-processing functions - an area in which, however, the supply of foreign components or elements is usual. For historical reasons the UK is particularly well established in radar processing.

UK experience in this last area includes long-term development of radar processors, associated with primary systems development by industry, and numbers of industrial, government and university groups working on radar data analysis and applications. In the case of applications of microwave data UK teamsare a major element in a well developed international community.

The UK position with regard to the potential secondary instruments on Radarsat is also strong. The low-rate instruments for the most part will represent no great problem and there are well-developed user communities in the UK working on the data problems. In the case of high-rate visible and infrared imaging systems the lead in Europe has been taken by France but the UK has the necessary capabilities and technology base to develop any system to its full potential. There is a great deal of long-term work, established facilities, and a very large user community to support initiatives in this area. Of the secondary instruments the scatterometer is the most problematical with regard to effective processing for applications, but all countries appear to be in the same position with regard to this.

The UK has a substantial capability in data station installation, both general and specific, in its communications and electronics industries. The main relevant remote sensing station capability is associated with the RAE facilities and in addition to this there is 'free-lance' university work in reception, pre-processing and processing.

In the most important area, that of SAR data processing, the chief expertise lies with Marconi, associated with the RAE facilities. Digital signal processing studies started from military initiatives in the 1960's and led to one of the first effectively real-time digital SAR processor systems in the 1970's. Expansion of this work led to definition studies for ground, airborne and satellite on-board processors, including a system for Seasat. The processor work is linked to SAR system definition studies for ESA and a digital SAR ground processor is shortly to be completed for the military. The company is also carrying out work in developing interpretation programmes.

The UK installed a SAR reception and processing system for Seasat operated by RAE and it can be expected that the processing capability will be retained and expanded and will utilise ERS-1 data, giving continuity of research, development and service up to the launch date of Radarsat. It should be noted, however, that much of the actual hardware - antenna, main computer, tapes recorders - is not of UK origin, and future systems are likely to have major foreign components.

Important UK data processing groups are, in summary:-

- For SAR processing and work on software: Marconi, SDL and Oxford Computers, as well as RAE and RSRE staff.

- For altimetry, scatterometry and other meteorological data work: IOS, Met. Office and Rutherford-Appleton Laboratory.

- For passive microwave work: BAe (Filton).

- For high-rate, high resolution visible and infrared image processing: a very large community including the established capability at the RAE Remote Sensing Centre.

- For general capability in data processing systems: Logica and the internationals like Scicon.

3.3 Clearly the development of Radarsat opportunities will be closely related to ERS-1 activities. British Aerospace will now be prime contractor for the ground segment of the ERS-1 Phase B developments with MDA responsible for the SAR quick-look facility at Kiruna. Logica will be dealing with some systems engineering aspects and the low-rate data and control facilities.

Precision processing of SAR data will be a national responsibility and both Dornier and Thomson will be developing their own processors in Europe, Dornier having links with MDA. An ESA bread-board processor being developed by MDA and Dornier involves some work by SDL on the pre-formating of Seasat SAR data types. Marconi see their processor developments taking a different direction from that of MDA. Marconi have done studies on the integrated data transfer and handling system (IDTH) for ERS-1.

4. USER REQUIREMENTS

The survey of UK user interests was based on groups who indicated a positive interest in microwave data in the BAe review of UK user interests in ERS-1 sponsored by the DoI. The most widespread interest was in the SAR but much of this is research orientated and it is apparent in most cases that insufficient is known about SAR in general for firm and reasonable views to be held on the required Radarsat instrument performance. For this reason, as well as the optimisation of the instrument for ice studies, in which UK interest is limited but not excluded, there is no case for UK views to affect the specification.

On the other hand there is considerable scope in the UK to use the Radarsat SAR data provided it covers UK areas of interest. As expected, there is a wide variety of potential applications in ocean and land areas. A number of groups are already committed to the use of radar imagery from various sources including Seasat, and are planning to extend their interest to the ERS-1 AMI coverage. The key questions for UK users is that of the acquisition of data over their areas of interest and its availability to them. As data storage is not contemplated for the primary SAR instrument, this hinges on the provision of additional main read-out stations.

There is substantial UK interest in the secondary instrument options with relatively clear-cut preferences, and further, considerable scope for the UK to influence the choice of instruments through participation in the hardware programme. Again questions of geographic coverage and data relay are key, though the problems of on-board storage for the instruments contemplated and for the low-rate read-out stations required are much less severe than those for the SAR.

In the context of the UK occupying a leading position; in global ocean and meteorological data collection; in overseas land applications; and because of its geographic location, European user requirements have also been considered. These will have a considerable bearing on the UK strategies of data acquisition and dissemination.

4.1 UK Interests

4.1.1. Oceanography and Meteorology

The proposed microwave instrument package of synthetic aperture radar with optional wind/wave scatterometer and altimeter could provide extremely valuable data for a number of UK users. In general wave data is of most interest to the oceanographers and wind data of most interest to the meteorologists and the interest in the supplementary instruments is weighted accordingly. However, the rule is not hard and fast and there is considerable scope for combination and complimentarity in the selection of the instrument package. Data from the microwave instrumentation could be useable immediately in operational forecasting, modelling, and engineering design work as well as in various research fields.

The inclusion of an ocean colour monitor or a sea-surface temperature instrument would provide information mainly in research applications. Ice data both from Arctic and Antarctic areas is mainly of interest for global modelling.

The Radarsat microwave package, following on from and complimenting coverage by ERS vehicles could greatly improve key data collection from the Southern Ocean areas for the global weather model and for improved regional and local forecasting in areas that will probably be seeing increased activity in resources exploration and exploitation within the project time-scale.

The case for microwave ocean/met data gathering can be summarised as follows:

1. To fill in gaps in key data in the present global data collection networks.

2. To add new types of information, and different qualities of information on a synoptic basis.

3. To provide additional coverage for specific projects, areas, or events on an ad-hoc basis.

4. To calibrate information from global observation stations and provide interactive measurements.

5. In the case of the imaging SAR, to provide an additional element in the monitoring of vessels and other objects.

Ideally, processed information of key meteorological parameters like wind field data should be avilable at the synoptic, 3-hour internal for distribution by the Global Telecommunications System. Ocean data from selected sites in the Global Observation Network would be required less frequently. Data for individual projects could only be supplied on an opportunity basis.

The UK is a world centre for meteorological and oceanographic data and for ocean operations and engineering. Specific interests of U.K. bodies place importance on data for:-

- General up-grading of world meteorological and ocean data for operations-immediate purposes and longer term modelling and archiving;

- Specific offshore areas for operational planning and the establishment of engineering design tolerance.

There are complementary interests in ship and data buoy networks which could be closely integrated into the data collection system.

The monitoring rôles suggested for the SAR facility include marine traffic census, fisheries control, and search and rescue operations. In the last case position-fixing and radio-relay elements would be combined. As coverage of sea areas will be either partial or intermittent, the data can be expected to be only part of a multi-element systems. Its use outside the range of the primary stations will require additional, though possibly down-graded quick-look, stations. Some of these could be mobile shipboard facilities.

Suggestions have been made to up-grade packages proposed so far by increasing the performance of supplementary instruments and increasing complementarity and by providing additional instruments.

UK group suggestions for payload objectives include the following.

1. <u>Improved altimetry</u>

This would be for better wave data and for geoid studies and would combine improved satellite position fixing with high-accuracy on-board instruments. The Radarsat payload would be one element in a global altimetry system which would include other satellites and ground radio, radio-reflector and laser position-fixing networks.

The European interest group of which the UK forms a part is looking for an improvement to 1-2 cm accuracy in the 1990s compared with a current state-of-art of 5-10 cms. Other satellites likely to be involved in the project are later ERS and SPOT vehicles and Indian remote sensing satellites. Other vehicles will, however, be necessary for geoid and ocean tidal effect studies as remote sensing satellites are limited to sun-synchronous orbits. One suggestion is for small dedicated altimetric vehicles on the pattern of the University of Surrey low-cost vehicles.

2. Atmospheric pressure sounding

This is the element of most interest to the operational meteorologists and inclusion of a pressure sounder could considerably increase interest by that community. An atmospheric microwave pressure sounder as proposed, but not accepted, for the ERS-1 payload could ideally be combined with a wind scatterometer as their data would be mutually corrective. Altimeter data could also enhance the readings.

Both data types would require on-board storage and additional low-rate read-out stations as global coverage would be required. In the case of the weather forecasting interest, a fully operational service would be required.

3. Upper atmosphere data

There is considerable UK research interest in upper atmosphere and considerable experience in instrument development in this field.

4.1.2 Land Applications

SAR imagery is seen to be of interest for terrestrial studies in the fields of soils, vegetation, crops, geology and hydrology. For the most part, for these applications, once-off, non time-dependant data has sufficed to date. In future there is expected to be more interest in temporal comparisons giving rise to more demanding acquisition schedules. Satellite SAR data could have a rôle in monitoring land features demanding high spatial resolution over the short to medium term, equivalent to ice monitoring. This would be particularly the case in areas subject to high cloud cover frequencies. So far, however, none of the applications proposed for this mode of operation have attracted sufficient support to justify a dedicated operational programme, or one in which the user is the primary client.

It should be appreciated that Radarsat SAR imgery will for the most part be regarded as one of a number of remote sensing sources available to the various disciplines. It will probably continue to be used mainly as a supplementary rather than a primary data source.

Altimeter and position data, particular if it is at the highest possible spec., will attract interest for geodetic survey and operational position fixing (including, possibly, in search-and-rescue situations). Again, this will be only one of a number of potential sources for users.

Requirements for high resolution visible band and infrared imagery will be essentially the same as for the Landsat and SPOT programmes. Such an instrument aboard Radarsat would contribute to already well-developed and expanding programmes of use for this type of data. However, for the full opportunity to be realised, on-board storage and/or high-rate data stations will be required, though these would presumably be joint facilities dealing with similar transmissions from a number of vehicles.

4.1.3 Geographic Coverage Requirements

Certain of the applications discussed so far have been aimed at global interpretations of meteorological, oceanographic and geodetic parameters. Clearly the data collection requirements would ideally be global in these cases, though this does not rule out valid possibilities for select area coverage as the Radarsat vehicles will be one element in an integrated global satellite observation system. The interest in this type of data is international, either of value for the scientific community in general or to users of the global services. This does not preclude specific UK-national interest in becoming a data and service centre for world-wide users.

Some specific UK requirements may thus have global scope, but in evaluating UK interests it is necessary to determine the geographic areas of primary interest as these will have a considerable bearing on national initiatives in data acquisition and supply and the necessary supporting technology.

In the area of marine applications the main interest is 'UK designated waters' including the Rockall Shelf for forecast and engineering data primarily for oil operations. Current requirements will extend well into the proposed Radarsat time-frame with general movement of areas of prime interest towards the edges of the continental shelf. Because of the leasing mechanisms, however, it is not possible to identify specific blocks of interest more than 5 to 10 years ahead.

The extent of UK designated waters, their strategic importance and the extent of interest in them assures a strong case for direct data acquisition from Radarsat by a UK station or stations. Beyond these the areas between Greenland and Norway have particular strategic significance and justify UK interest in a high latitude reception station.

Oil interests, and to a yet undefined extent other offshore resource exploitation interests, dominate many other areas of continental shelf. Many of these are only just beginning to be explored and it can be foreseen that there will be a considerable need for operational forecasting services for the exploitation phase and pre-exploitation data collection for engineering design and planning purposes. Again, it is difficult to predict which shelf areas will be of interest in the Radarsat time frame. The position is clouded by the lack of international agreements on the explotation of the sea-bed beyond national limits and on the Antarctic Shelf.

Because of the strong scientific and commercial presence in the field it can be expected that UK interests could emerge in any of the new continental shelf areas being developed. The approach to data acquisition from these areas by satellites cannot for the most part be pre-determined. Consequently Radarsat coverage will be fortuitous and the ability to make use of it dependant on establishing read-out stations where the need arises.

The Falkland shelf and Antarctic waters, however, are one area of particular interest to the UK by reason of our extensive historical and scientific involvement in the area, and because of the likelihood of a huge resources potential. Any prospects are long-term so that even the 10 to 20 year lead-in time for data collection considered necessary for new marine exploitation areas could be serviced in the Radarsat time-frame. Ambitions of this kind require that a long-term data collection network be set up covering the area and including a high-rate satellite data station. The UK has substantial research interests in the Arctic, working in collaboration with Canada and on other international programmes.

For land applications it must be concluded that data from any Radarsat instruments will only be obtained on a fortuitous or ad-hoc basis, depending on acquisition station policies or orbit patterns determined for other reasons. UK coverage would be supplied by a UK or European station justified primarily by maritime applications.

As with ocean applications, UK land application interests are world-wide and requirements for data could arise virtually anywhere. It can be envisaged that new regional reception facilities could be established to serve as yet unidentified projects of sufficient importance. However, such facilities would be unlikely to be exclusively for Radarsat.

4.2 European Interests

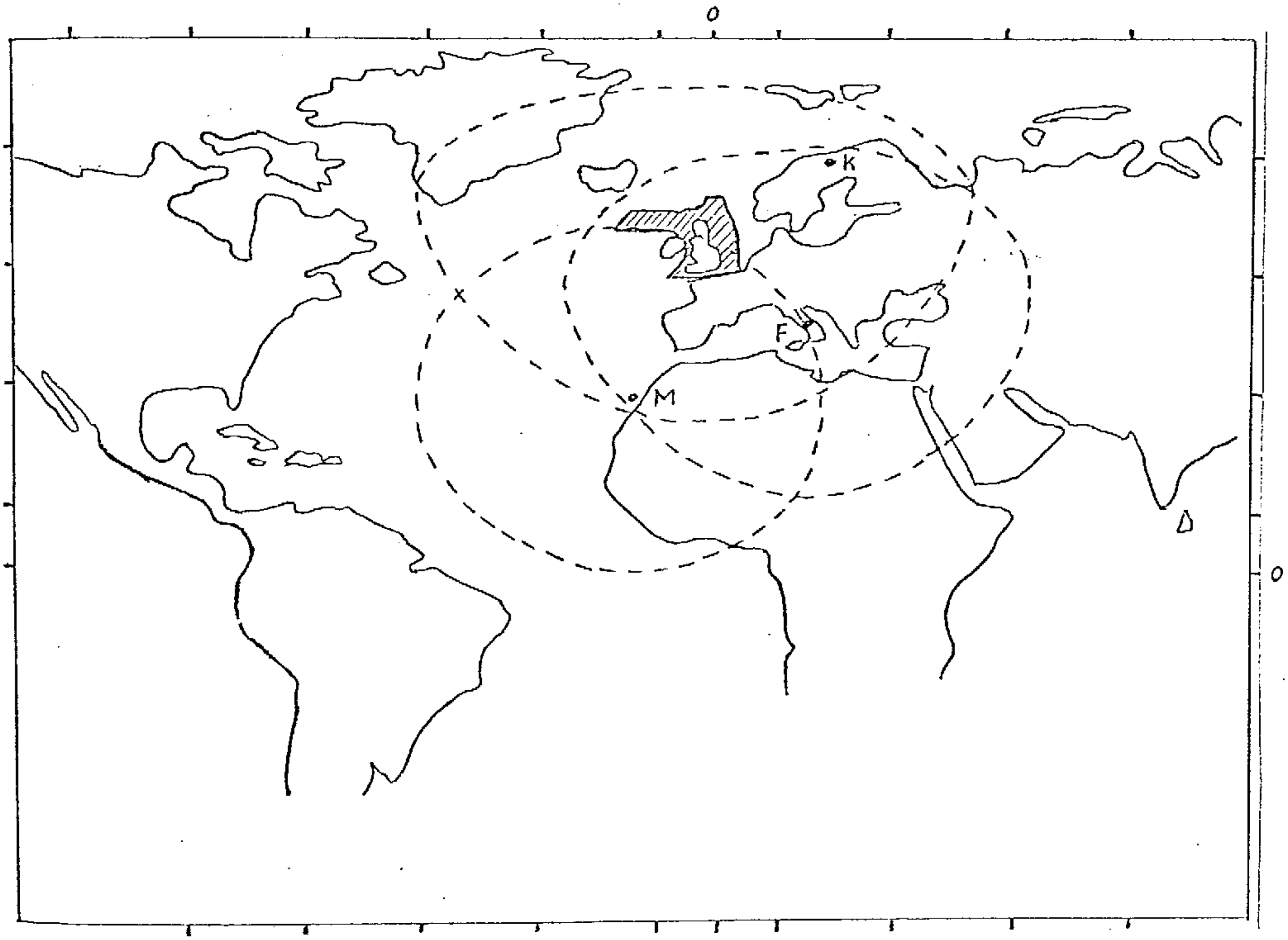
European interest in Radarsat (and in other sources of SAR) are of interest to the UK in the context of the services that might be provided to other European countries. Though, of the European countries, the UK has potentially the greatest interest in radar imagery, there is strong interest in several other countries. Though visible and IR coverage is undoubtedly in greater overall demand, the selection of AMI (active microwave instrument) as the primary system on ERS-1 confirms this, the visible/IR MSS role having been pre-empted by the French SPOT programme.

For the secondary instrument data it can be assumed that there will be at least an equivalent European demand for data, particularly as, in the case of the low-rate instruments, major uses are in internationally - organised applications.

Estimates for European (ESA member-states) demand for remote sensing satellite data (including SAR) were made in the FEDS (Future Dissemination Systems) study carried out for ESA in 1980. The model used did not include Radarsat, but assumed a continuing SAR service following-on from ERS-1 using equivalent proposed vehicles.

Figure 2

<u>Proposed Earthnet Station Coverage</u>
<u>For a 900 km Orbit</u>



K. - Kiruna
F. - Fucino
M. - Mas Palomas

UK-Designated waters

Table 1

European SAR Coverage Requirements on basis of 100 x 100 km Scenes for European Earthnet Coverage Area [(1)]

User Group	Coverage. No. of Scenes acquirable[(1)]	Annual Repetition	Utilisation Factor	Total No. of Scenes Required
Mineral Exploration	345	1	.2	69
Land Use Planning	204	1	.1	21
Crop Management	82	13	.4	427
Disaster Warning	20	2	.4	16
Ship Routing	162	26	.4	1685
Ocean Engineering	137	6	.2	165
Offshore Oil Operations	137	26	.4	1425
Offshore Mining	324	13	.2	843
Military Operations	3240	26	.4	33696
Ocean Survey Operations	324	13	.1	422
Environmental Monitoring	150	26	.4	1560
Search and Rescue	324	2	.2	130
Transportation Management	150	26	.2	780
Scientific Research	324	1	.1	33
Annual Total Acquisitions				41272

(1) Coverage area of stations at Kirura, Mas Palomas and Fucino.

Source: Future Earthnet Dissemination System Study. ESA. 1980.

Table 1 is a summary of a prediction user model for the European area of the proposed Earthnet data dissemination system, a good part of which is UK designated waters (see Figure 2). It shows an estimate of demand by user-groups in terms of numbers of standard 100 x 100 km image scenes multiplied by the annual repetition and down-graded by a notional utilisation factor determined from estimates of data value and the credibility of the user group. The number of scenes determined per year is the probable upper level of actual usage that will be established in the 1990's, if satellites are available to supply the data. The demand growth is projected to start with ERS-1 with exponential growth taking place following the establishment of an operational service, and achieving saturation at the levels indicated after 7 to 20 years.

The main feature of this model is the predominance of the military demand which, if it emerged,would be comprehensive both in area coverage and repetition time. The importance of this potential demand to justify an operational satellite SAR service warrants major efforts being made to interest the military in the project.

A number of conclusions and implications can be drawn from these projections:-

- There is a substantial European demand for satellite SAR but a large part of this is for military use. Implications are that the military might require their own secure data systems as national ventures or through a centralised executive body like NATO.

- From the nature of satellite SAR coverage, more than one satellite would be necessary to provide a multi-purpose operational service. This is a requisite to achieve the full customer demand and Radarsat is clearly a candidate for this.

- Several high-rate read-out stations are necessary to service the European Earthnet demand area. Though the Earthnet model assumed stations at Kiruna, Fucino and Mas Palomas (see Figure 2) station details are not yet determined and this will not necessarily be the distribution of radar read-out stations, particularly as data processing has been taken out of the ESA programme and will now became a national responsibility. There is a case for a UK station covering the whole N. E. Atlantic area and most of Western Europe and supplying a large part of the European user's needs. This has been proposed for the ERS series and the prospect of Radarsat reinforces the case.

4.3 Needs for Data Stations

These arise from user requirements and the provision of ground stations is an area in which there are major prospects and advantages for UK involvement. Associated with the Radarsat programme are four main kinds of station opportunity.

- High-rate, full specification SAR receiving stations with associated advanced precision processing facilities.

- Quick-look or down-rated SAR reception facilities, available for less cost.

- High rate stations for a visible/IR imaging instrument (OCM/MSS) if one of these is included in the secondary package.

- Low-rate stations for other secondary instrumentation.

It is unlikely that separate reception facilities for an OCM/MSS type instrument on-board Radarsat will be required as it can be serviced by stations planned for similar Landsat and SPOT instruments in Europe and elsewhere in the world. Individual facilities for other secondary instruments will be relatively small and simple. The most interesting prospects for the UK lie in the SAR reception and processing facilities, particularly if these are combined with ERS-1 needs.

- A high rate SAR station in the UK, which, because of its area of coverage, would serve most of the European requirements. This would have associated facilities for precision processing.

- Quick-look or reduced-spec. raw-data acquisiton stations only for possibly for special purposes - e.g. military applications. Such stations could be portable.

- Regional SAR stations. These would be permanent stations of high-rate or reduced specification types depending on requirements. They would cover areas of UK interest as part of national or international programmes.

A full-spec. UK SAR station would comprise a major project for UK industry. In order to gain the maximum benefit for such an approach to the ERS and Radarsat programmes it is essential that the station should be specifically tailored for the purpose and not be an ad-hoc arrangement. The case for a UK reception facility is strengthened by the already advanced and planned development of complementary SAR image processing facilities at RAE.

The establishment of such facilities will be a major encouragement for the development of UK expertise in the subject of imaging radar in which we already have a lead. It will allow the development of operational experience which will be of great value as a market for overseas facilities and services develops. The setting up of a UK station, intially for ERS-1, could effectively capture the market for satellite SAR data in the European sector as it is unlikely that other countries would seek to duplicate, in the first instance, such expensive installations.

Lower specification SAR stations could be in demand to take advantage of Radarsat coverage anywhere in the world. These would include quick-look stations for operations of limited scope and/or advanced, but still slightly down-graded portable stations which could either be constructed as easily transportable units or mounted on ships. Their possible rôles are in military or military-type surveillance and coverage of new areas of special interest - for instance for an ocean-data collection campaign for a new continental shelf area.

The Tromso quicklook station set-up for Seasat is an example of the first kind. In the second case a ship-borne SAR station combined with satellite altimeter or scatterometer and met-data reception could form part of an ocean data system including data buoys and ship observations.

The possibility of the UK installing high-specification regional stations is not high unless a UK reception facility is established in the first instance. The idea of a station giving coverage of the Antarctic has been suggested and this is certainly on an area where there could be a concentration of UK interests in the long term. Presumably a SAR station would be combined with other satellite reception and relay facilities. Technologically there is no serious obstacle but logistics would be difficult. For this operational experience in connection with a UK facility would be invaluable. Other European countries like West Germany have research interests in the Antarctic and the possibility of a bilateral approach could be explored.

Propositions for stations in other regions established for, or in collaboration with the local authorities could arise. Most of UK Arctic interests can probably be covered by Canadian stations but there is a case for a military orientated station in Northern Norway.

5. STRATEGIC IMPLICATIONS

The establishment of a satellite service by Canada,whose objectives are primarily to facilitate the exploitation of very large new oil and gas resources,secondarily to improve world meteorological and oceangraphic forecasting services,, and also to contribute in other fields, must have substantial strategic implications to the UK. With respect to specific UK interests, considerations fall into three main categories:-

- The implications of the new hydrocarbon resources coming onto the world market.

- The implications of improved data on new resources-rich continental shelf-areas.

- The scientific and technical position in Canada vis-a-vis the UK.

5.1 Oil and Gas Supplies

Considering the uncertainties in supply, demand and even in short-term development policy in hydrocarbons, only the broadest implications can be drawn.

New finds on the Canadian North Shore, including in the Beaufort Sea, and off EasternSeaboards are likely to lead to Canadian self-sufficiency in oil products in the near future, with the favourable situation continuing long-term. In the even longer term the very large inland heavy oil reserves suggest even greater hydrocarbon security. Under these circumstances there is everylikelihood of Canada becoming a substantial exporter of oil. Large discoveries, particularly on Melville Island on the Arctic Pilot route indicate a similar position for natural gas - which could be shipped out as liquified natural gas (LNG) or possibly, in some propositions, converted to liquids like methanol for easier transport.

The natural market for surplus Canadian hydrocarbon is the USA. However, there is the possibility of export to Europe and several European countries have been looking at Canada as a strategic source. The development of the Artic Pilot Project will considerably improve the position with regard to Canada as a supplier to Europe and allow direct export of crude or only primarily - processed products (LNG, fuel-grade methanol) to Europe direct, though this would have an effect on refinery development in the Gulf of St. Lawrence and the Canadian Maritime Provinces. Europe on the other hand has a refinery capacity surplus.

Considering the world oil supply position in general and the time-scales of planned development,Canadian exports to Europe past 1990 should not adversely affect UK exports and would fall in well with European objectives to diversify sources of supply, particularly away from the middle East.

The position with regard to gas may be less favourable as the economics of long-distance transport of LNG or gas-derived liquids like fuel-grade methanol are less favourable and Canadian exports would be competing with very large long-term exports from sources nearer to Europe. Question of energy security will have large bearing on this.

5.2 Resources Areas

With the extension of hydrocarbon exploration and exploitation offshore there is an increasing demand for environmental data from continental shelf areas. Over 300 major oil and gas offshore basins have been recognised with key areas of interest like the North Sea and Labrador Sea already being exploited under difficult circumstances. Many other basins are only beginning to be explored and in the medium term we can expect that large areas of the Antarctic continental shelf and the adjacent areas like the Falklands shelf will come to be exploited. Exploitation is already underway on for south as Tierra del Feugo.

Efficient exploitation of offshore areas calls for long-term ocean-met data collection and as good a forecasting service as possible to assist planning and design and actual operations. Radarsat will be a valuable contributor of such data.

Apart from its own considerable area of 'designated waters' the UK could have an interest in almost any other new offshore resources area through its internationally operating industries and where it could exploit its expertise in offshore and oil technology acquired in the North Sea. Of these areas the Antarctic and its fringes are of particular interest. The UK has a long established background of research in this area and the question of an Antarctic satellite receiving station has already been raised in Section 4.3. On top of the requirement for planning and operational data in this area, that could be partly supplied through a Radarsat series, the current crises over the Falkland Islands suggests that there could be considerable security benefits from an improved system of Southern Hemisphere surveillance. Radarsat timing corresponds with the expiry in 1989 of the Antarctic Treaty, which, if not renewed will be bound to lead to many conflicting claims. Under these circumstances an additional vehicle in the global observational system could be of particular value to European and Canadian interests in the area.

5.3 Science and Technology

Canada and the UK clearly have large areas of common interest in the fields of science and technology so as Canada's objective to obtain technical excellence include international collaboration, the UK is potentially a favoured partner. Specifically the two countries already collaborate in Arctic research and interest by the UK in satellite data acquisition systems designed for this could clearly be complementary. Such a link could be profitably extended into Antarctic and Southern Ocean work.

6. A UK POSITION : PROVISIONAL RECOMMENDATIONS

6.1 General

UK participation in the Radarsat programme is desirable for a number of reasons :

- It is a major remote sensing satellite project promising to establish an operational service in a variety of data types of interest to UK users.

- It will be a major element of a global satellite data collection network in which the UK can be expected to be involved on at least a regional basis.

- It offers a number of opportunities to UK industry for long-term collaboration in the development of hardware and services.

- It is essentially compatible with the remote sensing programme objectives of ESA in which the UK can be expected to play a leading role.

UK direct industrial opportunities fall broadly into two areas.

- Opportunities in space engineering and on-board instruments.

- Opportunities in data processing equipment and services.

Of these the first appear to be of the most immediate interest and is more exclusively bound to Radarsat. The data processing and services opportunities, on the other hand, will form part of the developing UK posture in satellite remote sensing overall.

As the previous report sections describe, industrial opportunities on the spacecraft side lie in the provision of LSat as the bus vehicle for the series and the provision of a range of on-board instruments, complete or in part.

On the ground segment side the assurance of a continuing service in SAR data and the expansion of interest in this data could create a market for data stations and SAR processors of varying size from full specification main stations to limited capability quick-look or tactical portable stations. Data from Radarsat could contribute to regional data services provided by the UK, particularly from microwave instruments and emphasing oceanographic and meteorological applications.

6.2 Space Segment Strategy

Until the final specification of the vehicle and instruments is decided upon, the strategy should specifically concentrate on the following items:

i. The promotion of LSat as the bus.
Studies on the modification of LSat as a low-earth-orbit SAR-carrying vehicle have been undertaken by BAe for ESA and BAe is in close contact with Canada over the possibility and the wider prospects for collaboration in a major LSat programme development.

ii. Collaboration with Canada in the development of the C-band SAR system, principally involving Marconi and using the experience to be gained with the ERS-1 AMI.

iii. Promotion of a range of secondary instrument possibilities that could be provided by the UK.

Of these the first line of activity is well underway and various options are being pursued by BAe and DoI and an outcome in relation to Radarsat can be expected before the end of the study in September 1982. The selection of LSat could have a considerable bearing on item iii, allowing, possibly, more than one instrument in the secondary package. It should be borne in mind, however, that LSat may prove not to be a satisfactory solution.

Possibilities of collaboration between Marconi and Spar Aerospace in the development of space-borne SAR are already being considered but it is felt that further encouragement is needed in this area to secure for the UK a commanding position in SAR development.

Activities in exposing the full range of UK capability to provide secondary instruments and supporting systems are only now getting underway. Despite the initial preference in the provisional concept design review for a scatterometer or a high resolution imaging instrument as the first choice for the secondary package, the fact that Canada is also looking for the secondary instrument to be provided free suggests that the final selection may be more open than this. The choice of bus also has a major bearing in the instrument package. It could be that an offer by the UK to supply a secondary instrument and to enter into an arrangement on the bus could be closely inter-related.

At the moment a high precision altimeter combined with an improved satellite tracking and position-fixing system appears to be the best prospect for the UK both on commercial grounds and in terms of the value of the data provided. Ideally, a combined package of altimeter, scatterometer and AMPS with an advanced position-fixing system would give the most valuable immediately perceived results in meteorology and oceanology. The UK could, however, also provide or contribute to a passive microwave or a visible-infrared imaging instrument and associated pointing systems.

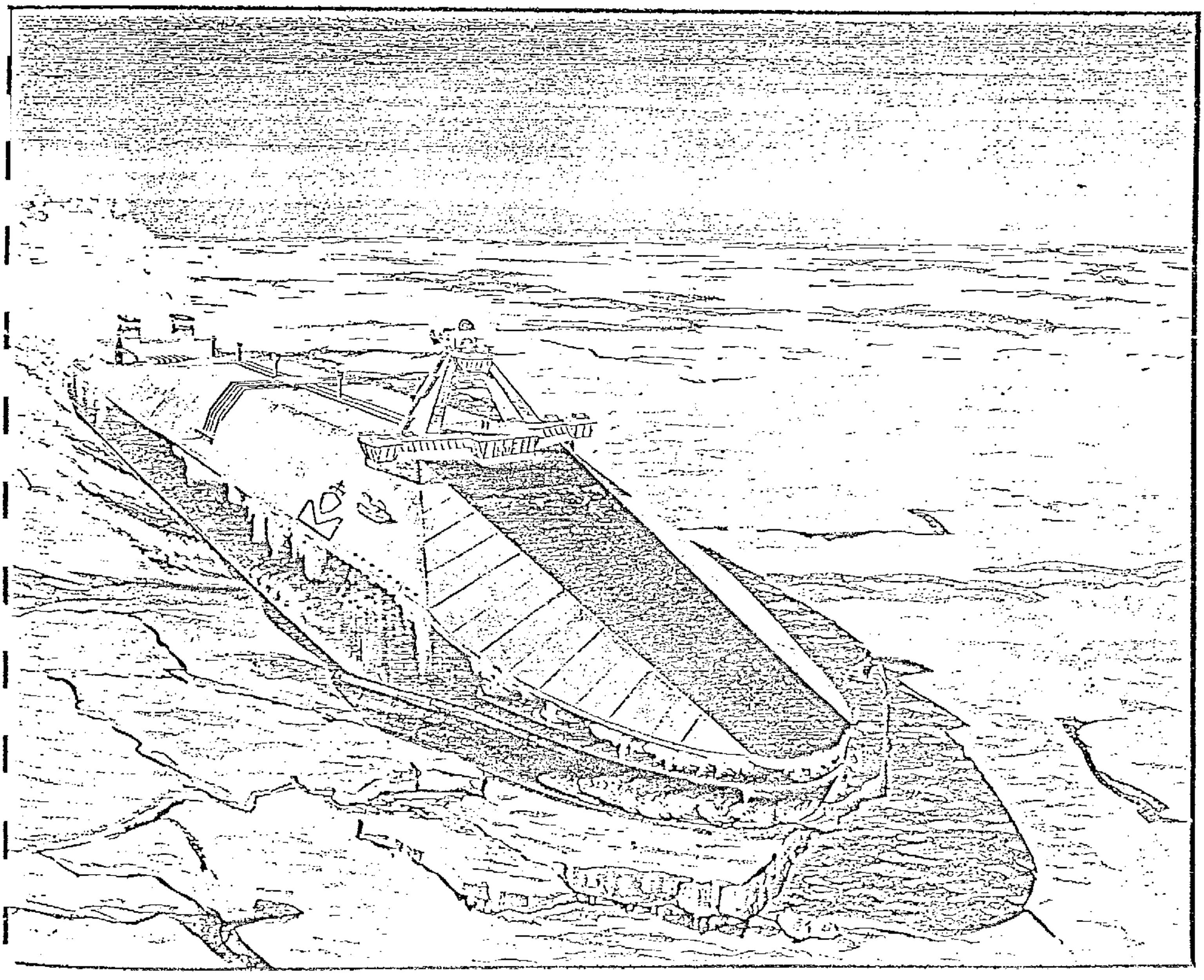
6.3 Data Segment Strategy

Acquisition and dissemination of Radarsat data will form a part of a postulated UK strategy to provide regional satellite microwave coverage over the eastern Atlantic and western Europe. This is compatible with the UK developing its leading role in global meteorology and oceanology. Both these are prime objectives in an overall remote sensing policy and will be a driving force in the development of SAR processing in the UK leading to industrial opportunities for data stations and processing equipment, and commercial opportunities in data services .
Clearly government has the key role in the data acquisition strategy through RAE. It may be possible to obtain support for the development of the service overall from the EEC and IMCO.

ANNEX I

THE ARCTIC PILOT PROJECT

Arctic Pilot Project



INTRODUCTION

The Arctic Pilot Project (APP) is designed to test the feasibility of producing natural gas from wells in the Arctic Islands, transporting the gas by a 160 km buried pipeline, transforming the gas into liquefied natural gas (LNG), and shipping the LNG by ice-breaking carrier to a regasification plant in southern Canada – all on a year-round basis.

The project has been called a pilot because it is designed at the minimum scale necessary to prove the technical and economic feasibility of delivering Arctic Islands natural gas by ship. It will be one-tenth the size of any full-scale alternative for the delivery of Arctic gas. Even though the project is small in scale, it offers significant benefits for transportation and industrial development, job creation and access to frontier resources.

The project represents the leading edge of technology. Implementation of the project at this time will allow Canada to acquire the experience of developing, on a controlled scale, transportation systems that will be needed for future movement of northern resources.

Petro-Canada initiated the project in 1976 as a way to stimulate frontier exploration and to increase Canadian energy supply. The other participants in the project are NOVA, An Alberta Corporation; Dome Petroleum Limited; and Melville Shipping Ltd., all of which are large, responsible Canadian companies.

NORTHERN FACILITIES

The supply of gas for the project will originate from the Drake Point gas field on the northern Sabine Peninsula of Melville Island. Natural gas was first discovered in this area in the late 1960s. Continued exploration has since proven that reserves in the field are in excess of 150 billion m^3.

Panarctic Oils Ltd. will own and operate the production wells, the gathering system and other facilities to produce the 60 billion m^3 of gas required during the 20-year life of the project.

From the Drake Point field, the gas will be carried south 160 km by a 559 mm diameter pipeline across Melville Island to the liquefaction plant at Bridport Inlet.

Since Melville Island is in a zone of continuous permafrost, a buried chilled gas pipeline will be used over the entire route. The gas flowing into the pipeline will be chilled to -6°C to prevent melting of the permafrost.

Bridport Inlet, on the southern coast of Melville Island, is a 93 km^2 natural harbour. It is here that the natural gas will be liquefied and temporarily stored before being loaded onto the ships for the 5 200 km journey south.

The natural gas will be liquefied in a series of steps in which it is cooled to about -162°C. During this liquefaction process each 600 m^3 of natural gas is reduced to about 1 m^3 of LNG, resulting in a very compact energy source.

The LNG plant and storage tanks will be barge mounted. It is planned that the three barges will be built in southern Canada where control over cost and construction schedule can be effectively maintained. The barges will be towed to Melville Island and installed there as part of the Bridport facilities.

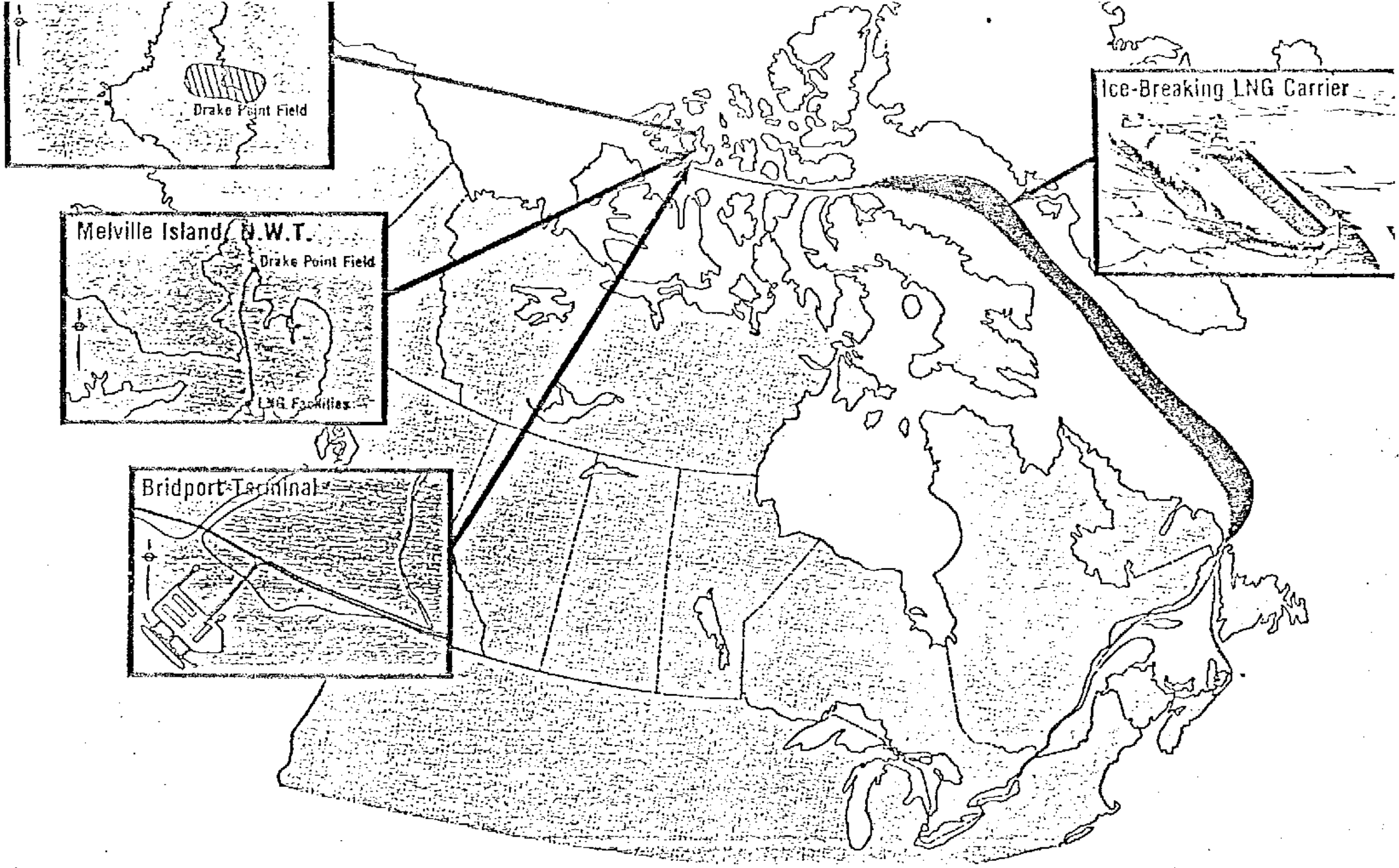
SHIPPING

The two ships carrying the LNG to southern markets will be among the most sophisticated and powerful commercial vessels ever built. They will be the world's first LNG carrying ships with ice-breaking capabilities. Each ship will be 395 m in length overall with a beam of 50 m and will have a draft of 11.5 m in open water, 18 m in ice.

The route to be taken by the ships has been carefully studied for several years using satellite imagery and on-ice surveys. The historic size, location and number of icebergs and ice pressure ridges have been taken into account in designing a route that will optimize fuel consumption without adversely affecting the environment.

The route chosen reflects the current state of knowledge of physical and biological processes in the regions traversed. This route will continue to be studied both before the ships are launched, and during the operations phase. Each ship passage will avoid or minimize environmental damage and physical hazard to the ships and crews. It will also preserve public safety and the traditional northern way of life, while maintaining economic feasibility of the project.

As an indication of the participants' concern for preservation of the environment, during the past



year the route has been revised. The resulting route is a somewhat narrower corridor, avoiding environmentally sensitive areas, particularly in the Arctic. In consideration of resource harvest areas along the Greenland coast, the route has been adjusted to a minimum of 100 km offshore.

Propulsion for the ships will be provided by a combined gas turbine/steam turbine system, a choice that makes full use of the LNG cargo boil-off which occurs naturally on all LNG vessels. This boil-off occurs as a result of heat flow from the environment to the relatively cold cargo, causing a small percentage of the LNG to vaporize. The use of gas as a fuel source makes the carriers non-polluting energy transporters.

Each ship will have two crews of 42 persons which will alternate voyages. Return voyages are estimated to take 33 days in winter and 16 days in summer. A total of 16 trips per ship per year will be made.

The ships will be fitted with the most up-to-date radio and satellite communications equipment. Advanced radar and ice detection systems will be included along with independent position-fixing equipment.

All LNG ships have double hulls in order to protect the containment systems. The APP ships will extend this concept by having double hulls throughout and by strengthening the outer hull and support members to withstand the ice loads to be encountered. Movement through ice will be at a reduced speed to further enhance the safety of operations.

SOUTHERN FACILITIES

The APP participants and TransCanada PipeLines (TCPL) have undertaken extensive studies of the potential terminal sites in Eastern Canada. After careful review of all factors there are two possible sites for the location of these facilities: one is at Gros Cacouna in the Province of Quebec, and the other at the Strait of Canso in the Province of Nova Scotia. Both locations are acceptable to the sponsors on the basis of environment, socio-economics, shipping capability and public safety.

At the location of the terminal, TCPL will construct and operate the unloading dock, storage tanks, revaporization equipment and fully instrumented control facilities. Nearby will be office space for the land-based, carrier support staff.

The LNG will be unloaded from the ships into two 100 000 m^3 storage tanks. This liquid will be pumped up to pipeline pressure, and converted to a gas. The gas will then be distributed to the market via conventional pipelines.

If regulatory approval for the project is received early in 1982, delivery of Arctic gas will begin in late 1985 or early 1986. This gas will be sold to Eastern Canadian customers at the prevailing local price. In exchange, Western Canadian gas, which would have been pipelined east to supply this market, will be displaced and sold to customers in the United States at the prevailing current border price.

REGULATORY PROCESSES

Approval from various levels of authority is required before development endeavours such as the APP are permitted to begin construction and operations.

As a first step, in April 1980, the federal Environmental Assessment and Review Process (EARP) panel, operating under the auspices of the Department of the Environment, held detailed hearings in four Arctic communities. In November 1980, the Department of the Environment recommended approval of the northern components of the project, subject to certain conditions.

At the provincial level, public hearings were held in Quebec in January and February 1981, and acceptance of the Gros Cacouna terminal was given in June. In Nova Scotia, public hearings were held in April and June 1981, with approval granted for the Melford Point terminal in September.

During the summer of 1980, an application was made to the National Energy Board (NEB), the Department of Indian Affairs and Northern Development and the Department of Transport. The NEB has reviewed this information and scheduled public hearings concerning the technical and economic aspects of the project to begin in February 2, 1982. Based on the Board's assessment of the evidence presented, a recommendation which may incorporate the EARP findings and provincial conclusions will be presented to the federal Cabinet as to the terms and conditions under which the project may proceed.

If regulatory approval from agencies in the United States is not received for the import of displacement gas, the flexibility of ship transportation could allow different markets to be served. For example, the LNG could be sold to the European market where regasification terminals and other LNG facilities already exist.

The distance from Melville Island to northern mainland Europe and Eastern Canadian ports is comparable.

CANADIAN BENEFITS

As a unique venture, the APP promises to generate significant benefits for the development of year-round arctic shipping, Canadian frontier industrialization, resource access and development, and national and technological sovereignty. The project will provide extensive opportunities for the development of new technology in such areas as ship design, fabrication, and operations; arctic engineering, communications and navigation; environmental data collection and oceanography; and emergency management.

A major component of the APP is the long-term commitment to a research and development program. This program will address environmental, socio-economic and technological issues over a 20-year period. The program will be staffed by a combination of northern residents, APP personnel and scientists from Canadian research institutes.

The APP personnel, for some time, have had ongoing and extensive discussions with residents of northern communities on all aspects of the project. The proponents intend to continue this policy and anticipate a high level of involvement in the project by northerners.

A special purchasing policy and implementation plan have been developed to ensure that maximum industrial benefits are obtained for Canada during construction and operation of the project. Preference will be given to Canadian suppliers where the choice is consistent with normal competitive criteria. In cases where technology is new and vital to Canada, some preference beyond normal criteria will be given to Canadian companies.

PROJECT DESCRIPTION:

The Arctic Pilot Project is designed to produce and liquefy 9.0 million m^3 (317 million standard cubic feet) of natural gas per day in the Arctic and move it to eastern Canadian markets in ice-breaking ships.

GENERAL

Project partners: Petro-Canada Exploration Inc. (37.5%); NOVA, An Alberta Corporation (25.0%); Dome Petroleum Ltd. (20.0%); Melville Shipping Limited (17.5%). Partners in Melville Shipping are Federal Commerce and Navigation Ltd., Upper Lakes Shipping Ltd., and the CSL Group Inc.

Cost of project: $1.5 billion, excluding field development and southern receiving terminal (1980 dollars), ($2.1 billion as built).

Date of application to National Energy Board to export gas: October, 1980.

Development time and money spent to date: Five years and $33 million, to middle of 1981.

Construction time: Four years. (10,000 man years for ships, 13,000 man years for other).

Project life: 20 years.

NATURAL GAS FIELD DEVELOPMENT

Ownership: Panarctic Oils Ltd. 100%.

Field Location: Drake Point Field, Melville Island, N.W.T.

Field gas reserves: 150 billion m^3 (5.6 trillion cubic feet).

Gas reserves required for project: 60 billion m^3 (2.2 trillion cubic feet).

Cost of field development: $164 million (1980 dollars), ($279 million as built).

Operating staff: 21

PIPELINE

Ownership: Arctic Pilot Project

Length: From field to Bridport Inlet - 160 km (100 miles).

Diameter: 56 cm (22 inches')

Pipeline cost: $138 million (1980 dollars), ($188 million as built).

Operating staff: 6

LNG FACILITIES

Ownership: Arctic Pilot Project

Location: Bridport Inlet, southern coast, Melville Island, N.W.T.

Terminal costs: $620 million (1980 dollars), ($861 million as built).

Terminal storage capacity: 200,000 m^3; barge-mounted

Operating staff: 40 on site

METRIC CONVERSIONS

1 m^3 of natural gas	=	35.3 cubic feet
1 m^3 of LNG	=	626 m^3 of gas
1 m	=	3.3 feet
1 km	=	0.62 mile
-162°C	=	-259°F

ABBREVIATIONS

hp = horsepower

MARINE TRANSPORTATION

Ownership: Arctic Pilot Project

Number of ships: Two

Classification: Arctic Class 7 icebreakers

Length of ships: 395 metres

Beam of ships: 50 metres

LNG capacity for each ship: 140 000 m^3

Power level: 112 megawatts (150 000 hp.) - gas turbine/steam turbine (four times that of standard LNG carriers of comparable size).

Duration of voyage: 33 day round trip in winter
16 day round trip in summer

Cost of two LNG carriers: $625 million (1980 dollars), ($919 million as built).

Operating staff: 42 per crew (4 crews).

SOUTHERN RECEIVING TERMINAL

Ownership: TransCanada PipeLines 100%

Location: St. Lawrence River, Quebec or
Strait of Canso, Nova Scotia

Terminal Costs: $199 million (1980 dollars), ($299 million as built).

Terminal storage capacity: 200 000 m^3 in two tanks

Operating staff: 43

CONNECTING PIPELINE

Ownership: Trans Quebec and Maritimes Pipeline Inc. 100%
(TransCanada PipeLines 50%,
NOVA, An Alberta Corporation 50%)

Pipeline cost: $34 million (1980 dollars), ($49 million as built).

PROJECT SHRINKAGE

Melville pipeline	NIL
Bridport plant	6.8%
Marine transport	6.9%
TOTAL	13.7%

ANNEX II

RADARSAT SPECIFICATIONS. May 1982.

Radarsat Specifications

Vehicle		ERS-1 : Comparison
Orbit	1001 km	663.6 km
Inclination	99.48^{o}	98^{o}
Design life	80% to 5 years	-
Launch compatability	STS/Ariane IV	

Main Instrument

SAR		
Frequency	C-band/5.3 GHz	5.3 GHz
Addressable Swath Domain	500 km	-
Acquisition Swath	150 km	75 km
Look Angles	$20\text{-}40^{o}$ (steerable)	35^{o}
Look Direction	Left	
Subswaths	3-5	
Resolution	25m	30m
Ground Position Accuracy	Pixel - 100m (Geocoded data)	
Coverage/Looks	1 per 24 hrs N of 70^{o} N 1 - 2 per 72 hrs 00 to 70^{o} N	
Duty Cycle in Sun	15 - 20 mins.	
Duty Cycle in Eclipse	10 - 15 mins. (plus low-rate instrument data).	
Data Storage	Limited	

Secondary Instrument Package

First Choice:		Determined
- Scatterometer		Scatterometer combined in AMI.
Frequency	Ku-band/14.5 GHz	C-band/5.3 GHz.
		Altimeter combined in AMI. C-band/5.3 GHz.
		Along-Track Scanning Radiometer.

Second Choice:

- Unspecified VIR
  (Visible-infrared Imaging Radiometer).

ANNEX III

PROPOSED RADARSAT ICE AND OCEAN INFORMATION SYSTEM

Source:- Minutes of Radarsat Information Standards Committee Meeting: September 28/29 1981 Richmond, B. C.

Whatever sensor combination is chosen for Radarsat, the raw data will be received in real time by one or more of three ground stations at Prince Albert, Saskatchewan, Resolute, NWT, or Shoe Cove, Newfoundland. Alternatively, there may be a single receiving and processing facility at Churchill, Manitoba, which would be less costly, but feasible only if the satellite orbit is sufficiently high (1000 km or more). SAR, and other necessary, data processing facilities will be located at the Prince Albert and Shoe Cove Stations. Raw SAR data received by these stations will be converted to imagery and then transmitted on to users including Ice Forecasting Central in Ottawa for interpretation. Raw data from Resolute will be relayed either to Prince Albert or Shoe Cove for processing. Other sensor data received by the ground stations will be processed and then transmitted on to the appropriate user or interpretation centre.

Imagery and other data provided by Radarsat will be blended with data from other sources at Ice Forecasting Central or METOC to produce information products. Such products would be designed and packaged to meet the needs of users.

The information network will consist of three different nodes:

(1) main processors (MP s)

(2) intermediate processors (IT s)

(3) user processors (UP s).

This terminology was used by AES in defining their future communication systems from 1985 onwards. The communications system for ice and ocean information between these nodes will probably parallel the existing and planned AES network.

IP s will receive regional and asynoptic data that does not coincide with the timing of the MP data stream. IP s receive information for a specific area as well as products from the MP s. They will store regional information not at the MP. IP s will impose their own regional knowledge to data from an MP. A small number of IP s distributed throughout the system is envisaged.

UP s will be on ships, at drill sites, CCC, MEDS and others (CCC and MEDS archival function). UP s receive some data products directly from the MP and/or the IP. They use the received data for their own purposes. The described system will be interconnected by a communications network so that the user can enter the system at any point. It is also consistent with the evolving AES communications system philosophy and implementation. The communication requirements connecting processors will be a major constraint to design. How the system is used and where data is stored has major impact on the communications. For example, to transmit historical imagery would require a high bandwidth which adds to the current information dissemination. Therefore, storage of information must be moved towards the UP end of the system to minimize retrieval time for historical data. Storage at the user end however involves high capital cost for equipment while communication costs would be reduced. Therefore, there is a fundamental trade-off between storage of information locations and communication needs. The likely scenario will be some storage capability at the UP since storage costs/byte are decreasing while transmission costs/byte are increasing.

MP's will receive national and synoptic data at regular intervals. Radarsat will be a primary data source but it will be only one of many which will include aircraft, ground stations, buoys, international data and ships of opportunity. The main MP will be the Ice and Ocean Information Centre (IOIC). This will be an expansion of the existing Ice Central facility. Other MP s include PASS, Shoe Cove, Resolute, Van-GOES and the Downsview Satellite Data Lab. (SDL). Their primary function will be to provide information products to other MP s as well as directly to IP s and UP s. The MP will also serve as an archiving facility for medium and long term data.

I P's will receive regional and asynoptic data that does not co-incide with the timing of the MP data stream. IP's receive information for a specific area as well as products from the MP's. They will store regional information not at the MP. IP's will impose their own regional knowledge to data from an MP. A small number of IP's distributed throughout the system is envisaged.

UP's will be on ships, at drillsites, CCC, MEDS and others (CCC and MEDS archival function). UP's receive some data products directly from the MP and/or the IP. They use the received data for their own purposes.

The system will be interconnected by a communications network so that the user can drop into the system at any point. It is also consistent with the evolving AES communications system philosophy and implementation. The communication requirements connecting processors will be a major constraint to design. How the system is used and where data is stored has major impact on the communications. For example, to transmit historical imagery would require a high bandwidth which adds to the current information dissemination. Therefore storage of information must be moved towards the UP end of the system to minimize retrieval time for historical data. Storage at the user end however involves high capital cost for equipment while communication costs would be reduced. Therefore, there is a fundamental trade off between storage of information locations and communication needs. The likely scenario will be some storage capability at the UP since storage costs/byte are decreasing while transmission costs/byte are increasing.

Communications between processors must be two way, particularly between the IP and the UP. Data might be sent from the UP back to the IP for processing and decision making. Decisions would then be sent back to the UP. In Dome Petroleum's case, their UP and IP will have the same hardware at both processors. The IP from Dome would interface with the ice and ocean information system. Provision may be made however to transmit images directly to the IP or UP of users without going through an MP if companies wish to operate independently.

Concerning the question of what data gets processed first, there will need to be a central facility such as the IOIC MP which coordinates the data processing effort and receives and acts on requests. The IOIC will have complete knowledge of all data gathering efforts so that users will know where data is being collected and how to access it.

The IOIC is likely to be a three level processor, MP, IP, and UP if it is co-ordinated and/or funded by Canadian Coast Guard (CCG). CCG will require processing at all three levels for its operations. As well, the multiple role for the IOIC is needed for users who cannot afford thier own IPs or UPs.

ANNEX IV

POTENTIAL RADARSAT PAYLOAD AND SUPPORT CONTRIBUTIONS FROM THE U.K.

This summarises the position described in Chapter 2.

Item	Relevant Company/Group Experience/Interest
Primary SAR System	
SAR System expertise and developments.	Marconi
Future space SAR experience.	Marconi
Klystron developments.	EMI-Varian
Secondary Payload Instruments	
Future space scatterometer experience.	Marconi
Future space altimeter experience.	Marconi
Radar altimeter design.	Rutherford-Appleton Laboratory BAe
OCM design experience.	Marconi
ATSR design experience.	Rutherford-Appleton Laboratory
Passive microwave system design.	BAe Rutherford-Appleton Laboratory
AMPS	Meteorological Office Rutherford-Appleton Laboratory
Other Payload Items	
FADS - star sensor - gyro - electronics	Marconi Ferranti BAe
TPS - design concepts	Rutherford-Appleton Laboratory
SAR Processor and Functions	
Design	Marconi RAE
Software	SDL Oxford Computers
Instrument accommodation	Rutherford-Appleton Laboratory

Abbreviations

AMPS : Active microwave pressure sounder
ATSR : Along track scanning radiometer (infra-red)
FADS : Filtered attitude determination system
TPS : Tracking positioning system
OCM : Ocean colour monitor
SAR : Synthetic aperture radar.

ANNEX V

RADARSAT STUDY

INTERIM REPORT

FEBRUARY 1982

RADARSAT STUDY
General Technology Systems Limited
MID-TERM PROGRESS REPORT

CONTENTS

1. PROGRESS

1.1 Activities

During the first part of the study activities have consisted primarily of holding discussions with key personel with potential interest in, or influence on, the Radarsat programme both as recipients of data from the satellite or as contributors to the programme. A list of contacts in Annex I summarises stated interests and views in both groups.

Survey has also been carried out by questionnaire, principally of UK users who responded to the BAe ERS-1 user survey of 1981 and who expressed an interest during that survey in SAR or other microwave instrumentation. The results of the survey are summarised in Annex II.

Discussions have been held with the CCRS programme manager during his visit to the UK in December 1981 and during a visit to Canada by P. Brunt in January to attend a users briefing meeting and to talk to programme participants. Information on the programme from these sources is summarised in Annex III.

1.2 Results

These are related below to the main study tasks :

1.2.1 Programme Information

Contacts have been made directly with the CCRS programme manager and the Phase A study participants, Canadian Astronautics and Philip A. Lapp Ltd during the January visit. A further visit is planned in March.

1.2.2. Assessment of UK user interests

A reasonably high percentage of those sent the questionnaire have responded. Of these, it is acknowledge in most cases that insufficient is known about the SAR system for firm views to be held on its performance. For this reason UK views are unlikely to influence the specification.

In the case of secondary instruments there is general agreement on preference - depending on the subject of chief interest to the user. Additions proposed to the candidate instruments include an active microwave pressure sounder (AMPS) and a tracking/position - fixing system.

The UK user community is primarily of 'secondary' users regarding satellite data as one of a number of processed data sources contributing to their operational or R&D activities.

1.2.3. Relationship to FEDS

Radarsat was not included as one of the satellites in the Logica/GTS model for the inputs to the future Earthnet Dissemination System. Radarsats were: ERS-1 and MOS-2. The report, however, outlines the limits of the European market for satellite data and the information should be passed to the Canadians with comments. A factor in this is the large potential military demand.

1.2.4. UK SAR Expertise

Position to be explored further.

1.2.5. UK Expertise in other instruments

CCRS has already talked with the Rutherford-Appleton Laboratory concerning their radar altimeter work. The Active Microwave Pressure Sounder put forward by the Met. Office-led team for ERS-1 could be considered for Radarsat under some form of arrangement.

1.2.6. UK Oceanographic Interests

A number of interests emerge from the questionnaire. The prime interest is in 'UK designated waters' but interests extend globably and there may be a case for particular concentration on the Antarctic area.

1.2.7. ERS-1 Connections

Aspects are being explored

1.2.8. L-Sat connections

The choice of L-Sat for the Radarsat bus is under discussion between SPAR, BAe and DoI. Its choice would allow a greater number of instruments to be carried - some of which could be UK supplied.

Subject being explored further.

1.2.9 Energy Strategy Implications

Broad issues are being researched. Conversation with the Department of Energy policy division has been suggested.

1.2.10 Software Interests

These are strongly bound up with the possibility of a UK receiving station.

1.2.11 European Hardware Aspects

Subject being explored.

2. ISSUES IDENTIFIED

A number of issues have been identified which could form elements of a UK approach to participation in the Radarsat programme.

2.1 Prospects for a UK Receiving Station

As there are definite moves towards a UK receiving station for ERS-1, if Radarsat is seen as an operational continuation of the ERS-1 SAR service there is an obvious case to ensure that the UK station is equipped to receive and process SAR (and other) data from Radarsat.

The advantages of the UK developing its own microwave facility are well appreciated though the position is not sufficiently supported by user groups. Major justifications would be the location of a UK site in relation to the north-east Atlantic and its own interests in that region, and the potential for capturing the high radar data demand as shown in the FEDS projection for Europe as a whole. (Annex IV). The complexity of SAR data processing and the unique all weather quality of the data implies that it has a higher 'value added' aspect than other satellite data.

In principle Canadian agreement can be expected and ambitions by West Germany in SAR can probably be accomodated without conflict.

2.2 The Need for an Antarctic Receiving Station

There is interest in this from several sources, including Canada. The prospect has strong international or multi-national dimensions. Major UK interests, however, lie in data gathering during a period leading up to the eventual exploitation of offshore oil and gas, and possibly other, resources.

The case for UK participation will not be strong unless a station is already established in the UK.

2.3 The Possibility of Large Military Customer Requirements

A large military requirement for SAR data in particular was postulated in the FEDS study, once the possibilities of operational systems were proved. This would include the use of data for basically civil activities customarily conducted by the military, like search and rescue, policing fisheries and pollution monitoring. Purely military activity requirements will be hard to establish due to security requirements. However, there are indications that the possibilities have, as yet, not been fully presented to the military who could be a key group in furthering UK ambitions in satellite remote sensing.

2.4 UK Expertise in SAR Technology

The UK has major expertise in SAR processing in aircraft but not satellite SAR. The main interest in the subject, then, is in relation to receiving and processing facilities for which there is adequate supporting expertise.

2.5 UK Instrument Developments

Canada is considering outside participation in the provision of the secondary instruments. UK possibilities so far identified are a radar altimeter, currently being discussed between CCRS and the Rutherford-Appleton Laboratory, and the Met. Office group AMPS - which so far has not been put forward.

The use of the L-sat bus for Radarsat will provide space for more instruments (up to 5 total) and create a strong case to use UK-provided instruments.

2.6 The Possible Use of the L-sat bus.

This has many ramifications and possibilities among which UK participation in the data collection programmes is but one.

2.7 New International Initiatives

It is believed that the EEC is finally going to take a more active stand in satellite remote sensing programmes. Funding from this source (usually part-funding) could be a valuable contribution in the furtherance of UK objectives.

On the other hand the agency of IMCO could be used to establish new international initiatives in which the UK could play a prominant part. These can only be initiated by a member state - Canada or the UK - putting forward the proposition.

3. PROPOSED ACTIONS (INTERIM RECOMMENDATIONS)

The following are a number of possible recommendations for action arising out of the studies to date and the issues that have come to light. Further study and discussion with DoI may further clarify these interim conclusions.

<u>General</u>

i) Ensure that planning for UK ERS-1 activity is properly geared to follow on to continuous satellite programme activity like that of Radarsat. This would include having all equipment and systems developed as permanent rather than as temporary entities, which will also have marketing advantages.

ii) Ensure that proper consideration is given to Radarsat in any proposed EEC remote sensing programmes, and that UK interests are fully represented in these.

<u>Specific</u>

i) Present UK interests to Canada as follows :

- A strong interest in archiveable ocean/met. data both globally and for UK-designated waters.

- A general interest in global ocean/met. real-time inputs into the World Weather Watch Network.

- Interest both in Arctic and Antarctic for long-term sea and ice data collection

- Priority user interest is in scatterometer and altimeter instruments with possible supporting instrumentation like a satellite position fixing system and AMPS.

- Receipt of Radarsat data (including SAR) at a UK station developed for ERS-1.

- Participation in international programmes of integrated data collection, including the establishment of new read-out stations.

ii) Advise key users and interest groups of the 'final' specifications for Radarsat performance and the opportunities arising in terms of their individual interest. This should include an appreciation of the broader issues and enhanced prospects.

iii) Initiate a presentation of the Radarsat concept by CCRS to the UK military, in conjunction with ERS-1 prospects.

iv) Explore the possibility of putting forward proposals for marine remote sensing activity to appropriate committees of IMCO - e.g. the Marine Environment Protection Committee. These could be Anglo-Canadian propositions.

ANNEX I

CONTACTS

SUMMARY OF INTERESTS

I-1. DATA USERS

Marine Committee of Mechanical and Engineering Requirements Board (Formely SMTRB)	No activity in directly relevant work and no new recent funding for data-buoy work that may be relevant to satellite ocean data collection work.
MATSU	Are continuing work with long-term data gathering by ocean data buoys which could complement satellite data collection. They are, however, dubious about the value of satellite wind/wave data. Areas of interest are moving out towards the edge of the continental shelf.
Department of Energy - Petroleum Exploration and Development Division	Are interested in wind and wave data that could be provided by satellite. General area of interest is whole of 'UK designated waters' out to 100 fathoms. Priority interest is in new concession areas to be granted in next 5 to 10 years. Precise prediction as to which these will be is difficult. Will not hazard official views on other offshore areas.
NMI	Would have some interest as a secondary user on an ad-hoc basis.
Meteorological Office	Interest in data would be as input to the current forecasting network and to long-term global models. Particular interest in filling in gaps in the Southern ocean coverage.
IOS	Primarily secondary users and would favour an AMPS as proposed by the Met. Office. Consider that a satellite position fixing system of some sort would considerably enhance the radar altimeter data which is of most use to them.

Scott Polar Research Institute	Main interest is in Arctic data, particularly relevant to shipping and oil exploration activities.
British Antarctic Survey	The subject of Antarctic sea ice in particular could benefit from Radarsat coverage but there are reservations about the value of satellite data in general.
NERC - Remote Sensing Services	Radarsat should fit into a general pattern of developing and complementary satellite data services. NERC overall would be as interested in over-land coverage as much as ocean coverage.
Sea Mammal Research Unit.	Unlikely to have any direct requirement.

I-2. INSTRUMENT-FACILITY PARTICIPANTS

RAE

Contacts with the Canadian programme suggest that they would look favourably on the UK taking responsibility for data collection and dissemination in the E. Atlantic area.

It is understood that the UK is already in contact with West Germany over the sharing-out of interest in the satellite radar area. Costing exercises have been done for a UK ERS-1 station, which could also handle Radarsat data.
There has been mention of the idea of an Antarctic Station.

Meteorological Office

The AMPS instrument submitted by METO and others for ERS-1 could be offered/proposed for Radarsat.
They would, in principal, favour the establishment of an Antarctic Station.

IOS

Would favour an Antarctic Station and believe that Argentina has offered collaboration and also talked to West Germany on this.

IMCO

IMCO are not active in remote sensing because this has not yet been required of them by the member states. If requested, they could forward international satellite marine remote sensing activities.

ANNEX II

RADARSAT QUESTIONNAIRES
Summary of responses

1. Brief questionnaires on the preferred specifications for RADARSAT were sent on 21st December 1981 to 44 companies, institutions, government and university departments and other organisations which had previously responded to the British Aerospace survey of user requirements for ERS-1. By 1st February 1982 seventeen had responded positively (and one to say that it was not interested), either by completing the questionnaire or by supplying equivalent information : they are listed at Schedule I. A further distribution of questionnaires to parties thought by GTS to be potentially interested in RADARSAT had by the same date not drawn any responses.

2. Under the principal questionnaire heading of synthetic aperture radar applications, thirteen respondents indicated specific interest : the applications are listed at Schedule II, and there was evidence of overlapping between a number of potential users. Geographical locations in which SAR could be used include the polar regions and sea areas (especially continental shelves and areas of offshore exploitation interest).

3. Few respondents specified a preferred frequency or wave band. C predominated over L.

4. There was general consistency in minimum resolution acceptability. Only one user was prepared to accept up to 100 m; most fell in the 25-50 m band. Two did not specify.

5. The question on polarisation evoked few responses. All of the five who responded preferred HH.

6. Of the seven respondents who expressed views on preferred incidence, six indicated 30-45^{o} and the seventh also did so for one application. 10-30^{o} was preferred only for soil slope measurements.

7. Preferred swath width was generally 50-100km, although three respondents were prepared to accept up to 200 km and five did not specify.

8. There was a surprising variety in expressed requirements for positional accuracy, reflecting possibly the detail or coarseness of the features being studied by each respondent. Two users stated an accuracy requirement of 20 m or less; one of less than one metre; and two of 1 km.

9. Likewise, required frequency of coverage varied widely depending on the type of data collected and its use. Ocean wave and meteorological studies require up to four times daily coverage, while mapping and geological studies may need only once-only or very occasional data.

10. Among additional sensors there was a marked preference for a radar altimeter, followed by scatterometer and visible-infra-red radiometer. Two respondents specifically indicated a use for a microwave pressure sounder. Schedule III lists some of the applications for this additional equipment. Noteworthy is that several respondents expressed a wish for duplication of readings by other instruments to enable checking and correction.

Schedule I

Organisations which responded positively to questionnaire

Scott Polar Research Institute, Cambridge
Institute of Hydrology, Wallingford
Macaulay Institute for Soil Research, Aberdeen
Hunting Technical Services Limited, Elstree
Hunting Surveys Limited, Elstree
Hunting Geology & Geophysics Limited, Elstree
Meteorological Office, Bracknell
British Antarctic Survey, Cambridge
Department of Energy (Petroleum Engineering Division), London
Scottish Development Department, Edinburgh
Marine Exploration Limited, Cowes
Department of Atmospheric Physics, Oxford
United Kingdom Atomic Energy Authority, Harwell
Texaco Overseas Tankship Limited, London
British Petroleum Limited, London
National Maritime Institute, Feltham

Schedule II

Applications indicated for synthetic aperture radar

Detection of soil surfaces and slopes and vegetation patterns for hydrological models;
Delineation of river flooding;
Wind-wave modelling;
Sea condition forecasting;
Detection of plankton blooms;
Peat, vegetation, forestry and land-use surveys;
Natural resource monitoring;
Ice-edge monitoring;
Wave-spectra monitoring;
Measurement of land ice-sheet extent and velocity;
Fifty-year wind and wave prediction;
Wave climate study for offshore structure design;
Mapping in bad-weather areas;
Geological interpretation for mineral and oil exploration;
Establishment of tanker routes in poorly-charted areas;
New tanker terminal location;
Pollution monitoring;
Sea traffic monitoring.

Schedule III

Applications indicated for additional sensors

Sea ice roughness and concentration measurement;
Ice floe size distribution;
Digital terrain modelling;
Hydrological thematic mapping;
Ocean circulation studies;
Cloud imagery and moisture studies;
Urban monitoring;
Geoid studies.

ANNEX III

RADARSAT PROGRAMME STATUS

January 1982

ANNEX III - I

RADARSAT PROGRAMME STATUS

January, 1982.

INFORMATION FROM: PHILIP A. LAPP LIMITED

1. BACKGROUND

The purpose of the visit to PAL was to discuss the Radarsat project and to attend the 4th meeting of the Radarsat Information Standards Committee.

2. CANADIAN SPACE ACTIVITIES & EXPENDITURE

Over recent months Canada has undergone a period of soul-searching concerning its role in space.

When SPAR bought RCS Canada the government undertook to ensure continuity of work so as to maintain a national space capability with the potential to bid for contracts outside Canada.

The Canadian common carrier, Telesat, bought Anik A and C from HAC and Anik B from RCA, the Canadian industrial content increasing until Anik D which is primed by SPAR. Anik E is not yet defined, hence an underutilisation ofSPAR personnel became apparent. A resource satellite was envisaged as the gap-filler (budgeted at approx C$300m) and Mobilesat was intended to supply internal federal services particularly in the North and remote areas. C$3-400m was budgeted for this together with some C$300m for ancilliary activities.

After an extensive review of the possible future scope and directions of the space programme the government allocated an additional C$132m for the new initiatives during the period 1981/2 to 1984/5. Together with the previously approved programmes these new expenditures mean that the Government of Canada will spend C$476m on space over these four years, broken down as shown in Table 1.

Mobilesat (MSAT) has been placed ahead of Radarsat in priority and a 16 month hold inserted between Phases A and B of the latter project. (However it is intended to 'stretch' Phase A somewhat to avoid a complete stop).

Studies have pressed for a resource satellite ever since the 1967 Arctic Waters Pollution Prevention Act aimed at minimising danger to the Arctic environment. Inter alia the act stipulates times of the year at which vessels of various classes can be in various locations depending on expected freeze/thaw times.

After the 1978 International Law of the Sea Conference Canada declared a 200 mile limit thus making the NW passage Canadian territory. Surveillance of these waters is carried out by weekly aircraft flights. The frequent bad weather militates towards the use of radar surveillance and the use of satellites for this purpose is of interest. During the late '70s and early '80s effort has been and is being devoted to flight testing of radars (SLR and SAR) on aircraft, and to studies of resolution requirements and expected performance of satellite systems.

The flight tests have been carried out using a Convair 580 carrying a two-frequency (C/X) SLR and more recently a two-frequency (L/X) SAR. A converter which enables imagery at C band to be obtained has now also been fitted. Studies of a surveillance satellite, Sursat, were reported on in 1980 - see documents referenced in Attachment1 to this visit report - though Canadian fears that the name would give offence to the US led to its being changed to Sarsat then Radarsat.

In the autumn of 1980 Canada and NASA signed a joint agreement on Radarsat. The NASA involvement has subsequently diminished because of reductions in funding and they are now providing

- a study of user requirements
- the launch
- one sensor (most likely the scatterometer)

Shortly after the agreement PAL was awarded the Canadian Ice and Ocean User Requirements Study contract, the statement of work for which is attached as Attachment 2. A sixth work package was added more recently covering a study of the relative merits of the various means of carrying out surveillance (aircraft, satellite, etc). Land applications are being studied elsewhere under a separate contract placed by the Radarsat Project Office.

3. RADARSAT INFORMATION STANDARDS COMMITTEE

The 4th meeting of the Radarsat Information Standards Committee was held in Toronto at the Atmospheric Environment Service establishment on 12th January. The minutes are appended as Attachment 3.

During lunch with Ed Shaw of the Radarsat Project Office, he mentioned that subsequent to his meeting with L. P. White of GTS in London he had talked to David Croom of Appleton & Rutherford Labs. Croom had expressed interest in the Radar Altimeter and hoped that the UK would win the ERS1 instrument competition.

Attachment 1 to Visit Report No. 1.

DOCUMENTS HANDED OVER BY P.A. LAPP LTD.

- PA Lapp Ltd Study : Statement of Work
- Preliminary Mission Requirements Document June 1981
- Preliminary Statement of User Requirements for Ice and Ocean Information July 1981
- Radarsat Information Standards Committee, Minutes of
  - 3rd Meeting, 23 November 1981
  - 2nd Meeting 27 October 1981
  - Initial Meeting 28/29 September 1981
- Bilateral SAR Satellite Mission Requirements Study Program Implementation Plan Approval
- Memorandum to File : Ice Reconnaissance Systems (Prelim Draft)
- Radarsat Cvs L Band Meeting 13 November 1981
- L v C Band - A Comparison of System Performance and Processing Implications for Radarsat
- The Canadian Space Program Plan for 1982/83 - 1984/5
- Fact Sheet : Canadian Space Program Expenditures 1981/2 - 1984/5
- The Canadian Space Program Plan for 1982/83 - 1984/85
  - Notes for a Statement by the Hon. John Roberts Minister of State for Science & Technology 9 Dec 1981
- Roberts Announces Major Boost for Canada's Space Program - Press Release 9 December 1981

In addition the following rather larger documents were shown as being available if required :

- Sursat : A conceptual Design Study March 1980
- Sursat Ice Experiment . Report : Surveillance Satellite Project Workshop on Active & Passive Microwave Measurements of Sea Ice & Icebergs

RADARSAT Planning	3.2	8.9	5.1	-	17.2
Airborne Remote Sensing Applications	2.7	2.6	2.5	2.4	10.2
Remote Sensing R&D	2.8	2.6	2.5	2.7	10.6
Assistance to Users of Data	0.7	0.8	0.9	0.9	3.3
Technology Transfer	0.1	0.2	0.2	0.2	0.7
Oceonographic and Fisheries Applications	0.8	1.0	0.8	0.8	3.4
Meteorological Satellite R&D	1.3	1.6	1.6	1.8	6.3
Provision of Meteorological Satellite Data	4.4	4.5	3.7	3.6	16.2
Monitoring Ozone Layer	0.2	0.7	0.8	0.8	2.5
CCRS Operating Costs	3.4	4.0	4.2	4.4	16.0
Sub-total	26.3	42.2	35.4	31.8	135.7
Space Science Programme					
International Cooperative Projects	4.0	9.4	10.5	9.2	33.1
Research Facilities	5.2	6.7	7.3	7.9	27.1
Herzberg Institute	0.5	0.6	0.6	0.7	2.4
Salaries (NRC)	2.1	2.4	2.7	3.1	10.3
Sub-total	11.8	19.1	21.1	20.9	72.9
Technology Development Programme					
LSAT (DOC)	10.2	24.4	23.8	13.2	71.6
Subsystem Development	1.8	5.0	6.0	6.0	18.8
R&D Support (DOC)	2.0	1.0	2.0	3.0	8.0
ANNEX-C and -D Support (DOC)	2.8	1.7	0.4	0.3	5.2
International Technical and Bid Support (DOC)	1.5	1.7	1.8	2.0	7.0
Key Technology Program (DOC & EMR)	3.0	1.0	-	-	4.0
DOC Technology Development Program	3.2	2.8	2.8	4.0	12.8
Space Industry Support (ITC)	3.7	3.8	3.9	4.0	15.4
Gallium Arsenide Device Development	0.1	0.5	0.3	0.2	1.1
Remote Manipulator System (NRC)	5.3	2.6	3.8	-	12.2
Sub-total	34.1	44.5	44.8	32.7	156.1
Relationship with ESA	1.7	1.8	1.9	2.1	7.5
GRAND TOTAL	96.7	136.9	136.0	106.2	475.8

TABLE 1 : TOTAL CANADIAN SPACE PROGRAMME EXPENDITURES (1981/82 - 1984/85)

PROGRAMME	MILLIONS OF BUDGET YEAR DOLLARS				
	81/82	82/83	83/84	84/85	TOTAL
Communications Programme					
Military Communications and Navigation	3.1	5.3	5.6	4.1	18.1
Search and Rescue Satellite	2.0	1.3	1.9	-	5.2
Civil Aeronautical and Maritime	0.1	0.1	3.6	1.1	4.9
ANIK-B Experimental Program	3.3	2.1	-	-	5.4
Mobile Satellite (M-SAT) Planning	1.7	8.0	9.0	-	18.7
Direct Broadcast Satellite Planning	0.8	0.8	-	-	1.6
David Florida Laboratory	3.0	1.4	1.5	1.7	7.6
Laboratory Equipment	0.3	0.4	0.4	0.4	1.5
High Reliability Laboratory	0.3	-	-	-	0.3
Spectrum and Orbit Planning	0.1	0.1	0.1	-	0.3
Controls Laboratory	0.2	0.1	0.1	-	0.4
EHF Technology Equipment	0.1	0.3	0.2	-	0.6
Operating Costs (DOC)	2.5	3.0	3.3	3.6	12.4
Salaries (DOC)	5.3	6.4	7.1	7.8	26.6
Sub-total	22.8	29.3	32.8	18.7	103.6
Remote Sensing Programme					
Provision of LANDSAT Data	2.8	3.3	3.5	3.5	13.1
LANDSAT Station Upgrade	1.6	7.8	4.7	1.8	15.9
MOSAICS	-	1.3	3.2	5.9	10.4
TOPAS (phase 1)	-	0.2	0.7	3.0	3.9
ESA Remote Sensing Program	2.3	2.7	1.0	-	6.0
RADARSAT Planning	3.2	8.9	5.1	-	17.2
Airborne Remote Sensing Applications	2.7	2.6	2.5	2.4	10.2
Remote Sensing R&D	2.8	2.6	2.5	2.7	10.6

You shall carry out the following tasks:

1. Description of User Requirements

Develop and Implement a questionnaire with the following users;

- federal government
- provincial governments
- industry

The questionnaire should address the present levels of information required for operations in marine environments as well as anticipated requirements for 1985, 1990 and 2000. Implementation of the questionnaire should be in the form of personal interviews with the identified users.

2. Data Presentation Products

Develop in consultation with the above users data presentation products bases upon the following structure:

Level 1 - SAR image generation
- quick-look images
- corrected images
- CCT's

Level 2 - geophysical data products

Level 3 - predictive information products

Simulation - simulation of Arctic operations such as ship movements

Data presentation products should consider the balance between user needs and the feasibilities of producing such required information. They should also be based upon the organizational framework of the government and industrial ice information system.

3. Economic Study

Conduct a tradeoff analysis of appropriate platform, sensor and communication system for a Canadian Ice information system. The analysis should consider:

- best platform mix
- best sensor mix
- alternative communication system

The analysis should also estimate the export potential for information, hardware and complete systems.

4. Policy Formulation

Develop policy alternatives for consideration by the government in respect to levels and types of service to users for site-specific, close tactical, tactical and strategic support. Service alternatives should also include ice modelling and archiving levels of effort. Cost recovery for such services should also be addressed.

5. Interaction with Users

In consultation with users, prioritize information and develop a plan for phasing in services as aircraft and satellite platforms are put into place. Propose a structure for updating user requirements.

A. User Requirements

1. Develop and validate user requirements for ice and oceans information (Seven missions/functions)

2. Develop Data Presentation Products

B. Canadian Ice Information System

3. Conduct engineering and economic analysis of "best" options for Canadian Ice Information System

4. Develop policy alternatives for Government consideration

5. Develop implementation plan for Canadian Ice Information System

C. RADARSAT

6. Benefit and Cost Study - In addition to the satisfaction of user requirements for ice and oceans information through satellite remote sensing data postulated in 3 and 4, identify and develop additional mission/function ice and ocean information needs which can be satisfied by satellite remote sensing data (in terms of RADARSAT proposed coverage combined with physical/technical payload and sensor constraints specified in Annex 1.) Such data requirements are to be classified as (1) necessary (2) desirable (3) marginal. Prepare and present a statement of the totality of data requirements by mission/function which can be satisfied by RADARSAT together with full cost implications.

7. Interdependency with other Systems

Assess the relevance and the suitability of proposed data products from currently planned satellite programs (Annex 1) which may in whole or part duplicate or are interdependent with the postulated output from RADARSAT. Assess the possible advantages and problems associated with the options for data production which arise from this review and determine the "best" option which will satisfy Canadian Ice and Oceans Information requirements for the time frames applicable to the Study.

1. CATEGORIES OF SENSOR COMBINATION

Benefits unique to SAR (Ref. 2)
Benefits unique to a passive microwave radiometer (SSM/I, type, Ref. 3),
Benefits unique to a scatterometer (NOSS type, Ref. 4),
Benefits unique to a VIR sensor, (Landsat-D Thematic Mapper, Ref. 5),
Benefits unique to a radar altimeter (SEASAT type, Ref. 6),
Benefits unique to SAR plus passive microwave radiometer,
Benefits unique to SAR plus scatterometer,
Benefits unique to SAR plus VIR sensor,
Benefits unique to SAR plus altimiter.
Various types of benefits will be considered as appropriate.

2. INTERDEPENDENT PLANNED SATELLITES

The satellites considered are RADARSAT, the ESA program (ERS-1), U.S. Programs (TOPEX, LS-D, NOAA, DMSP, Landsat follow-on), and Japanese Programs (MOS-1, ERS-1).

RADARSAT INFORMATION STANDARDS COMMITTEE

Minutes of 4th Meeting

Date: January 12, 1982

Location: Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario

Chairman: Dr. P.A. Lapp

The fourth meeting of the information standards committee covered five main topics:

1) Preliminary findings on the aircraft vs satellite comparison study.
2) An update on the status and schedule of the Radarsat Project.
3) British interests in the Radarsat program.
4) Comments on proposed data products.
5) Initial reaction to the activity/information product matrix.

Dr. Lapp first outlined the future course and direction of the committee's work. The work will be completed once the data products required for each mission from the IOIC have been specified and agreed upon. The plan will then be to write a draft report on the data products and results from the committee's discussions which would be circulated to committee members for review. A final meeting will be convened sometime in early March, by which there would be sufficient time for all committee members to review the report and be prepared to make comments. These would be stated and discussed at this final meeting, after which the final report would be completed for the end of March.

1. Aircraft/satellite tradeoff study update - J. Barry

As a starting point for the study, the results of the user survey were reviewed to develop a table of seasonal requirements and frequency of data collection which is attached to these minutes. A corridor for Arctic oil and gas shipping on a year round basis is to be used in the comparison, noting it will be a major user of ice and ocean information. The scenario has been developed to require daily coverage of the areas for periods when ice is present or of concern. Initial calculations show it requires 6300 flying hours per year to fulfill ice reconnaissance needs within the corridor. This compares to 2200 hours for the present operation. This figure includes hours already used in East Coast operations which would be needed whether there is a satellite or not. The figure also includes 2 hours ferrying time on a daily basis. Using the number of flying hours and considering maintenance requirements, 6 aircraft are required. Thus 4 more aircraft are needed to cover the requirements. The tendency is to consider 4 engine aircraft however it has been suggested that smaller aircraft may be able to cover areas on a more regional basis. The number of hours also includes iceberg surveillance, although detection of smaller bergs is questionable.

Questions to be answered include the choice between SLAR vs SAR. The user community is divided on this question. At present configurations, SLAR has much larger swath width but loses detail with range while SAR maintains detail but has smaller swath and more flying is required. One possibility for the latter is to have two SARS on the same aircraft. However, SLAR has been found very useful in operations and may meet needs for a large portion of the year. The differences in resolution and whether or not the high resolution is required on a strategic level is still an open question. Aircraft and satellite reliability must also be assessed. Aircraft availability can be estimated by its service record; however satellite reliability is more difficult to assess.

The study is assuming 200 flying days/year for each aircraft. The crew would number 4-5 in summer and 3-4 in winter.

A major issue in the study is the communication of data from the gathering system to the IOIC. It must be demonstrated to be feasible from both platforms in order for a suitable comparison of the two systems. Once the data reaches the IOIC the two systems become equal and can then be compared on other criteria. While satellite transmission is little problem, the transmission from aircraft depends on how much degradation can be tolerated in getting imagery back to the IOIC. The satellite can transmit either full resolution or degredated resolution imagery.

2. Radarsat Program Update - E. Shaw

The government has now made its space decisions for this year relating to M-Sat, a mobile communications satellite and Radarsat. M-Sat is slated to be launched first with phase B starting in 1984, a delay of about one year.

A revised schedule for Radarsat has been developed and is attached to these minutes. The phase A and SAR R and D portions have been funded. Aspects of phase A of interest to the committee include the preliminary design of the IOIC and the ground segment, both studies being done by MDA. The ground segment would include the reception stations at Prince Albert and Shoe Cove plus one at Resolute, if necessary. The coverage envelopes are such that the latter may not be needed if the satellite is maintained at its present altitude. Phase A is to be completed by 1983. The SAR R and D Program is the major expenditure in the program to date, and includes developing technology for a spaceborne radar, a high throughput processor and developing a complimentary aircraft SAR system to support the satellite program. Phase B of Radarsat would start in 1984 with the cabinet submission submitted in fall 1983.

The schedule has been developed so that the ground segment would be in place to receive data from the European satellite ERS-1 to be launched in 1988. This satellite will have a C-Band radar with 25m resolution and 90km swath. The Japanese are likely to launch an L-Band radar in 1988 which is much like SEASAT. The two satellites will have sun-synchronous orbits providing LANDSAT like coverage. With the ground segment in place, experience will be gained with the other satellites before Radarsat.

The space segment will not be implemented until 1986 so that launch of Radarsat would not be before 1990.

The Radarsat oribit is so designed to provide daily coverage of the NWP up to 75°N. A desirable goal to increase frequency of coverage would be to develop a swath steering capability so the beam could be aimed to obtain the desired coverage. This would be similar to the French who have developed an optical sensor with ±15° manipulation capability.

The Radarsat project will decide on the frequency of the radar C or L by the end of this month. They are still waiting for cost estimates. In terms of sea ice, the scatterometer work at Mould Bay was inconclusive in determining C vs L capability. The project office just received some X, C and L-Band imagery for the Beaufort Sea from the Convair 580 work. The imagery was shown on an overhead. Both L and C Band optically processed imagery were shown versus X-Band and showed the C-Band to have lower contrast than X but still looked closer to the latter than L.

The overall government view on Radarsat is that the program is expensive; therefore, the impetus is to seek international partners to reduce costs. To this end, E. Shaw is pursuing both the U.S. and Britain for possible participation. Discussions will be held this month with NASA to consider providing a second sensor such as a scatterometer or an optical sensor plus a launch as their contribution to the program. The U.K. might supply an altimeter and perhaps the L-Sat bus which is a candidate bus for Radarsat. In terms of the secondary sensor, oceans favour a scatterometer while the land groups favour an optical sensor.

Dr. Lapp expressed concern about the scheduling of Radarsat in relation to the schedules of Arctic energy development. Both APP and Dome have stuck to their 1986-87 timetables for the beginning of vessel movements. Ice reconnaissance is required as part of their environmental approval from FEARO (Federal Environmental Assessment Review Office). If a major aircraft program is launched to meet the requirement, then Radarsat becomes less and less important. There is a difference in perception of the timing of these projects between government and industry. EMR sees nothing moved out of the Arctic before 1990 and, if, true, then the delay in Radarsat would nicely match the timing of these Arctic projects.

3. British role in Radarsat - P. Brunt

Peter Brunt from General Technology Systems (GTS) talked briefly on the British interests in Radarsat. GTS is currently under contract to Britain to survey what uses Britain has for Radarsat data. They have prepared a questionnaire and sent it to 30-40 users around Britain. This will be followed up by visits. In addition, they are examining the relationship between Radarsat and the ERS-1 program as well as determining Britain's technical capabilities in hardware and software systems in support of the ground segment. They are reviewing ocenographic interests, primarily focussing on ocean data networks for route planning, search and rescue, etc. The study is to last 5-6 months. Britain has an interest in Radarsat data for ice applications in the Antarctic.

4. Comments on Proposed Information Products

A first cut at the activity/information product matrix was presented for review by the committee. Included was a list of candidate data products which were renamed information products. The revised product list is attached to the minutes. Further deletions or additions may be forthcoming from committee members.

Ice imagery was the first product and this was expanded to include an interpretive chart to go with the imagery since some users would not be able to interpret the latter. The ice analysis chart would present a composite of the current ice conditions which would cover the nowcast need and would present information on ice type, concentration, floe size and, optionally, motion, pressure and topography.

Discussions covered ocean information products. The original list contained a sea surface temperature chart, nowcast and forecast wave chart and an ocean features analysis chart which were now being produced at METOC. The METOC centre, however, would not be interested in these products from the IOIC. Their main interest would be in the data and imagery with which to enhance its own products. Therefore these three information products were eliminated and replaced with a single ocean data products, that being the partially processed scatterometer data which would input into METOC's own information product generation system.

C. Jarvis noted several other information products which could be generated:

1) oil spill trajectory forecast
2) surge forecast
3) ice accretion forecast

The last product is currently produced as an alphanumeric forecast; however, there is a request by METOC to change this product into a chart form. This is required for search and rescue operations, particularly for deploying ships and helicopters. AES is also required to provide information on the projected trajections of oil spills. These products are generated by AES regional centers except for the west coast where Ocean Science and Surveys has responsibility.

Another desired product was a surface water current analysis even on a once weekly basis. This would assist users in projecting the movements of icebergs; recognizing subsurface currents would be more useful but impractical to obtain.

Another possible product was a forecast of iceberg fluxes across particular latitudes on a 24 hour basis. Work is underway in developing the model.

Another issue raised was the duration of forecasts which could be similar to weather forecasts:

1) short term - 1 to 2 days, high resolution
2) medium term - to 5 days, coarser resolution
3) longer term - weeks, months, freezeup, breakup

All these time scales would be useful although the first product may be site specific and perhaps the responsibility of the user.

Consideration of the information products generated by the IOIC (perhaps should be renamed Ice Information Centre) must take into account the following:

1) Will likely evolve from what exists today
2) Must take into account the distribution systems - is it rational to go through a central facility?
3) Needs for archival products.

Archival products are yet to be determined.

5. Activity/Information Product Matrix

The first cut at the matrix was reviewed in a general way by the committee. It was felt the ideas presented in the matrix required further thought and review by all so comments were limited to a first cursory view of the contents. A copy of the matrix with these few initial comments and corrections is included in these minutes. Members of the committee are expected to respond with their comments on the matrix by February 1.

It was decided to not place any priority on the products required since different situations may require different priorities in product needs. The matrix should be simplified by combining areas and seasonal needs.

Each information product should be described in terms of its format and presentation as well as to specify the data products required. Data vs information products must be clearly differentiated.

The matrix also included a specification for the time needs for nowcast and forecast information. The nowcast spec is simply the turnaround time required from acquisition to final delivery to the user. The forecast time need was the time duration of the forecast, i.e. its projected validity or prediction time.

It was felt that the 2 hour requirement may be feasible for first cut imagery; however, further processing would delay this by a further two hours. Much depends on the resolution required. In terms of information products, 6 hours was felt to be a reasonable time to generate the charts and forecasts which would have already used the imagery in their analysis.

Unknown at present is how critical is the time need? Could the user accept a delay of a couple of hours? It was thought this would be acceptable for most cases; however, at infrequent times this time delay may be critical. This question relates to the design philosophy - do we design for the critical case which happens only 10% (for example) of the time?

Final Meeting

The final meeting of the committee will likely be held in Calgary sometime between the 1st and 10th of March. By this time all members will have received the draft report and will come prepared to discuss and comment on its contents.

David Lapp
January 13, 1982

ATTENDANCE LIST

4th RADARSAT INFORMATION STANDARDS COMMITTEE MEETING

January 12, 1982

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ATTENDANCE LIST

4th RADARSAT INFORMATION STANDARDS COMMITTEE MEETING

January 12, 1982

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TABLE

SEASONAL ICE RECONNAISSANCE REQUIREMENT

Section →	① BEAUFORT	② AMUNDSEN	③ PRINCE OF WALES STRAIT	④ VISCOUNT MELVILLE SOUND	⑤ BARROW STRAIT	⑥ LANCASTER SOUND	⑦ BAFFIN BAY (≥ 70°N)	⑧ DAVIS STRAIT (≥ 60°N)	⑨ LABRADOR SEA ≤ 60°N	⑩ [illegible]	⑪ BELLE-ISLE GROCACOUNA	⑫ BELLE-ISLE CANSO	TOTAL HRS PER WEEK ON SITE (7)
Corridor km²	33,000	23,000		20,000	6,000	6,000	37,500	175,000	70,000		Reference (5)		
A/C Hours on site (10)	0.72	0.7	0.5	1.2 (550km)	1.75		3 + .5 (6)	3.8 + .5 (6)	21.5 (6)				
JANUARY	9/10 + cover (1) 0-9/10 MY D ↓	9/10 - 10/10 cover 0-7/10 MY D ↓		9/10 cover 5/10 - 8/10 MY shorefast 3/wk ↓	10/10 cover 1/10 - 6/10 MY shorefast 3/wk ↓	9/10 cover trace MY bergs 3-4/wk ↓	9/10 cover bergs & 2/10 MY D ↓	0 - 9/10 cover (3) trace MY bergs D ↓	D ↓ (9)		40/wk ↓		
FEBRUARY										40/wk ↓			
MARCH													
APRIL	↓	10/10 cover 0-2/10 MY 2-3/wk				↓	↓	↓	↓		clear		
MAY	9/10 - 9/10 cover (3) 0-9/10 MY (4) D	9/10 - 10/10 cover trace MY D				9/10 cover 1/10 MY bergs D	9/10 cover & 2/10 MY bergs leads D	0 - 9/10 cover trace MY bergs DB	icebergs D				
JUNE	0 - 10/10 cover (4) 0-9/10 MY D	5/10 - 10/10 cover 0-2/10 MY D (reduced area)		↓	↓	0-4/10 cover icebergs & 1/10 MY D	5/10 - 9/10 cover 0-2/10 MY (1) bergs DB						
JULY	0-7/10 cover (4) 0-9/10 MY D			9/10-10/10 shorefast D	1/10 - 9/10 cover 0-9/10 MY D	trace MY trace MY icebergs DB ↓	0-7/10 cover 0-2/10 MY bergs D	↓	.00	7 hrs per wk			
AUGUST	0-7/10 cover (4) 0-7/10 MY Edge cleaner D	clear 0 MY ✗		4/10 - 9/10 cover 4/10-9/10 MY D	0-5/10 cover 0-1/10 MY D		0-7/10 cover 0-2/10 MY bergs D	0-3/10 cover trace MY bergs D		00			
SEPTEMBER	reduced area			4/10 - 7/10 cover 1/10 - 5/10 MY D	0-5/10 cover Traces MY D reduced area	↓	clear bergs DB	clear bergs DB					
OCTOBER	0-7/10 cover (4) 0-7/10 MY Edge clean 4? from shore D	0-5/10 cover 0-2/10 MY D		9/10 - 10/10 cover 5/10 - 8/10 MY D	7/10 - 9/10 cover D	5/10 - 9/10 cover trace MY icebergs D	0-5/10 cover bergs DB	trace MY bergs DB					
NOVEMBER	9/10 + cover (4) 0-9/10 MY D	9/10 - 10/10 cover 0-2/10 MY D		9/10 - 10/10 cover 5/10 - 8/10 MY 2-3/wk	9/10 cover 1/10 - 6/10 MY D	9/10 cover trace MY icebergs	9/10 cover bergs & 2/10 MY	0-9/10 cover trace MY bergs D		↓			

REMARKS

* additional time is for end lane turns

D = Daily

DB = Daily for bergs only

(1) MY is patchy in ⑤, [illegible]

(2) ice edge is well active, daily reconnaissance needed re ice edge

(3) distinct pack edge [illegible] 9/10 MY; pack edge [illegible] continuous

(4) ice island fragments year round

(5) Table 3.16, page 77

(6) additional hours are for end of lane turns in pattern flying

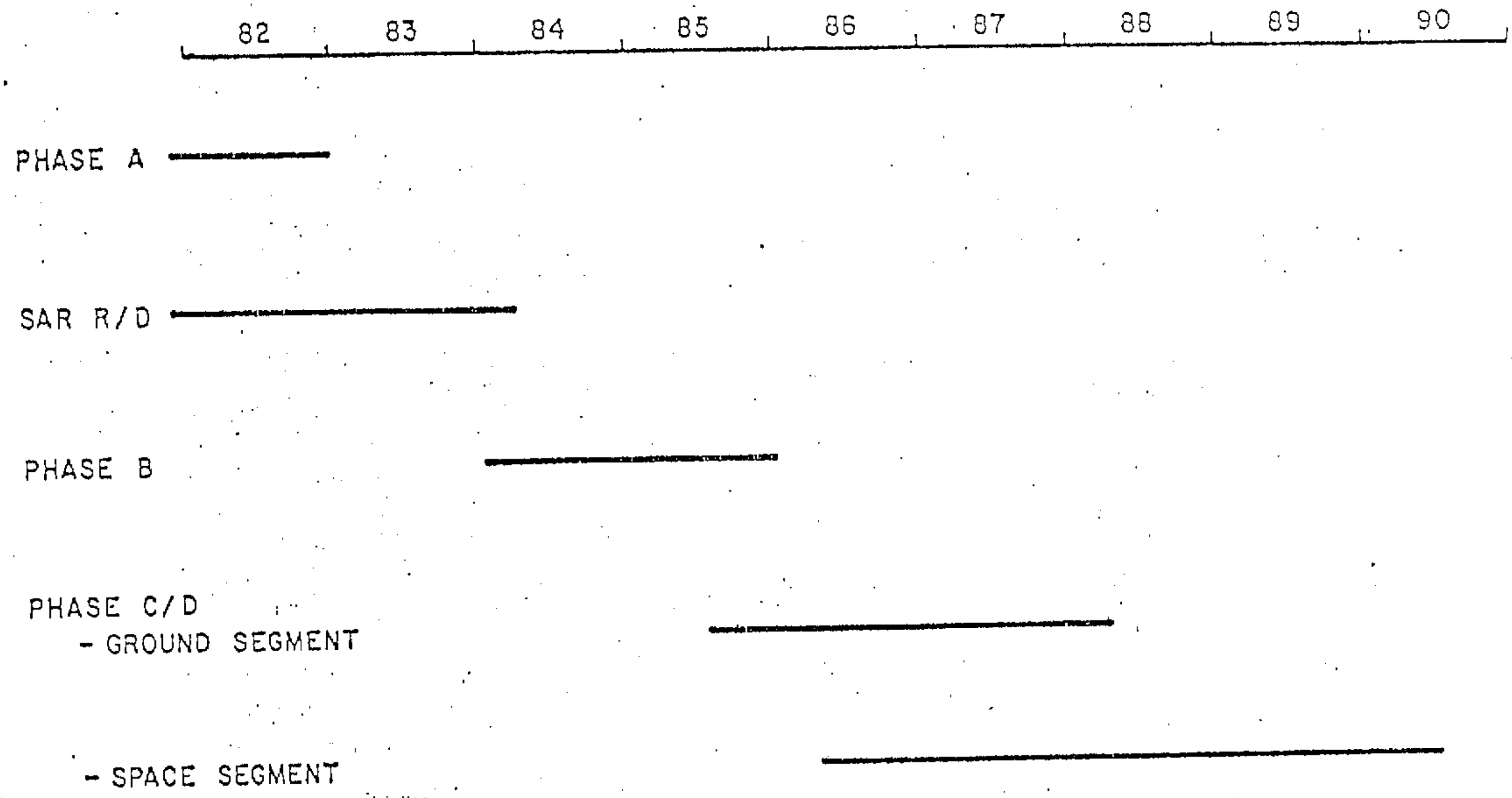
(7) 1½ hrs per day per aircraft for climb, descent, manoeuvres

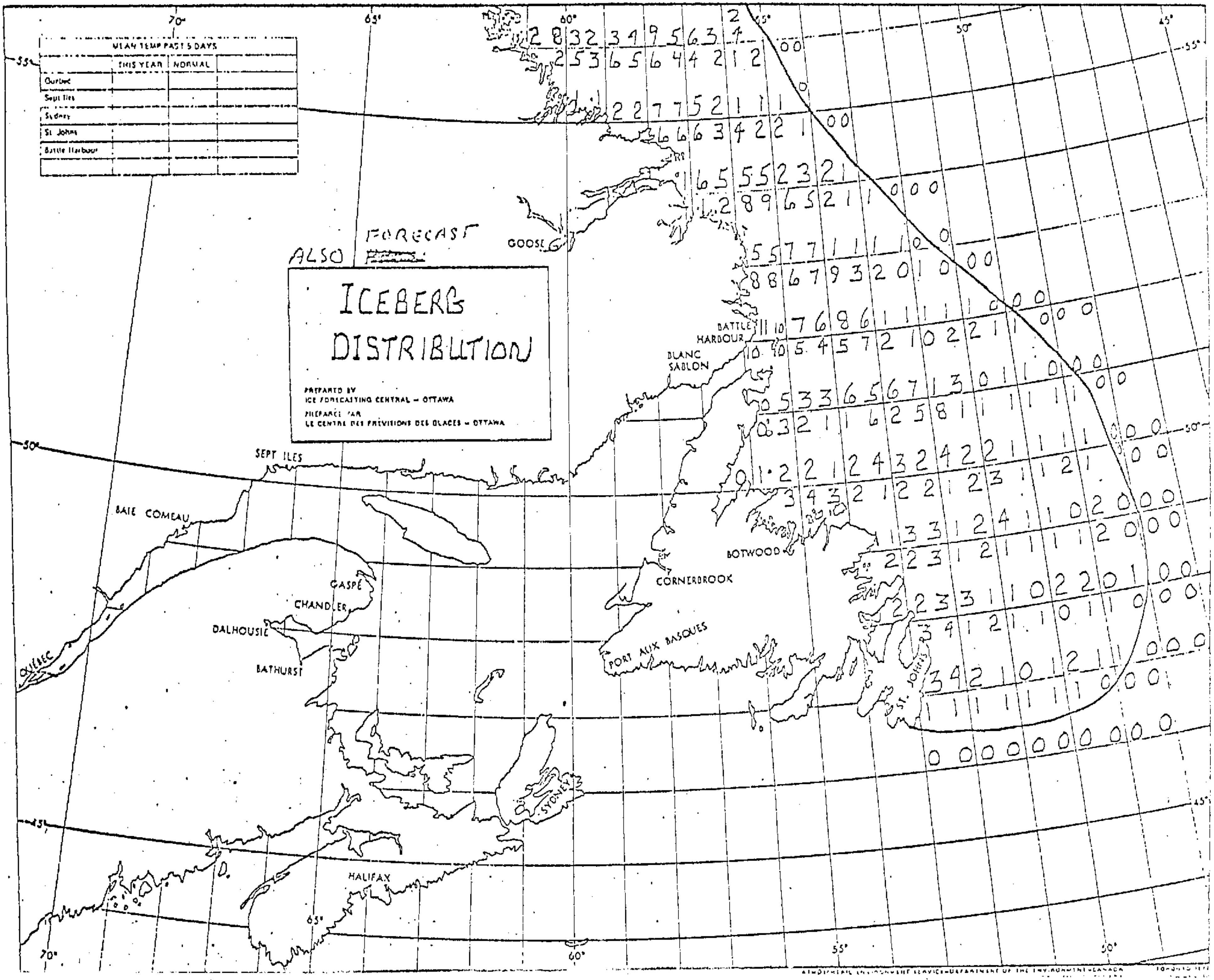
(8) aircraft speed 250 kts (460 km/hr), 100 kms [illegible]

(9) area of interest moves

(10) where corridor width ≤ 100 km, aircraft time derived from length of track instead of area

RADARSAT SCHEDULE





MEAN TEMP PAST 5 DAYS
THIS YEAR
NORMAL
Quebec
Sept Iles
Sydney
St. Johns
Battle Harbour
ALSO FORECAST
ICEBERG DISTRIBUTION
PREPARED BY ICE FORECASTING CENTRAL – OTTAWA
PRÉPARÉ PAR LE CENTRE DES PRÉVISIONS DES GLACES – OTTAWA
GOOSE
BATTLE HARBOUR
BLANC SABLON
SEPT ILES
BAIE COMEAU
QUEBEC
GASPÉ
CHANDLER
DALHOUSIE
BATHURST
BOTWOOD
CORNERBROOK
PORT AUX BASQUES
ST. JOHNS
SYDNEY
HALIFAX

ORIGINAL INFORMATION PRODUCT LEGEND

NO.			PRODUCT
1			ICE IMAGERY
2			ICE TYPE ANALYSIS CHART
3			ICE RIDGE DISTRIBUTION
4	A	NOWCAST	ICE CONCENTRATION/THICKNESS
	B	FORECAST	
5	A	NOWCAST	ICE DRIFT/ICE PRESSURE
	B	FORECAST	
6			SEA SURFACE TEMPERATURE CHART
7	A	NOWCAST	WAVE DATA CHART
	B	FORECAST	
8			OCEAN FEATURES ANALYSIS
9			ICEBERG SIZE/LOCATION MAP
10			VESSEL LOCATION MAP

- Ridge distribution map to be produced weekly, all others would be daily

REVISED INFORMATION PRODUCT LEGEND

1. ICE IMAGERY/INTERPRETED CHARTS
2. ICE ANALYSIS CHART
3. ICE RIDGE DISTRIBUTION
4. FORECAST ICE CONCENTRATION/THICKNESS
5. FORECAST ICE DRIFT/PRESSURE
6. ICEBERG LOCATION MAP - NOWCAST/FORECAST
7. VESSEL LOCATION MAP
8. DATA FOR GENERATION OF REGIONAL OCEAN INFORMATION PRODUCTS

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS NOWCAST	TIME NEEDS FORECAST	FREQUEN
Oil and Gas Shipping	Movement	Beaufort Sea	Jan-Apr	1,4B,5B,3,2	2-6 hrs	12-48 hrs	DAILY
			May-July	1,5B,4B,2			
			Aug-Sept	1,5B,4B,2,7B			
			Oct-Dec	1,4B,5B,2,3			
		Amundsen Gulf Prince of Wales	Jan-Apr	1,4B,3	2-6 hrs	12-48 hrs	DAILY
			May-July	1,4B,2,5B			
			Aug-Sept	1,4B,2			
			Oct-Dec	1,4B,2,3			
		Western Parry Channel (VMS & Barrow St.) High Arctic	Jan-June	1,3,2,5B,5A	2-6 hrs	12-48 hrs	3/wk
			Jul-Aug	1,5B,2,4B			DAILY
			Sept	1,5B,2,4B			DAILY
			Oct-Dec	1,4B,3,2			3/wk
		Lancaster SD./ Baffin Bay	Jan-Apr	1,5B,4B,9,2	2-6 hrs	12-48 hrs	DAILY
			May-June	1,9,5B,2			
			July-Aug	1,9,7B,5B,2			
			Sept	1,9,7B			
			Oct-Dec	1,9,7B,2,4B,5B, 2			
		Davis Strait	Jan-Apr	1,5B,9,3,4B,2	2-6 hrs	12-48 hrs	DAILY
			May-July	1,5B,9,4B,2			
			Aug-Oct	1,9,7B			
			Nov-Dec	1,9,4B,5B,2			

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS		FREQUENCY
					NOWCAST	FORECAST	
Oil and Gas Shipping	Movement	Labrador Sea	Jan-Apr May-Dec	1,9,5B,4B,2,7B 9,7B	2-6 hrs	12-48 hrs	DAILY
		Gulf of St. Lawrence	Jan-Apr May-Dec	1,5B,4B,2 7B	2-6 hrs	12-48 hrs	DAILY
		East NFLD	Jan-Apr May-Dec	9,7B,5B,4B 9,7B	2-6 hrs	12-48 hrs	DAILY
	Supply Vessels Shuttle Tankers	East NFLD	Jan-Apr May-Dec	2,3,7B,5B,4B,6,8 9,7B,7,8	2-6 hrs	12-48 hrs	DAILY
		Scotia Shelf	All-year	6,7A,7B,8	2-6 hrs	12-48 hrs	DAILY
Canadian Coast Guard	Escort (1)	Beaufort Sea	June-July Aug-Sept Oct-Nov	5B,2,4B,5A 5B,2 4B,5B,2,3	6-12 hrs	12-72 hrs	DAILY
		Amundsen Gulf, Prince of Wales	June-July Aug-Sept Oct-Nov	5B,2,4B 2,4A 4B,5B,4A,3,2	6-12 hrs	12-72 hrs	DAILY
		Western Parry Channel (VMS & Barrow Strait)	June July-Aug Sept Oct-Nov	3,2,5B,4B,4A 5B,2,4B,4A 5B,2,4B,4A,5A 5B,5A,2,4B,4A,3	6-12 hrs	12-72 hrs	DAILY

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS		FREQUENC
					NOWCAST	FORECAST	
Canadian Coast Guard	Escort (1)	Lancaster SD/ Baffin Bay	June	9,5B,3,4B,2,4A	6-12 hrs	12-72hrs	DAILY
			July-Aug	9,5B,4B,4A,2			
			Sept	9,2,5B,7B			
			Oct-Nov	9,5B,4B,2,4A			
		Davis Strait	June-July	9,5B,4B,4A	6-12 hrs	12-72 hrs	DAILY
			Aug-Oct	9,7B,2,5B			
			Nov	9,4B,5B,2,4A			
		Hudson's Bay and Approaches Foxe Basin	June-July	5B,4B,2,4A	6-12 hrs	12-72 hrs	DAILY
			Aug-Oct	2,5B,7B			
			Oct-Dec	4B,4A,2,5B,3			
		Labrador Sea	June-Dec	9,7B,5B,4B,2	6-12 hrs	12-72 hrs	DAILY
		Gulf of St. Lawrence	Dec-May	5B,4B,3,2,4A	6-12 hrs	12-72 hrs	DAILY
		East NFLD	December	9,4B,2	6-12 hrs	12-72 hrs	DAILY
			Jan-June	9,5B,4B,4A,2			

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS NOWCAST	TIME NEEDS FORECAST	FREQUENCY
Canadian Goast Guard	Transit (2)	Beaufort Sea	Jan-Apr May-July Aug-Sept Oct-Dec	3,2,4B,4A,5B 2,4B,5B,5A 5B,2 4B,3,5B,2	6-12 hrs	12-72 hrs	DAILY
		Amundsen Gulf Prince of Wales	Jan-Apr May-July Aug-Sept Oct-Dec	3,2,4B,4A SB,2,4B 2,4A 4B,3,2,4A,5B	6-12 hrs	12-72 hrs	DAILY
		Western Parry Channel (VMS and Barrow Strait	Jan-June Jul-Aug Sept Oct-Dec	3,2,4B,4A,5B 2,4B,4A,5B 2,4B,5B,4A 4B,3,2,5B,4A	6-12 hrs	12-72 hrs	3/wk DAILY
		Lancaster Sound/Baffin Bay	Jan-Apr May-June July-Aug Sept Oct-Dec	9,5B,3,4B,2,4A 9,5B,2,4B,4A,3 9,5B,2,4B 9,2,7B,5B 9,2,4B,4A,5B	6-12 hrs	12-72 hrs	DAILY

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS NOWCAST	TIME NEEDS FORECAST	FREQUENC
Canadian Coast Guard	Transit (2)	Davis Strait	Jan-Apr May-July Aug-Oct Nov-Dec	9,4B,5B,4A 9,4B,4A,5B 9,7B,2 9,4B,2,5B,4A	6-12 hrs	12-72 hrs	DAILY
		Hudson's Bay Foxe Basin	Jan-Apr May-July Aug-Oct Nov-Dec	3,4B,2,4A,5B 5B,4B,2,4A 2,7B 4B,4A,2,SB,3	6-12 hrs	12-72 hrs	DAILY
		Labrador Sea	Jan-Apr May-Dec	9,5B,4B,2 9,7B,2,5B,4B	6-12 hrs	12-72 hrs	DAILY
		Gulf of St. Lawrence	Jan-Apr May-Dec	4B,5B,4A,3,2 7B	6-12 hrs	12-72 hrs	DAILY
		East NFLD	Jan-Apr May-Dec	9,4B,5B,2,4A 9,7B,2,4B	6-12 hrs	12-72 hrs	DAILY

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS NOWCAST	TIME NEEDS FORECAST	FREQUENC
Canadian Coast Guard	Transit (2)	Davis Strait	Jan-Apr May-July Aug-Oct Nov-Dec	9,4B,5B,4A 9,4B,4A,5B 9,7B,2 9,4B,2,5B,4A	6-12 hrs	12-72 hrs	DAILY
		Hudson's Bay Foxe Basin	Jan-Apr May-July Aug-Oct Nov-Dec	3,4B,2,4A,5B 5B,4B,2,4A 2,7B 4B,4A,2,SB,3	6-12 hrs	12-72 hrs	DAILY
		Labrador Sea	Jan-Apr May-Dec	9,5B,4B,2 9,7B,2,5B,4B	6-12 hrs	12-72 hrs	DAILY
		Gulf of St. Lawrence	Jan-Apr May-Dec	4B,5B,4A,3,2 7B	6-12 hrs	12-72 hrs	DAILY
		East NFLD	Jan-Apr May-Dec	9,4B,5B,2,4A 9,7B,2,4B	6-12 hrs	12-72 hrs	DAILY

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS NOWCAST	TIME NEEDS FORECAST	FREQUENCY
Offshore Drilling and Production	Exploration (3)	Beaufort Sea (4)	July Aug-Sept Oct	1,5B,4B,2 1,4B,5B,2,7B 1,4B,2,5B	TBD	TBD	DAILY
		Beaufort Sea (5)	Jan-Apr May-July Aug-Sept Oct-Dec	1,4B,2,5B,3 1,5B,4B,2 1,2,7B 1,2,5B,4B,4A	TBD	TBD	DAILY
		Beaufort Sea (6)	Jan-Apr May-July Aug-Sept Oct-Dec	1,2,3,4B 1,2 1,2,7B 1,2,4B,3	TBD	TBD	DAILY
		Baffin Bay/ Davis Strait (7)	June-July Aug-Oct	1,9,5B,2 1,9,7B,2	TBD	TBD	DAILY
		Labrador Sea (8)	Jan-Apr May-Dec	1,9,2,4B,5B,6 7B,1,9,5B,2,6	TBD	TBD	DAILY
		Hibernia/ Scotia Shelf	Jan-Apr May-Dec	7B,9,1,2,6 7B,9,1,6	TBD	TBD	DAILY

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS NOWCAST	TIME NEEDS FORECAST	FREQUENC
Offshore Drilling and Production	Construction (4)	Beaufort Sea (10)	July Aug-Sept Oct-Dec	1,5B,4B,2 1,5B,7B,2 1,5B,4B,2	TBD	TBD	DAILY
		Labrador Sea	June-Nov	7B,9,1,2,5B	TBD	TBD	DAILY
		Hibernia / Scotia Shelf	Jan-Apr May-Dec	7B,9,2,6,1 7B,9,6,1	TBD	TBD	DAILY
	Production	Beaufort Sea (11)	Jan-Apr May-July Aug-Sept Oct-Nov	1,2,3,4B,5B 1,2,5B 1,2,7B,5B 1,2,5B,4B,3	TBD	TBD	DAILY
		Labrador Sea	Jan-Apr May-Dec	1,9,2,4B,5B,6 7B,1,9,5B,2,6	TBD	TBD	DAILY
		Hibernia/ Scotia Shelf	Jan-Apr May-Dec	7B,9,1,2,6 7B,9,1,6	TBD	TBD	DAILY

ACTIVITY/INFORMATION PRODUCT MATRIX

GROUP	ACTIVITY	LOCATION	SEASON	NEEDED INFORMATION PRODUCTS	TIME NEEDS		FREQUENC
					NOWCAST	FORECAST	
DND	Anti-Submarine Warfare	-	Year Round	8,7B,7A,6	6hrs	12-36 hrs	DAILY
	Ship Movements	-	Year Round	7B,7A,6,9	6hrs	12-36 hrs	DAILY

INFORMATION FROM: CANADIAN ASTRONAUTICS LTD.

RADARSAT

CAL have overall system responsibility and are supported by SPAR and MDA as subcontractors.

The two main topics which were discussed were the candidate buses for RADARSAT, and orbit coverage.

CAL handed over a document entitled 'Radarsat Candidate Bus Matrix'. Anyone interested in seeing this may borrow it from PB or LPW. The matrix presents detailed data on the eight candidate buses, namely

Tiros N
Landsat D
L Sat
Spot
GPS II
P80 I
Seasat
SCS

compared with the corresponding Radarsat specification. Weighting Factors, Scores, Total Marks and Bus Ranking will be included in a later revision. Some more detailed information on SPOT was subsequently given to me by the ESA Washington Office.

CAL had examined orbit coverages with the SAR pointing to the LHS or RHS of the satellite.

The RHS case gives a higher maximum latitude but results in poorer coverage of the Beaufort Sea and North West Passage.

The LHS case - which is now the baseline - gives coverage up to a maximum of $75\frac{1}{2}^{o}$N and good coverage of the Beaufort Sea and NW Passage but leaves gaps in the coverage of the Straits of Labrador which would need to be filled either by aircraft flights or swath stepping of the satellite. This latter approach suffers a number of difficulties but is under study at present.

RADARSAT CANDIDATE BUS MATRIX

The following four pages present detailed data on the eight candidate busses for RADARSAT. Each page contains one "quadrant" of the complete bus matrix, which has the following format:

TITLE	TIROS-N	LANDSAT-D	L-SAT	SPOT	GPS-II	P80-1	SEASAT	SIS
MANUFACTURER MISSION PROFILE COMPATIBILITY WEIGHT POWER CAPACITY BUS VOLTAGES BATTERIES SOLAR ARRAY THERMAL TEMPERATURE ACS STRUCTURE DIMENSIONS RADIATION HARDENING	QUADRANT 1				QUADRANT 2			
DATA CAPABILITY TT&C SATELLITE TRACKING DESIGN LIFE RELIABILITY MODIFICATIONS DELIVERY SCHEDULE MATURITY OF DESIGN RESOURCES LAUNCH VEHICLE INTERFACES TOTAL COST TOTAL MARKS	QUADRANT 3				QUADRANT 4			

This package is REVISION A, correct to January 7, 1982. Outstanding data and minor revisions to existing data will be incorporated shortly. Weighting Factors, Scores, Total Marks and Bus Ranking will be included in a later revision.

L-SAT		SPOT		RADARSAT SPECIFICATION
BRITISH AEROSPACE	SCORES	MATRA	SCORES	
SUN-SYNC & GEO-SYNC. OPTIONS FOR: NOON/MIDNIGHT. DAWN/DUSK. RANGE OF LOCAL TIMES. MULTI-MISSION OPERATIONS.		SUN-SYNC POLAR ORBITS. 600-1200 KM. 98.2° 0800-1600 HR. EQUATOR CROSSING. EARTH OBSERVATION PROGRAMMES.		SUN-SYNCHRONOUS - POLAR ORBIT.
ARIANE AND STS		ARIANE		STS AND ARIANE 4.
1552 KGS. 450 TO 700 KGS. (450 KGS). 1550 KGS. (252 KGS) (INC. 15 KG. 850 KGS. STK)		1918 KGS. 820 KGS. (450 KGS) 300 KGS. (377 KGS) (INC. 15 KG. 1091 KGS. B.K.)		MAX 2400 KG PRIOR TO LAUNCH. 450 K GRM ESTIMATED.
2000 TO 7000 WATTS - SUNLIGHT. 1000 TO 4000 WATTS/HOUR ECLIPSE. 200 WATTS FOR 24 BATTERY DISCHARGE REGULATOR MODULES. -2 SHUNT DUMP MODULES (6.5 A. EOL). 3K WATT PRESENT SOLAR ARRAY CAPACITY. 3.3K WATT/WING (LATEST DESIGN).		3000 WATTS. 440 WATTS. POWER SUPPLY SUBSYSTEM. POWER CONTROL UNIT-PROVIDES CONTROL & MONITORING. POWER DISTRIBUTION UNIT-PROVIDES PROTECTION & ISOLATION. BATTERY MODULE-24 SERIES CONNECTED 24 AHR N. CAD. CELLS. POWER SUPPLY-O/P CAPABILITY UP TO 2000 WATTS. SOLAR ARRAY-CAPABILITY UP TO 1730 WATTS.		3.3 K WATTS EST.
50 VOLTS DC ± 1% AT REGULATION POINT. SUNLIGHT: IMPEDENCE RESISTANCE 20 m OHM AT DC. RIPPLE 500 m VOLTS P TO P. ECLIPSE: IMPEDENCE 400 m OHM DC. RESISTANCE 20 m OHM. RIPPLE 500 m VOLTS MAX P TO P.		50 VOLTS DC ± 1% REGULATED. 27V TO 37 VOLT UN-REGULATED.		50V DC UNREGULATED EST.
1 OFF - 35 AHR N. HYD. 1 OFF - 24 AHR N. CAD.		2 TO 4 OFF - 24 AHR N. CADMIUM.		MIN. 2 75 AHR EST.
100 SQ. FEET WINGS MOUNTED ON +Y & -Y FACES. ASTRO-MAST CARRIES SOLAR BLANKETS. SOLAR ARRAY DRIVE (SAD) OR BAPTA PROVIDES ROTATION CAPABILITIES AROUND Y AXIS.		LENGTH 38.4 FEET MAX. USES THE 'SPACE TELESCOPE' SUBSTRATE. DEPENDING ON ORBIT - S/C ROTATION THROUGH 90°.		T.B.D.
PASSIVE TECHNIQUES WITH ELECTRICAL HEATERS. 17 SQ. FEET OF N-S RADIATOR AREA COVERED WITH OPTICAL SOLAR REFLECTS. NEW S/C TECHNOLOGY - CONSTANT CONDUCTION PIPE HEAT RADIATORS.		PASSIVE SYSTEM WITH ELECTRICAL HEATERS. PAYLOAD & PLATFORM THERMALLY DECOUPLED. DISSIPATION TIME DEPENDENT ON PAYLOAD.		PASSIVE WITH HEATERS POSSIBLE ACTIVE CONTROL LOUVRES & HEAT PIPES.
NON-OPERATING -40°C TO +70°C. OPERATING -25°C TO +60°C.		0° < 0 < 40°C.		DESIGN MARGIN 10°C.
INFRA-RED & SUN SENSORS. CONTROL LOOP SYSTEM. 3 AXIS STABILISED FOR TRANSFER ORBIT. 0.1° PITCH & ROLL 0.5° YAW. *(SEE MODS) PITCH & ROLL BY IRES. YAW BY RATE INTEGRATING GYRO. 3 AXIS TORQUE CONTROLLED BY REACTION WHEELS.		INFRA-RED & SUN SENSORS. COMPUTER CONTROLLED SYSTEM. 0.15° MAX. (3 AXIS) WITH PREDICTED 0.12°. ANGULAR RATE 10^{-3}°/SEC. ANY AXIS. REACTION WHEELS (15 NMS) & MAGNETIC TORQUERS.		SENSING: R 0.1°, P 0.4°, Y 0.06° (C) 0.20° (L) CONTROL: R 0.2°, P 0.2°, Y 0.2°
210 M/S = 100 KGS. 470 M/S = 237 KGS. ≏ 15 KGS.		210 M/S = 150 KGS. 476 M/S = 362 KGS. ≏ 15 KGS. (FOR ORBIT 1000 KM ≏375 M/S ≏ 279 KGS.)		CAPABLE OF RAISING SPACECRAFT FROM SHUTTLE PARKING ORBIT TO DESIRED ALTITUDE.
GASEOUS HELIUM. BLOW-DOWN RATIO 3 TO 4. 16 OFF REACTION CONTROL THRUSTERS. PRESSURE REGULATORS & TRANSDUCERS. LATCHING & PYROTECHNIC VALVES. RELIEF & NON-RETURN VALVES.		HYDRAZINE FUEL CAPACITY - ORBIT LIMITING. 6 OFF - 3.25 N THRUSTERS FOR ATTITUDE & ORBIT CONTROL. 2 OF 4 OFF 14 N THRUSTERS FOR ORBIT CHANGING.		3 AXIS STABILIZED.
CENTRAL CYLINDER IS THE MAIN LOAD BEARING STRUCTURE WHICH TRANSMITS LOADS TO SEPARATION PLANE. DIAGONAL STRUTS SUPPORT COMMUNICATION MODULE LATERAL WALLS. STRUCTURE PROVIDES FLEXIBILITY & GROWTH POTENTIAL.		VERSATILE PLATFORM AREA. PLATFORM SUPPORTING WALLS FOR EQUIPMENT MOUNTING.		T.B.D.
1 FT. 7 INS. X 5 FT. 8 INS. x 6 FT. 1 INS.		7 FT. X 6 FT. 2 INS. x 6 FT. 2 INS.		T.B.D.
-GEOSYNC ORBIT EQUIPT. DESIGNED FOR 7 YEAR LIFE (3K RADS PER YEAR).		PLATFORM DESIGN GUARD FACTOR OF TWO. LOWER ORBITS - GUARD FACTOR INCREASES. HIGHER ORBITS RADIATION HARDENED PARTS IMPLEMENTED.		MINIMIZE ENERGY STORAGE DUE TO DIFFERENTIAL CHARGING & NOT BE AFFECTED BY UNIFORM SPACECRAFT CHARGING.

WEIGHTING FACTOR	TITLE MANUFACTURER	TIROS-N (SAATR) RCA ASTRO-ELECTRONICS	SCORES	MMS/LANDSAT-D GENERAL ELECTRONICS	SCO
	TYPICAL MISSION PROFILE A) ALTITUDE B) INCLINATION C) MISSION	SUN-SYNC NEAR POLAR CIRCULAR ORBITS. 833-870 KM. 98° 0600-1000 HR. EQUATOR CROSSING. SEARCH & RESCUE OPERATIONS.		SUN-SYNC CIRCULAR. 705 KM. 97.6° 0930 HR. EQUATOR CROSSING. MULTI-MISSION/REMOTE SENSING APPLICATIONS.	
	COMPATIBILITY	ATLAS AND STS		DELTA AND STS	
	WEIGHT TYPICAL LAUNCH WEIGHT TOTAL PAYLOAD DRY WEIGHT CAPABILITY PROPULSION FUEL WEIGHT CAPACITY BUS WEIGHT (TYPICAL DRY)	1392 KGS. 454 KGS. (450 KGS) 730 KGS. (277 KGS) (INC. 15 KG. STK) 665 KGS.		2182 KGS. 380 KGS. (450 KGS) (427 KGS) (INC. 15 KG. STK) 1305 KGS.	
	POWER CAPACITY PAYLOAD PEAK AVERAGE DESCRIPTION SOLAR ARRAY	1900 WATTS 420 WATTS 200 WATTS -BUS AVERAGE/ORBIT 40 WATTS -TAPE RECORDER 8 WATTS -POWER SUPPLY 1470 WATTS		3000 WATTS ON A 10% ORBITAL DUTY CYCLE. 1200 WATTS 1000 WATTS - NOMINAL MODULAR POWER SUBSYSTEM CONTROLS SOLAR ARRAY GENERATED POWER. UN-FUSED POWER TO EACH SUBSYSTEM MODULE. FUSED POWER TO INSTRUMENTATION	
	BUS VOLTAGES MAIN VOLTAGE SECONDARY REGULATION TRANSIENTS	± 28 VOLTS DC. ± 5 VOLTS DC. ± 0.3 VOLTS - ON MAIN VOLTAGE RECHARGE 79.5 AMP HR. DOD 20% (3 BATTERIES) ± 0.3 VOLTS ECLIPSE		22 V TO 35 VOLTS. ± 28 VOLTS - UNREGULATED - CHARGE & DISCHARGE OF BATTERIES WITHIN SPECIFICATION LIMITS: S-7000-17 & S-7000-14	
	BATTERIES	3 OFF - 50 AHR N. CADMIUM (ADV. TIROS-N)		3 OFF - 50 AHR N. CADMIUM.	
	SOLAR ARRAY GEOMETRY DEPLOYMENT TYPE ROTATION RESTOWABILITY SADAPTA	125 SQ. FEET (8 PANELS) 36° CANT TO THE ORBIT NORMAL ONCE PER ORBIT POWER SUPPLIED THROUGH SLIP RINGS		150 SQ. FEET (4 PANELS) ADDITIONAL PANELS CAN BE ADDED GIVING INCREASE OF 20% SINGLE & DUAL AXIS ROTATION CURRENTLY NOT RESTOWABLE	
	THERMAL	PASSIVE MULTI-LAYER INSULATION BLANKETS ACTIVE - LOUVRES VANE & PIN WHEEL COVERING MAIN RADIATORS 36 WATT REJECTION CAPACITY		PASSIVE - INSULATION & RADIATORS ON THE INSTRUMENTATION MODULE. ACTIVE - LOUVRES ON SUBSYSTEM MODULES 400 WATTS ON INSTRUMENTATION 350 WATTS ON SUBSYSTEMS	
	TEMPERATURE	QUALIFICATION -10°C TO -30°C		SUPPORT STRUCTURE INTERFACE 11°C TO 30°C	
	ACS SENSOR TYPE SYSTEM TYPE POINTING ACCURACIES SENSING ACCURACIES CONTROL SYSTEM	PITCH & ROLL EARTH SENSOR. YAW SUN SENSOR. NOMINALLY A ZERO MOMENTUM CONTROL SYSTEM. 3 AXIS STABILIZED 0.15° MAIN BODY 0.14° REACTION WHEEL ASSY MAGNETIC CONTROL COILS & GAS BEARING REMOTE INTEGRATING GYROS.		STAR TRACKER. PRECISION DIGITAL & COURSE SUN SENSORS. HIGHLY AUTOMATED SYSTEM. ± 0.01° ALL AXIS ± 0.01° REACTION WHEELS MAGNETOMETER & MAGNETIC TORQUERS.	
	PROPULSION DELTA V STATION KEEPING	210 M/S = 109 KGS. 476 M/S = 262 KGS. ≈15 KGS.		210 M/S = 171 KGS. 476 M/S = 412 KGS. ≈15 KGS.	
	RCS FUEL TYPE THRUSTER CHARACTERISTICS AND TANKAGE TYPE	HYDRAZINE & NITROGEN USED ON SOLAR ARRAY DEPLOYMENT		HYDRAZINE & NITROGEN PM I SYSTEM - BLOW-DOWN RATIO 3 TO 1 PM II SYSTEM - BLOW-DOWN RATION 5 TO 1 PROPELLANT LATCH VALVES ISOLATE THE THRUSTER GROUPS FROM THE PROPELLANT TANKS	
	STRUCTURE	ADV. TIROS-N HAS GROWTH CAPABILITY. AT PRESENT SCATTEROMETER BEING DESIGNED AS PART OF ATN PAYLOAD. STRUCTURE CONSISTS OF 4 COMPONENTS: 1) REACTION SYSTEM SUPPORT 2) EQUIP. SUPPORT MODULE 3) INSTRUMENTATION PLATFORM 4) SOLAR ARRAY		LIGHT WEIGHT MODULAR SUPPORT STRUCTURE. ONE DESIGN IN THE MECHANICAL & THERMAL SYSTEMS. BASIC ELECTRICAL SYSTEM IS FIXED. MMS STANDARD CONFIGURATION: 1) MMS 2) SC & CU 3) TA (TRANSITION ADAPTER) 4) MPS 5) MACS 6) C 3 DH 7) PMI OR PMII	
	DIMENSIONS	ADV. TIROS-N 13 FT. 10 INS. X 6 FT. 2 INS.		17 FT. x 7 FT.	
	RADIATION HARDENING	TO NASA STANDARD SPECIFICATIONS		REF. LANDSAT-D SYSTEM SPEC WITHIN SPEC LIMITS. REF. NASA X-601-77-73	

CONCEPT NO. 1 (SEASAT) LMSC INC.	SCORE	CONCEPT NO. 2 (SCS) LMSC INC.	SCORE	RADARSAT SPECIFICATION
GEO-SYNC PLANETARY & LUNAR. 60° - 100° ALT. 15 OHM TO 2500 NM. BASIC SEASAT DESIGN.		NEAR EARTH. INFORMATION RESTRICTED. SATELLITE CONTROL SECTION.		SUN-SYNCHRONOUS - POLAR ORBIT.
ARIANE AND STS		TITAN		STS [illegible] ARIANE 4.
1431 KGS. 356 KGS. (450 KGS) 250 KGS. (291 KGS) (INC. 23 KG. R.E.) 690 KGS.		2419 KGS. 356 KGS. (450 KGS) 2814 KGS. (460 KGS) 2509 KGS.		MAX [illegible] KG PRIOR TO LAUNCH. 450 K [illegible] ESTIMATED.
3000 WATTS - VARIABLE. GROUND 2-WIRE POWER DISTRIBUTION. LOW IMPEDENCE BONDED. 3000 WATT - MAX. FROM SOLAR ARRAY.		3000 WATTS - VARIABLE. 550 WATTS NOMINAL POWER CAPACITY. 3000 WATT - MAX. FROM SOLAR ARRAY		3.3 K WATTS EST.
24 VOLTS TO 32 VOLTS DC DOD 70% (AS ON SEASAT) ± 24 VOLT DC 10 MICRO-SEC. ECLIPSE EXIT TRANSIENT.		28 VOLTS DC		50V DC UNREGULATED EST.
2 TO 4 OFF - 25 AHR N. CADMIUM.		4 OFF - 25 AHR N. CADMIUM.		MIN. 2 75 AHR EST.
410 SQ. FEET RIGID FRAME SUBSTRATE. SINGLE AXIS TRACKING. STANDARD SOLAR ARRAY CHARGE CONTROLLER. SOLAR ARRAY CAN BE RETRACTABLE.		410 SQ. FEET WITH ARRAY DRIVE ASSEMBLY. SOLAR ARRAY CAN BE RETRACTABLE.		T.B.D.
PASSIVE THERMAL CONTROL WITH HEATERS. S/C THERMALLY ISOLATED FROM PAYLOAD. 350 WATT DISSIPATION.		PASSIVE THERMAL CONTROL WITH HEATERS. S/C THERMALLY ISOLATED FROM PAYLOAD. 400 WATT DISSIPATION. $<$10 WATT HEAT TRANSFER FROM SATELLITE CONTROL SECTION TO PAYLOAD.		PASSIVE WITH HEATERS POSSIBLE ACTIVE CONTROL LOUVRES & HEAT PIPES.
DESIGN AIM $-20^{\circ}C$ TO $+20^{\circ}C$.		DESIGN AIM $-20^{\circ}C$ TO $+20^{\circ}C$.		DESIGN MARGIN $10^{\circ}C$.
STAR, HORIZON & SUN SENSORS. COMPUTER CONTROL. 3 AXIS STABILIZED. 0.7 PITCH YAW & ROLL. 0.16° PITCH 0.12° YAW 0.14° ROLL SENSING RATE 0.0025°/SEC. P. 0.1°/SEC. Y & 0.0020°/SEC. R. DUAL GIMBALLED REACTION WHEELS.		HORIZON SENSORS. REFERENCE MODULE. 3 AXIS STABILIZED. 0.5° PITCH 0.6 YAW 0.4 ROLL SENSING RATE 0.01°/SEC. P. 0.01°/SEC. Y & 0.02°/SEC. R.		SENSING: R 0.1°, P 0.4°, Y 0.06° (C) 0.20° (L) CONTROL: R 0.2°, P 0.2°, Y 0.2°
210 M/S = 111 KGS. 476 M/S = 268 KGS. $\approx$23 KGS.		210 M/S = 191 KGS. 476 M/S = 460 KGS.		CAPABLE OF RAISING SPACECRAFT FROM SHUTTLE PARKING ORBIT TO DESIRED ALTITUDE.
HYDRAZINE. HOT GAS CONTROL THRUSTERS. THRUST CHAMBER CAN BE GIMBALLED.		HYDRAZINE. HOT GAS CONTROL THRUSTERS. NOMINAL FULL LOAD 1814 KGS.		3 AXIS STABILIZED.
AGENA BASELINE CONCEPT.		SATELLITE CONTROL SECTION. BAY AREAS. BAY 1) PYROTECHNICS BAY 2) POWER BAYS 3 & 4) BATTERIES BAY 6) ACS BAY 7) T & T BAY 8) COMMAND. BAY LOAD MOUNTING AREA IS 10 FT. DIA.		T.B.D.
4 FT. X 4 FT. 3 INS. X 2 FT.		10 FT. DIA. X 7 FT. 6 INS.		T.B.D.
NO NUCLEAR RADIATION HARDENING PLANNED. SOLAR ARRAY CELLS WILL BE SHIELDED FROM COSMIC ELECTRON & PROTON PARTICLES. SINGLE GRND. PT.		NO NUCLEAR RADIATION HARDENING PLANNED. SOLID STATE DEVICES SCREENED. CABLE END-TO-END SHIELDING, BONDING & GRND. STRAPPING.		MINIMIZE ENERGY STORAGE DUE TO DIFFERENTIAL CHARGING & NOT BE AFFECTED BY UNIFORM SPACECRAFT CHARGING.

TITLE MANUFACTURER	GPS-II ROCKWELL INTERNATIONAL	SCORES	P80-1 ROCKWELL INTERNATIONAL	SCORES
TYPICAL MISSION PROFILE A) ALTITUDE B) INCLINATION C) MISSION	HIGH CIRCULAR 12 HOUR ORBITS. NAVSTAR MISSIONS IN SUPPORT OF USAF.		OPERATIONAL ORBITS 800 KM. ≥ 72.5°. USAF MISSIONS BROAD RANGE OF LOW ORBITS.	
COMPATIBILITY	STS		STS	
WEIGHT TYPICAL LAUNCH WEIGHT TOTAL PAYLOAD DRY WEIGHT CAPABILITY PROPULSION FUEL WEIGHT CAPACITY BUS WEIGHT (TYPICAL DRY)	1559 KGS. 221 KGS. (450 KGS) 581 KGS. (229 KGS) (INC. 15 KGS. H.K.) 910 KGS.		1793 KGS. 693 KGS. (450 KGS) 1123 KGS. (353 KGS) (INC. 15 KGS. H.K.) 990 KGS.	
POWER CAPACITY PAYLOAD PEAK AVERAGE DESCRIPTION SOLAR ARRAY	1200 WATTS 900 WATTS – EXISTING SOLAR ARRAY. 1200 WATTS – WITH MODIFIED ARRAY & ELECTRONICS.		1200 WATTS DIRECT ENERGY TRANSFER FROM BATTERIES. DIRECT ENERGY TRANSFER VIA SLIP RING. ASSEMBLY FROM SOLAR ARRAY. 1200 WATTS DURING SUNLIGHT.	
BUS VOLTAGES MAIN VOLTAGE SECONDARY REGULATION TRANSIENTS	27 VOLTS ± 1.0 VOLT DC AT BUS. 26.5 VOLTS + 1.5V DC, – 1.0V DC AT LOAD TERMINAL. VOLTAGE RIPPLE (1) < 0.96 VRMS TO 15 KHZ. (2) < 0.4 VRMS TO 100 MHZ. TRANSIENTS < ± 33V FOR < 50 SECONDS.		24V TO 33 VOLTS DC TO LOADS. 52V TO 90 VOLTS DC TO IAPS THRUSTERS. NO DEGRADATION SUBJECTED TO THE FOLLOWING TRANSIENTS: T 60.6 M SEC. ± 66V LINE TO LINE. ± 33V LINE TO CASE T 60.6 M SEC.) TO 20 M SEC.) 35 VOLTS	
BATTERIES			2 OFF. – 35 AHR N CADMIUM.	
SOLAR ARRAY GEOMETRY DEPLOYMENT TYPE ROTATION RESTOWABILITY SADAPTA	2 SOLAR WINGS (5FT. 7 INS. X 11 FT. 9 INS.). SOLAR WINGS MOUNTED ON +Y & –Y AXIS. SINGLE DEGREE OF FREEDOM ORIENTATION. 78 SQ. FEET PRESENT ACTIVE AREA. 108 SQ. FEET POTENTIAL ACTIVE AREA.		3 PANELS (INNER MID & OUTER). 130 SQ. FEET. 35° TILE ANGLE. SINGLE DEGREE OF FREEDOM ORIENTATION.	
THERMAL	PRIMARY HEAT REJECTION BY SHEAR PANELS WITH THERMAL LOUVRES OR RADIATORS. THERMAL DOUBLERS PROVIDE HEAT CONDUCTION PATHS. 480 WATT CONTINUOUS DISSIPATION.		THERMAL COVERS, RADIATORS & HEATERS CONCEPTS BEING EVALUATED. 1000 WATT STEADY STATE DISSIPATION. 1500 WATT PEAK LOAD FOR SHORT PERIODS.	
TEMPERATURE	MOST EQUIPMENT –15°C TO +50°C. BATTERIES 0°C TO 30°C.		EXTERNAL ITEMS –62°C TO +92°C. BATTERIES 0°C TO 20°C.	
ACS SENSOR TYPE SYSTEM TYPE POINTING ACCURACIES SENSING ACCURACIES CONTROL SYSTEM	EARTH & SUN SENSORS SPIN STABILIZED & 3 AXIS CONTROL. 0.5° (3 AXIS)		CELESTIAL, HORIZON & SUN SENSORS 3 AXIS STABILIZED. 0.1° ROLL & YAW. 0.2° PITCH. 0.01° REACTION WHEELS WITH MAGNETOMETER/ ELECTROMAGNETS.	
PROPULSION DELTA V STATION KEEPING	210 M/S = 89 KGS. 476 M/S = 214 KGS. ≃15 KGS.		210 M/S = 140 KGS. 476 M/S = 338 KGS. ≃ 15 KGS. H.K. TOTAL IMPULSE 296 762 KGS. – SEC/MOTOR MAXIMUM THRUST 7526 KGS.	
RCS FUEL TYPE THRUSTER CHARACTERISTICS AND TANKAGE TYPE			HYDRAZINE STABILIZATION SYSTEM NITROGEN RCS ATTITUDE CONTROL. 4 OFF 45.4 KG. PITCH & YAW CONTROL THRUSTERS. 2 OFF 2.3 KG. ROLL CONTROL THRUSTERS. 12 OFF 90 M GRAM THRUSTERS (RCS) TANK TOTAL LOAD 1123 KGS.	
STRUCTURE	EMPLOYS TECHNOLOGY DEVELOPED & USED IN GPS I S/C. CONSISTS OF SEVEN SUBSYSTEMS. 20 MAJOR COMPONENTS & 30K EEE PARTS. TO DATE 100K SPACE HOURS FAILURE FREE OPERATIONS LOGGED BY 6 VEHICLES.		ALUMINUM HONEYCOMB FLAT PANELS. MONOCOQUE THRUST CYLINDER.	
DIMENSIONS	7 FT. X 7 FT. 6 INS. X 3 FT. 6 INS.		8 FT. 2 INS. X 7 FT. 6 INS. X 2 FT. 5 INS.	
RADIATION HARDENING	CAPABLE OF WITHSTANDING GEOMAGNETICALLY TRAPPED PROTONS, ELECTRONS & SOLAR FLARE PROTONS. REF. SPECS NSSDC 76-06 & NSSDC 76-04.		CAPABLE OF WITHSTANDING GEOMAGNETICALLY TRAPPED PROTONS, ELECTRONIS & SOLAR FLARE PROTONS. REF. SPECS NSSDC 76-06 & NSSDC 76-04.	

L-SAT		SPOT		RADARSAT SPECIFICATION
BRITISH AEROSPACE	SCORES	MATRA	SCORES	
1) DUAL DECODER 2) CONTROL DATA UNIT 3) REMOTE DATA UNIT		PAYLOAD HANDLING NOT ACCOMMODATED. PAYLOAD PROGRAMMING IS ACCOMMODATED. 20K WORDS OF 76 BITS.		NOMINAL 118 M BITS PER SECOND.
S-BAND 2025 - 2120 MHZ TC. 2200 - 2300 MHZ TM. 512 TELEMETRY CHANNELS. 26) COMMAND CHANNELS. 500 K BITS/SEC. STANDARD BIT RATE		S-BAND. UPLINK 2025 - 2110 MHZ DOWNLINK 2200 - 2290 MHZ 2 K BITS/SEC.		S-BAND.
O ON-BOARD TRACKING CAPABILITIES. RACKING & ORBIT DETERMINATION BY ROUND. (ATION MEASUREMENTS VIA S-BAND RANSPONDER.		MEASUREMENT OF 2-WAY PROPAGATION DELAY OF AN R.F. SIGNAL - TRANSMITTED BY THE PLATFORM. 100 KHZ SINE MAJOR TONE FOR FINE MEASUREMENT. RANGE RATE TX OF S-BAND SIGNALS WITH UPLINK/DOWNLINK RATIO 221/240.		T.B.D.
SIGN FOR 10 YR. MISSION LIFE.		2 YR. CONFIDENCE LEVEL 60%.		5 YEAR MINIMUM.
				AVOID SINGLE POINT FAILURES TO REDUCE CRITICAL FAILURE MODES.
AR MAPPER COULD BE USED TO INCREASE W ACCURACY. OLAR ARRAY DESIGN BEING UPDATED.		MINOR CHANGES WITH SPOT STANDARD ORBITS. DATA CAPABILITY SOLAR ARRAY MOTION & ELECTRICAL POWER CAPACITY.		
		26 MONTHS.		
		R.O.M. $32M 1980 $CDN. (INCL. SOLAR ARRAY).		

WEIGHTING FACTOR		TIROS-N (SAATH) RCA ASTRO-ELECTRONICS	SCORES	MMS/LANDSAT-D GENERAL ELECTRONICS	SCORES
	DATA CAPABILITY — PRIMARY COMPONENTS	1) TIROS INFORMATION PROCESSOR 2) MANIPULATED INFORMATION RATE PROCESSOR 3) 5 OFF DIGITAL TAPE RECORDERS		1) COMMAND GROUP 2) TELEMETRY GROUP 3) ON BOARD COMPUTER	
	CAPACITY	TAPE RECORDER CAPACITY 45×10^8 BITS ONE RECORDER/RECORDING TIME – 225 MINS.		CAN ACCOMMODATE THEMATIC MAPPER. 85 M BITS/SEC. FREQUENCY.	
	TT & C	S-BAND 1.7 GHZ (5 WATTS) 2.6 M BITS/SEC. MAX BIT RATE		S KU & X BANDS TRACKING & DATA RELAY SATELLITE SYSTEM (TDRSS) S-BAND (NARROW) 1000 BITS/SEC. (TDRSS) S-BAND (WIDE) 125 BITS/SEC. (EMERGENCY) S KU & X BAND INSTRUMENTATION. 115 K BITS/SEC.	
	SATELLITE TRACKING — RANGING SYSTEM	NO ON-BOARD TRACKING CAPABILITY		ORBIT COMPUTATION GROUP (OCG) WITHIN NASA & GLOBAL POSITIONING SYSTEM. DATA ACCURACY BASED ON THE PROPAGATION PERIODS INDICATED WITHIN PARENTHESIS (MINS).	
	DESIGN LIFE — MISSION LIFE, STORAGE	2 YR. BATTERY LIMITED UN-USED NITROGEN GAS		3 YR. BATTERY LIMITED	
	RELIABILITY — REDUNDANCY VS. SINGLE POINT FAILURES	NO SINGLE POINT FAILURES ON ORBIT		REMOTE INTERFACE UNIT FOR SUBSYSTEMS	
	EXTENT OF MODIFICATIONS — MINOR	GIMBALLING IMPROVEMENT CANT ANGLE CHANGE FOR SOLAR ARRAY DEPENDING ON ORBIT.		REASSESSMENT OF THERMAL CAPABILITIES. POSSIBLE CHANGE TO SOLAR ARRAY CANT ANGLES. POSSIBLE REASSESSMENT OF ACS ACCURACIES, DEPENDING ON SHAPE & SIZE OF SAR ANTENNA.	
	MAJOR	UPDATE OF DATA HANDLING SYSTEM. MAX. WITH PRESENT SYSTEM ≏ 50 M BITS/SEC.			
	DELIVERY SCHEDULE — LONG LEAD ITEMS, MECH. I/F, ASSEMBLY, ELECT. I/F, TEST PROGRAM	2 YR. CRITICAL PATH FOR PROPULSION SYSTEM. 27 TO 30 MONTHS FOR COMPLETE CHECK AS A BUS READY FOR PAYLOAD INTEGRATION.		36 MONTHS	
	MATURITY OF DESIGN — WEIGHT, POWER, BATTERIES, SOLAR ARRAY, THERMAL, ACS, PROPULSION/RCS, STRUCTURE, DATA/DOWN LINK, TT & C			FULLY QUALIFIED QUALIFIED FOR LANDSAT-D FULLY QUALIFIED FULLY QUALIFIED	
	RESOURCES & FACILITIES	COMPLETE FACILITIES FOR TIROS-N PROGRAMME.		FULL SYSTEM FOR TESTING & INTEGRATION.	
	LAUNCH VEHICLE — SHUTTLE, ARIANE 3, ARIANE 4				
	INTERFACE REQUIREMENTS				
	TOTAL COST	R.O.M. \$30M 1980 \$ U.S.		R.O.M. \$31M 1980 \$ U.S. (NO SOLAR ARRAY)	
	TOTAL MARKS				

CONCEPT NO. 1 (SEASAT)		CONCEPT NO. 2 (SCS)		RADARSAT SPECIFICATION
LMSC INC.	SCORES	LMSC INC.	SCORES	
CDC 469 COMPUTER. 64K MAX. NO. OF WORDS. WORK LENGTH 16 BITS. ADD/SUBTRACT 2.4 M SEC. MULTIPLY 10.4 M SEC. DIVIDE 30.4 M SEC. TAPE RECORDER CAPACITY 256 K BITS/SEC.		2 OFF PROGRAM MEMORY UNITS. EACH UNIT CAPABILITY FOR 1024. 40 BITS COMMAND WORDS. TAPE RECORDERS (2 OFF) 256 K BITS/SEC.		NOMINAL 118 M BITS PER SECOND.
S-BAND 2287 MHZ. STANDARD 64 CHANNEL CAPACITY.		S-BAND 2.2 TO 2.3 MHZ. 492 ANALOG CHANNELS. 240 DISCRETE CHANNELS.		S-BAND.
ON-BOARD TRACKING SYSTEM NOT PRESENTLY PLANNED. SATELLITE POSITION FROM GROUND & RANGE DATA. VELOCITY ERRORS (ECCENTRICITY): FOR RADARSAT TYPE ORBIT .0003 TO .00002		ON-BOARD TRACKING SYSTEM NOT PRESENTLY PLANNED. SATELLITE POSITION FROM GROUND & RANGE DATA. VELOCITY ERRORS (ECCENTRICITY OF PERIOD): FOR RADARSAT TYPE ORBIT .0003 TO .00002		T.B.D.
1 YR. PLUS		1 YR.		5 YEAR MINIMUM.
		REDUNDANCY FOR ALL CRITICAL HARDWARE ITEMS.		AVOID SINGLE POINT FAILURES TO REDUCE CRITICAL FAILURE MODES.
DEPENDING ON REQUIREMENTS: SOLAR ARRAY & BATTERY RE-SIZING. PROPELLANT LOAD INCREASE. TELEMETRY TX POWER & RX ANTENNA SIZE INCREASE. THERMAL CONTROL RE-ANALYSIS.				
HARDWARE TO BE MANUFACTURED IN TITANIUM - 30 MONTHS LEAD TIME.		HARDWARE TO BE MANUFACTURED IN TITANIUM - 30 MONTHS LEAD TIME.		
FLIGHT PROVEN CURRENT PRODUCTION LINE.		FLIGHT PROVEN.		
VAST EXPERIENCE, FACILITIES & RESOURCES		VAST EXPERIENCE, FACILITIES & RESOURCES		
FULL PROGRAMME: $67.7M 1982 $U.S.		FULL PROGRAMME: $73.1M 1982 $U.S.		

QUADRANT 4 REVISION A, JAN 7 1982

WEIGHTING FACTOR		GPS-II		P80-1	
		ROCKWELL INTERNATIONAL	SCORES	ROCKWELL INTERNATIONAL	SCORES
	DATA CAPABILITY PRIMARY COMPONENTS CAPACITY			RECEIVED COMMAND CAN BE DIRECTLY ROUTED TO PAYLOAD INTERFACES OR STORED. COMPATIBLE WITH AFSCF. THREE TAPE RECORDERS. 32 & 1024 K BITS/SEC. RECPRD RATES. 1024 K BITS/SEC. PLAY BACK RATES.	
	TT & C	L & S BANDS. UPLINK - COMMAND 1783.740 MHZ. DOWNLINK - TELEMETRY 2227.5 MHZ. 500 OR 4000 BITS/SEC. CAPABLE OF 256 K BITS/SEC.		L & S BANDS UPLINK - COMMAND 1771.729 MHZ }CARRIER DOWNLINK - TELEMETRY 2212.5 MHZ} 1 32 K BITS/SEC. TELEMETRY 2207.5 MHZ)CARRIER 1.024 M BITS/SEC. 2	
	SATELLITE TRACKING RANGING SYSTEM	GPS II USES PRIMARY PAYLOAD TO SATISFY MISSION POSITION REQUIREMENTS. SECONDARY TRACKING BY TURNAROUND RANGING.		TOTAL OVERALL ACCURACY = SUM OF SYSTEM ERRORS. REACHED BY INFORMATION FROM TURNAROUND RANGING, ADVANCED ORBITAL EPHEMERIS, SUBSYSTEM AUXILIARY MASTER TAPE, FLIGHT COMPUTER, ACDS & PAYLOADS & NEAR-REAL-TIME UPDATES.	
	DESIGN LIFE MISSION LIFE STORAGE	DESIGN GOAL 7.5 YRS. WITH 10 YRS. FOR SELECTED COMPONENTS.		CURRENT DESIGN FOR 3 YR. MISSION. UNUSED HYDRAZINE.	
	RELIABILITY REDUNDANCY VS. SINGLE POINT FAILURES				
	EXTENT OF MODIFICATIONS MINOR MAJOR			DEPENDING ON PAYLOAD REQUIREMENTS POTENTIAL THERMAL & POWER SUPPLY CHANGES ARE CONSIDERED.	
	DELIVERY SCHEDULE LONG LEAD ITEMS MECH. I/F ASSEMBLY ELECT. I/F TEST PROGRAM				
	MATURITY OF DESIGN WEIGHT POWER BATTERIES SOLAR ARRAY THERMAL ACS PROPULSION/RCS STRUCTURE DATA/DOWN LINK TT & C				
	RESOURCES & FACILITIES			FULL FACILITIES & POSSIBLE AIRBOURNE SUPPORT EQUIPMENT & STATE-OF-THE-ART TECHNOLOGY.	
	LAUNCH VEHICLE SHUTTLE ARIANE 3 ARIANE 4				
	INTERFACE REQUIREMENTS				
	TOTAL COST				
	TOTAL MARKS				

ANNEX IV

European Data Requirements

Results of Future Earthnet Dissemination System (FEDS) Study

For the FEDS study a European user model was developed to predict the data handling requirements for the proposed ESA Earthnet data dissemination system. This was based on predictions of user requirements for all sensor types on satellites expected to be operational in the period 1980 to 1990 and obtaining coverage of areas coming within the read-out range of the Earthnet Stations. The predictions were made separately for each of the main high-rate instrument types - i.e. imaging devices based on geographic coverage, frequency of coverage, sensor data and product type; and modified by 'user credibility factors'.

Demand growth for data products was projected on sigmoidal (Gompertz) curves with exponential growth taking place following establishment of service but acheiving saturation of predicted demand level in 7 or 10 years. The European demand in 1990 for satellite data in band scenes based on 7 year and 10 year growth curves is shown in Table IV-1. This is for a pre-Radarsat missions model with SAR not being available before 1986. At the 1990 limit of prediction SAR demand is just starting on its growth curve and would expect to saturate it in 5 to 8 years time. Users of SAR data, when it is available, are seen to be mainly in the 'high-demand' group and to be mainly 'high credibility' customers. 'Saturation demand' is estimated to rise to approximately 468,000 images a year.

Sensor Product Demand : European Users 1990 Table IV-1

Sensor/ Product	7 Year Growth Projection Band Scenes		10 Year Growth Projection Band Scenes	
MVI - QL	33697	Demand saturated	33697	Demand saturated
MVI - SC	2636	Demand saturated	2636	Demand saturated
HVI - QL	375	Demand saturated	115	–
HVI - SC	5494	Demand saturated	1121	–
HVI - PP	190	Demand saturated	188	–
OCI - QL	5386	–	409	–
OCI - SC	48	–	15	–
IRI(a) - QL	7163	–	2741	–
IRI(a) - SC	5140	–	489	–
IRI(b) - QL	46828	–	46398	–
IRI(b) - SC	200	–	163	–
SAR - SC	91	Demand just starting	63	Demand just starting
SAR - PP	50	Demand just starting	50	Demand just starting
IMR - QL	9586	–	1643	–
IMR - SC	1205	–	1109	–

Key :

MVI – Medium resolution visible instrument
HVI – High resolution " "
OCI – Ocean colour imager
IRI(a) – Low resolution IR radiometer
IRI(b) – Medium resolution IR radiometer
SAR – Synthetic aperture radar
IMR – Imaging Microwave radiometer

QL – Quick-look product
SC – Scene-corrected product
PP – Precision processed

CONTACTS
SUMMARY OF INTERESTS AND ASSOCIATIONS

I-1 DATA USERS

Marine Committee of Mechanical and Engineering Requirements Board, (Formerly SMTRB).	No activity in directly relevant work and no new recent funding for data-buoy work that may be relevant to satellite ocean data collection work.
MATSU - Marine Technology Support Unit.	Are continuing work with long-term data gathering by ocean data buoys which could complement satellite data collection. Areas of interest are moving out towards the edge of the continental shelf.
Department of Energy - Petroleum Exploration and Development Division.	Are interested in wind and wave data that could be provided by satellite. General area of interest is whole of 'UK designated waters' out to 100 fathoms. Priority interest is in new concession areas to be granted in next 5 to 10 years. Precise prediction as to which these will be is difficult.
NMI - National Maritime Institute.	Would have some interest as a secondary user on an ad-hoc basis for specific projects - e.g. Marine traffic monitoring.
Meteorological Office.	Interest in data would be as input to the current forecasting network and to long-term global models. Particular interest in filling in gaps in the Southern ocean coverage.
IOS - Institute of Oceanographic Sciences.	Primarily secondary users and would favour an AMPS* as proposed by the Met. Office. Consider that a satellite position fixing system of some sort would considerably enhance the radar altimeter data which is of most use to them.

*Amospheric Microwave Pressure Sounder.

Scott Polar Research Institute.	Main interest is in Arctic data, particularly relevant to shipping and oil exploration activities.
British Antarctic Survey	The subject of Antarctic sea ice in particular could benefit from Radarsat coverage but there are reservations about the value of satellite data in general.
NERC - Remote Sensing Services. (National Environmental Research Council).	Radarsat should fit into a general pattern of developing and complementary satellite data services. NERC overall would be as interested in over-land coverage as much as ocean coverage.
Sea Mammal Research Unit (NERC).	Unlikely to have any direct requirement.
U. K. Coastguard	Interested in INMARSAT for Search and Rescue and in any facilities of this kind that might be on Radarsat.
UKOOA - UK Offshore Operators Association/and Shell UK Survey Department.	Main interest is in met. /ocean data sets to justify less stringent and costly engineering specifications for oil/gas platforms. Also for operators immediate, operations planning and platform performance prediction. Would be in the market for sets of satellite data as one of a number of inputs. Interest is confined to UK designated waters.
Logica Ltd.	Interested in the development of UK processing expertise and a UK receiving/processing centre. Consider that the UK is now well behind in processing for land applications and should concentrate now on marine data.

INSTRUMENT-FACILITY PARTICIPANTS

RAE- Royal Aircraft Establishment	Contacts with the Canadian programme suggest that they would look favourably on the UK taking responsibility for data collection and dissemination in the E. Atlantic area. It is understood that the UK is already in contact with West Germany over the sharing-out of interest in the satellite radar area. Costing exercises have been done for a UK ERS-1 station, which could also handle Radarsat data. There has been mention of the idea of an Antarctic Station.
Meteorological Office	The AMPS instrument submitted by METO and others for ERS-1 could be offered/proposed for Radarsat. They would, in principal, favour the establishment of an Antarctic Station.
IOS - Institute of Oceanographic Sciences.	Would favour an Antarctic Station and believe that Argentian has offered collaboration and also talked to West Germany on this.
IMCO - International Marine Consultative Organisation.	IMCO are not active in remote sensing because this has not yet been required of them by the member states. If requested, they could forward international satellite marine remote sensing activities.
Rutherford/Appleton Laboratory of SERC - Science and Engineering Research Council.	Have considerable interest and activity in microwave instrumentation. - Are developing an airborne radar altimeter (RALT) for SPRI for the MIZEX programme. - Participating with France in the development of RALT for SPOT follow-ons.

	- Considering RALT in relation to the University of Surrey. Low-cost satellites.
	- Considering collaboration with India on microwave instrumentation.
	- They work with the Met-Office on upper atmosphere instrumentation, and have a specialist team working in instrument accomodation problems.
	They are involved with the European pressure group for improved and comprehensive satellite altimetry. Are interested also in IR sea-surface temperature instruments.
British Aerospace, Filton	- Working towards participation in RALT on ERS. Also interest in PAM.
British Aerospace, Stevenage	- Working with SPAR to study the modification of LSat as a platform for the Radarsat mission.
GEC-Marconi Electronics	- Extensive experience in SAR processing. Main ambition to become prime on AMI for ERS and manufacture some spaceborne and ground hardware. Also strong interest in image processing.

SUMMARY OF U.K. INTERESTS

- A strong interest in archiveable ocean/met. data both globably and for UK-designated waters.
- A general interest in global ocean/met. real-time inputs into the World Weather Watch Network.
- Interest both in Arctic and Antarctic for long-term sea and ice data collection.
- Priority user interest is in scatterometer and altimeter instruments with possible supporting instrumentation like a satellite position fixing system and AMPS.
- Receipt of Radarsat data (including SAR) at a UK station developed for ERS-1.
- Participation in international programmes of integrated data collection, including the establishment of new read-out station.
- Supplying bus, some instruments

RADARSAT QUESTIONNAIRES

Summary of responses

1. Brief questionnaires on the preferred specifications for RADARSAT were sent on 21st December 1981 to 44 companies, institutions, government and university departments and other organisations which had previously responded to the British Aerospace survey of user requirements for ERS-1. By 1st February 1982 seventeen had responded positively (and one to say that it was not interested), either by completing the questionnaire or by supplying equivalent information : they are listed at Schedule I. A further distribution of questionnaires to parties thought by GTS to be potentially interested in RADARSAT had by the same date not drawn any responses.

2. Under the principal questionnaire heading of synthetic aperature radar applications, thirteen respondents indicated specific interest : the applications are listed at Schedule II, and there was evidence of overlapping as between a number of potential users. Geographical locations in which SAR could be used include the polar regions and sea areas (especially continental shelves and areas of offshore exploitation interest).

3. Few respondents specified a preferred frequency or wave band. C predominated over L.

4. There was general consistency in minimum resolution acceptability. Only one user was prepared to accept up to 100 m; most fell in the 25-50 m band. Two did not specify.

5. The question on polarisation evoked few responses. All of the five who responded preferred HH.

6. Of the seven respondents who expressed views on preferred incidence, six indicated 30-45^{o} and the seventh also did so for one application. 10-30^{o} was preferred only for soil slope measurements.

7. Preferred swath width was generally 50-100km, although three respondents were prepared to accept up to 200 km and five did not specify.

8. There was a surprising variety in expressed requirements for positional accuracy, reflecting possibly the detail or coarseness of the features being studied by each respondent. Two users stated an accuracy requirement of 20 m or less; one of less than one metre; and two of 1 km.

9. Likewise frequency of coverage required varied widely depending on the type of data collected and its use. Ocean wave and meteorological studies require up to four times daily coverage, while mapping and geological studies may need only once-only or very occasional data.

10. Among additional sensors there was a marked preference for a radar altimeter, followed by scatterometer and visible-infra red radiometer. Two respondents specifically indicated a use for a microwave pressure sounder. Schedule III lists some of the applications for this additional equipment. Noteworthy is that several respondents expressed a wish for duplication of readings by other instruments to enable checking and correction.

Schedule I

Organisations which responded positively to questionnaire

Scott Polar Research Institute, Cambridge
Institute of Hydrology, Wallingford
Macaulay Institute for Soil Research, Aberdeen
Hunting Technical Services Limited, Elstree
Hunting Surveys Limited, Elstree
Hunting Geology & Geophysics Limited, Elstree
Meteorological Office, Bracknell
British Antarctic Survey, Cambridge
Department of Energy (Petroleum Engineering Division), London
Scottish Development Department, Edinburgh
Marine Exploration Limited, Cowes
Department of Atmospheric Physics, Oxford
United Kingdom Atomic Energy Authority, Harwell
Texaco Overseas Tankship Limited, London
British Petroleum Limited, London
National Maritime Institute, Feltham

Schedule II

Applications indicated for synthetic aperture radar

Detection of soil surfaces and slopes and vegetation patterns for hydrological models;
Delineation of river flooding;
Wind-wave modelling;
Sea condition forecasting;
Detection of plankton blooms;
Peat, vegetation, forestry and land-use surveys;
Natural resource monitoring;
Ice-edge monitoring;
Wave-spectra monitoring;
Measurement of land ice-sheet extent and velocity;
Fifty-year wind and wave prediction;
Wave climate study for offshore structure design;
Mapping in bad-weather areas;
Geological interpretation for mineral and oil exploration;
Establishment of tanker routes in poorly-charted areas;
New tanker terminal location;
Pollution monitoring;
Sea traffic monitoring

Schedule III

Applications indicated for additional sensors

Sea ice roughness and concentration measurement;
Ice floe size distribution;
Digital terrain modelling;
Hydrological thematic mapping;
Ocean circulation studies;
Cloud imagery and moisture studies;
Urban monitoring;
Geoid studies