MSAT PHASE B

FINAL REPORT

MSAT

Government of Canada
Department of Communications

Gouvernement du Canada
Ministère des Communications

Canada

MSAT PHASE B

FINAL REPORT

Cat. No. Co22-77/1987E
ISBN 0-662-15301-4

FOREWORD

This report depicts the events and activities that occurred in the MSAT Program up to the end of Phase B which concluded March 31, 1985. Some of the principles contained herein may have been changed or modified by the publication date.

CONTENTS

INTRODUCTION

INTRODUCTION

Canada has been in the forefront of satellite communications for over 20 years. This medium of communications has been proven ideally suited for overcoming the country's distance and population dispersion problems.

Satellite systems implemented to date in Canada provide good quality point-to-point channels for the transfer of voice, data and video communications where transmission quality requirements and traffic volumes justify their cost. They are not, however, an economically viable means of providing end-user voice and data services comparable to those provided by the public switched telephone network (PSTN) and terrestrial mobile radio systems.

The Mobile Satellite (MSAT) system being developed by the Department of Communications (DOC) will resolve this problem. It will provide affordable mobile telephone and radio end-user services by incorporating the following cost-saving features:

- improved satellite technology that will result in efficient use of power, leading to longer satellite life and capacity;
- transmission in the 800 MHz band or L-Band, which will allow the use of relatively inexpensive and compact end-user terminal equipment and antennas;
- a Demand Assigned Multiple Access (DAMA) feature that will permit flexible and efficient assignment of channels to end-users.

  With DAMA operation, channels are assigned only for the duration of a call and are then made available to serve other calls as required.

Despite the continuous expansion of fixed telephone services and the introduction of new and improved land-based mobile telephone and radio services, an estimated 250,000 Canadians still lack fixed telephone service and approximately 50,000 to 80,000 do not have much-needed mobile telephone and radio services.

MSAT is intended to meet this demand for basic communication facilities in rural and remote areas of Canada. Although the provision of mobile services has been the Program's main goal, some vital fixed services should, and in all probability will, be made available. It should be noted that MSAT service is intended to complement metropolitan terrestrial mobile services; not to compete with them.

Other vital services that will be satisfied by the MSAT system are data transfer from remote locations, digital monitoring of data collection sensors, remote control of industrial devices, nationwide paging services and possibly location finding.

Despite the sizable demand for MSAT services, a severe shortage of frequency spectrum in the 800 MHz band could limit the degree to which this demand can be met. Serious efforts are therefore underway to expand the MSAT capacity by sophisticated spectrum reuse techniques and by expansion into the 1.5 GHz band.

MSAT is a major program whose approval and execution must be carried out in sequential phases, and four such major phases have been defined. Phase A, designated the feasibility phase, was completed in 1982; because of its positive results, the government approved Phase B, known as the definition phase.

A major shift in Program emphasis has occurred during Phase B, which was originally expected to define a demonstration MSAT system to be funded and implemented by the federal government. Strong private-sector interest, in both Canada and the United States, for the provision of commercial services has prompted the government to support instead a commercial MSAT venture to be spearheaded by Telesat Canada.

This document provides a detailed account of the activities and results of Phase B, which was completed late in the 1984-1985 fiscal year, and outlines the planned activities that will lead up to the launch of a commercial MSAT system in late 1989 or early 1990.

CHAPTER 1

BACKGROUND

CHAPTER 1 - BACKGROUND

The goal of the DOC's MSAT Program is to assist Canadian industry in developing and establishing a first-generation commercial mobile-satellite system and service in Canada by 1990. Telesat Canada will implement a system to provide voice and data communications to vehicles, aircraft, ships and other portable stations located anywhere within the territorial boundaries of Canada. Beneficiaries of the improved communications offered by MSAT include most levels of government as well as a wide spectrum of private-sector users in such fields as resource exploration, forestry, fisheries, law enforcement, safety and emergency services, and transportation.

Although studies first demonstrated the need for and benefits of a national mobile-satellite system in the early 1970s, plans could not be developed until suitable radio frequency allocations were made. In 1979, the World Administrative Radio Conference (WARC) decided to allocate the 806-890 MHz band in the International Telecommunication Union (ITU) Region 2 to both terrestrial and satellite mobile services. The MSAT Program was initiated shortly thereafter with the following results.

- Concept feasibility studies (Phase A) were conducted from 1980-1982 to explore the use of satellites in improving mobile communications and to develop plans for a demonstration satellite project in co-operation with NASA.

- Program Definition Studies (Phase B) sponsored by the DOC were carried out by Canadian industry from 1982-1985 at a cost of $17.4M.

  They included a comprehensive examination of the MSAT market demand, commercial viability, socio-economic benefits, technology development, telecommunications policy, co-operative arrangements, spectrum co-ordination, institutional arrangements, plans for post-launch service trials and plans to implement a commercial mobile-satellite system for Canada.

- In November 1983, the DOC and NASA signed an arrangement for co-operation in the development of mobile-satellite systems for Canada and the United States.

Under this arrangement the DOC and NASA would assist commercial satellite operators in their respective countries to establish first-generation commercial mobile-satellite systems.

- In June 1984, the DOC and Telesat Canada signed a Memorandum of Understanding (MOU) concerning co-operation on the MSAT Program.

  Under this MOU, Telesat would undertake to establish a first-generation commercial MSAT system for Canada, in co-operation with the American mobile-satellite operator and with government financial support.

- The DOC issued Canada Gazette notices in May and June 1984 proposing the allocation of spectrum in Canada in the 806-890 MHz and L-bands for mobile-satellite services.

- In August 1984, the DOC published its telecommunications policy proposals concerning mobile-satellite services for Canada.

- In response to strong commercial interest and a NASA petition for a ruling, the U.S. Federal Communications Commission (FCC) issued, in January 1985, a Notice of Proposal Rulemaking (NPRM) concerning mobile-satellite services and a Call for Applications to provide these services.

  This is expected to lead to the selection of an American commercial operator who will develop business arrangements with Telesat Canada.

- In February 1985, NASA issued an Opportunity Notice to American industry offering to launch the first American mobile satellite in exchange for satellite capacity to conduct government experiments and service trials in the United States.

- Telesat Canada submitted to the Minister of Communications in February 1985 a proposal to establish a commercial MSAT system for Canada.

- In March 1985, the DOC announced federal government support in principle to industry for the implementation of an MSAT system for Canada by 1990.

- In May 1986, the DOC announced final Cabinet approval of a funding package that will lead to the implementation of a commercial MSAT system.

CHAPTER 2

OBJECTIVES

CHAPTER 2 - OBJECTIVES

MSAT PROGRAM

The primary strategic objective of the Program is to promote the development of new and improved telecommunications in Canada, and particularly to satisfy urgent national needs for improved public and government mobile communications in underserved areas.

A further objective is to support the private sector in the development of Canadian space systems technology and the required engineering skills and expertise in the Canadian labor force and manufacturing industry.

Of equal importance is to ensure that the limited spectrum frequency allocated to mobile communications for North America be shared with other nations on an equitable basis. To this end, bilateral actions and agreements are planned with the United States and possibly Mexico.

A final program goal is to have telecommunications policies that will encourage the development of the Canadian communications service and manufacturing industries' ability to respond to national needs and international market opportunities.

PHASE B

The main purpose of Phase B was to minimize or eliminate the technical, commercial and administrative risks involved in the development of the MSAT Program, as well as to identify and evaluate its benefits. In effect, the government invested approximately $20M to ensure that the $200M-$300M implementation investment would be justified. This, of course, is standard practice for all major projects in both the public and private sectors.

The government absorbed the complete cost of Phase B because under the original program direction, government was to be the main investor and owner of the demonstration MSAT system. The private sector's subsequent expression of interest in eliminating the demonstration system and moving directly to a commercially funded and owned system was in line with the strategic objectives defined for the Program at the outset. In fact, the private-sector interest in a commercial system is proof that the original targets set for Phase B have not only been met, but exceeded, in that the Phase B results eliminated the need for the intermediate step of a demonstration system.

This change in program direction did not significantly affect or alter the original objectives, although it did increase the strategic importance of the market and economic viability studies. The tasks associated with the objectives were carried out and concluded as originally defined but with an increased emphasis on issues relating to commercial viability.

The Phase B objectives and associated tasks are listed and discussed below.

Main objectives of Phase B

The following objectives reflect the four primary areas of investigation required to determine the MSAT Program's viability and define its parameters.

(a) **System and service definition**

The system definition objective was to investigate alternatives for both the space and ground segments, to carry out the necessary exploratory development of critical components and subsystems, and to arrive at commercially viable implementation proposals.

The service definition objective was to establish a broad dialogue with end-users and service-providers and, through this dialogue, to arrive at and define "user-friendly" service packages that could be implemented within the constraints of proposed system architectures.

(b) **Market definition and development**

The market definition objective was to estimate the potential MSAT market.

The market development objective was to enhance the MSAT marketability and to stimulate an early commercial demand.

(c) **Economic viability and benefit evaluation**

The economic viability objective was to assess whether an MSAT system would be a commercially viable venture for the telecommunications service industry.

The benefit evaluation objective was to assess the tangible benefits for the entire country as well as for distinct economic sectors.

(d) **Telecommunications policy: spectrum management and institutional arrangements**

The spectrum management objective was to ensure that the appropriate allocations existed in both Canada and the United States, given that the current allocations in the 800 MHz band did not contain a specific allocation for satellite services.

The institutional arrangements objective was to propose and establish an industry structure and services policy that would be supportive of the development of flexible and effective MSAT services and products.

Main tasks arising from the Phase B objectives

The following main tasks were carried out in support of the Phase B objectives.

System definition

- Spacecraft and antenna studies and selection
- Ground terminal and antenna prototype development
- Ground station and antenna prototype development
- Overall system control and network management exploratory development

Service definition

- Establishment of working groups with service providers and major user organizations and associations
- Extensive technical public briefings across Canada

- Individual service application engineering sessions with interested users
- Close interaction with Telesat's systems engineering organization

Market definition and development

- Long-range market studies by independent consultants and major communications associations
- Establishment of actual user requirements through the service applications engineering sessions mentioned under "Service definition"
- Sponsorship of technical and market trials and demonstrations

Economic viability and benefit evaluation

- Assessment of the impact of MSAT on the telecommunications service industry
- Assessment of its impact on the telecommunications manufacturing industry
- Assessment of the commercial viability of MSAT services, particularly with regard to the satellite owner and operator (Telesat)
- Assessment of the social and economic benefits to be derived through the use of MSAT services
- Assessment of the overall net benefits accruing to Canada as a result of the introduction of MSAT services and products

Spectrum management and co-ordination

- Provision of the required spectrum under the Canadian Table of Frequency Allocations
- Encouragement of similar American allocations and close contact with the FCC on all relevant spectrum issues and negotiation of the necessary bilateral agreements
- Organization of the necessary co-ordination under the Radio Regulations of the ITU, vis-à-vis the need for changes to the International Table of Frequency Allocations

Institutional arrangements

- Initiation of extensive preliminary dialogue with user and service industry sectors as well as with provincial and territorial governments regarding the institutional arrangements best suited to MSAT services
- Issuance of a preliminary discussion paper outlining the various options available and invitation for public comment
- Issuance of the departmental policy on institutional arrangements to govern the availability of MSAT services and products

CHAPTER 3

MSAT SYSTEM AND SERVICE DESCRIPTION

CHAPTER 3 - MSAT SYSTEM AND SERVICE DESCRIPTION

MSAT SYSTEM

General

In view of the strong interest that a number of American entities have expressed in providing mobile-satellite services in their country, Canadian plans have been adjusted to take into account potential co-operative arrangements between an American operator or operators and Telesat. Such co-operation would result in substantial mutual savings in non-recurring engineering and system procurement costs, although the Canadian and American systems would be independent and would provide services in their respective countries.

Mobile terminal access to MSAT will be via UHF or L-Band channels, as shown in Figure 1. Access to fixed-base stations will be via UHF/L-Band or SHF channels. The choice of channel type for base stations will be dictated by the size of the station and the amount of traffic handled. Since SHF channels require less power, the usage rates to be established will be lower than those for UHF/L-Band channels; however, the SHF antennas and terminal equipment will be more expensive. Therefore, users and service-providers will have to assess the optimum trade-offs.

Large multi-user base stations, gateways, and the common control station will communicate via SHF channels exclusively.

As shown in Figure 1, gateway base stations will provide the required interface between MSAT users of mobile telephone service and the PSTN.

The Central Control Station (CCS) will be the nerve centre of the entire MSAT system. It will perform all the functions required for the assignment of channels to terminals and base stations, the recording of calls for billing purposes, the overall management of the system and the required diagnostic and maintenance routines required in a public system of this complexity. It will be similar to a sophisticated telephone exchange capable of handling 50,000 to 100,000 subscribers. The CCS can be located anywhere in the country, although a central, southerly location would provide the best possible look-up angle to the satellite. Current plans call for the CCS location to also

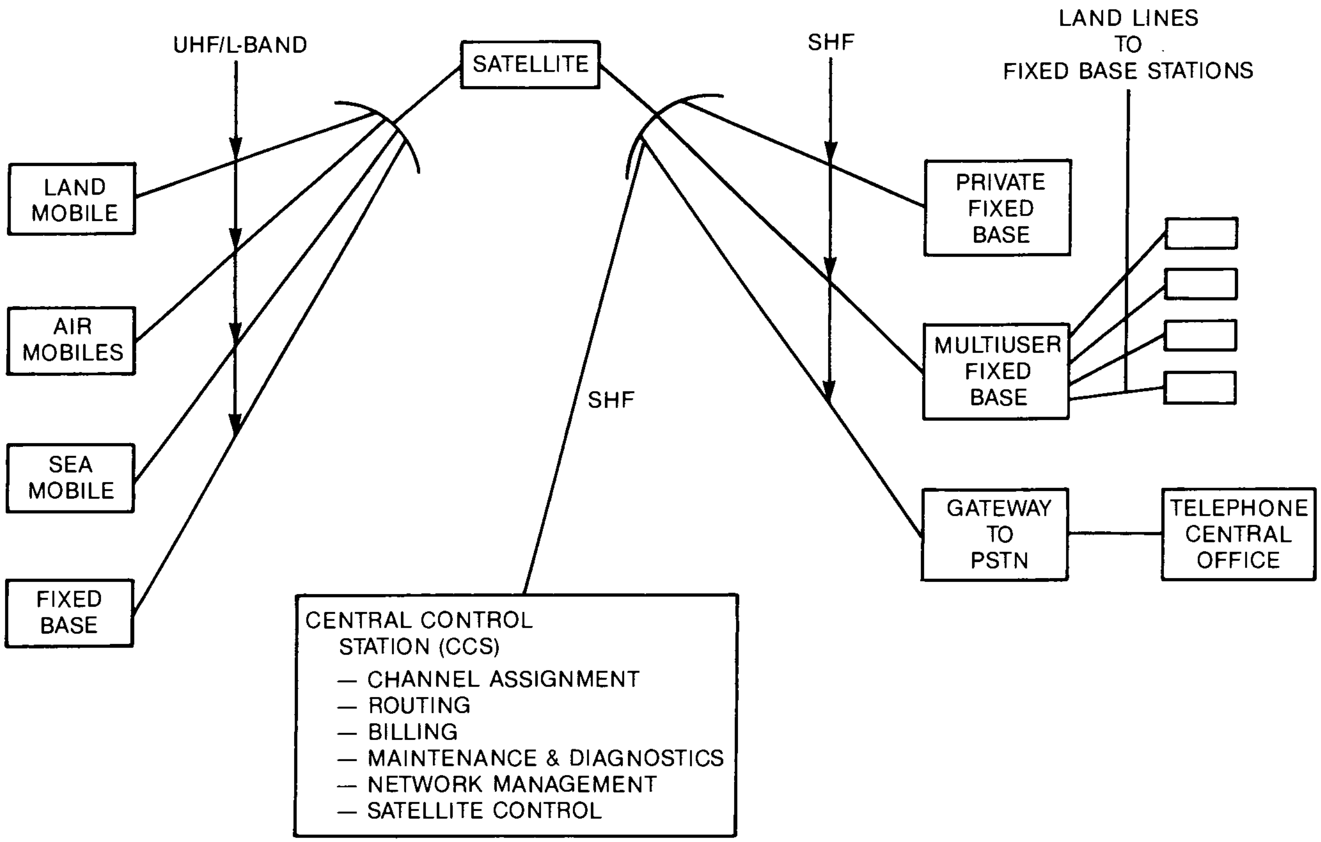


FIG. 1 MSAT SYSTEM ORGANIZATION

house the telemetry and other equipment required for tracking and controlling the satellite itself.

The various possible types of calls will use combinations of SHF-UHF/L-Band, SHF-SHF, and UHF/L-Band-UHF/L-Band channels. The basic call types will involve the following channel combinations:

. Mobile terminal-base station:	UHF/L-Band-SHF or UHF/L-Band-UHF/L-Band
. Mobile terminal-mobile terminal:	UHF/L-Band-UHF/L-Band
. Base station-base station:	SHF-SHF, SHF-UHF/L-Band or UHF/L-Band-UHF/L-Band
. Mobile terminal-gateway station:	UHF/L-Band-SHF

Spectrum utilization efficiency can be improved by means of frequency reuse through spatially isolated spot beams and/or by means of multiple orbit locations through the use of directive mobile terminal antennas.

The satellite coverage options currently under consideration for the first-generation MSAT system include a two-beam system covering Canada and the United States with a five-metre spacecraft antenna, as illustrated in Figure 2; and a four-beam system (illustrated in Figure 3) using a nine-metre spacecraft antenna, which allows for some degree of frequency reuse.

Due to the limited availability of spectrum, communications via MSAT will be established using narrow channels of five kHz each as compared with the wider 25 or 30 kHz channels adopted for the 800 MHz terrestrial cellular systems. Satellite channels will be assigned to specific users on a demand assignment basis, thus allowing the system to provide service to a large number of users on relatively few channels. The DAMA system represents the nerve centre of the MSAT communications system, assigning channels and recording airtime usage for billing purposes.

The speech modulation/coding techniques employed in the MSAT systems are constrained by the five kHz channel bandwidth. Two alternate schemes currently under consideration and development are Amplitude Companded Single Side Band (ACSSB) and Pitch Excited Linear Predictive Coding with Differential Minimum Shift Keying (PELPC/DMSK) transmission.

Figure 2: MSAT coverage - two beams

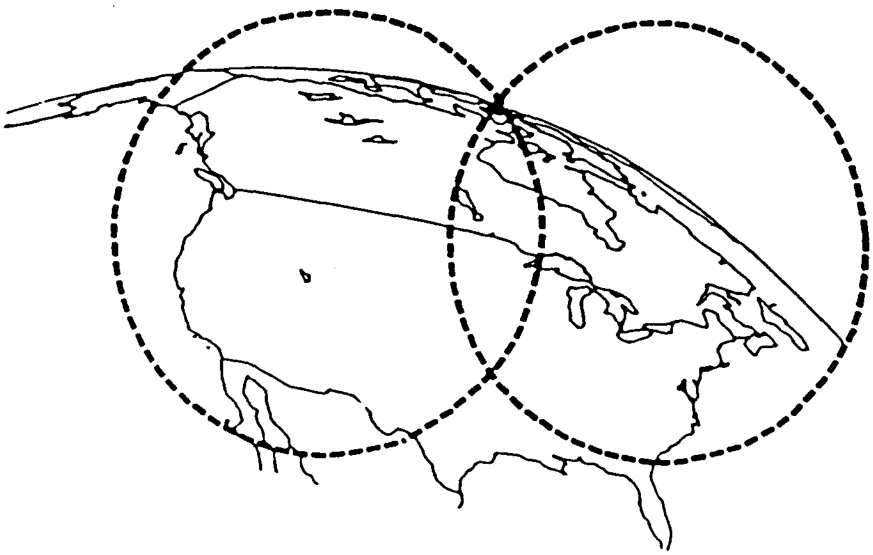
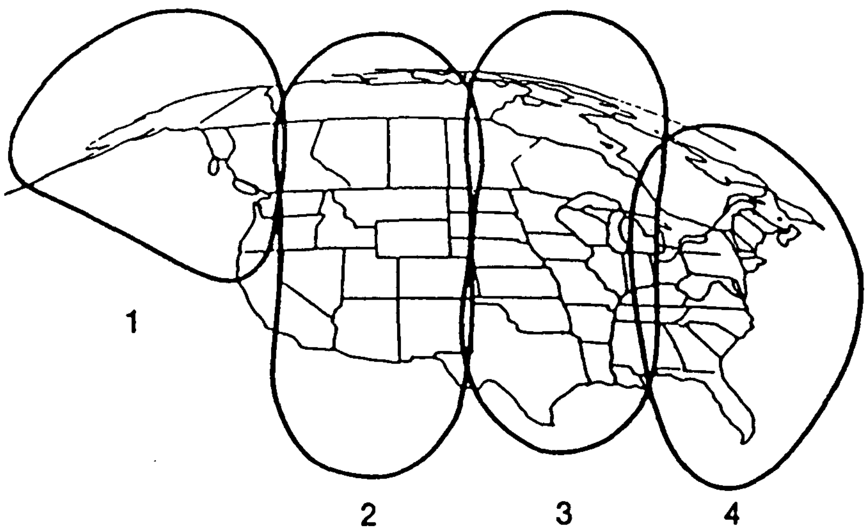


Figure 3: MSAT coverage - four beams

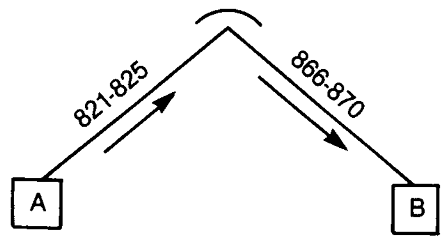


Channel assignment and organization

For the purposes of this discussion, the 800 MHz spectrum available for the Canadian part of mobile satellite services is assumed to be two MHz in the 821-825 MHz band for uplinks and two MHz in the 866-870 MHz band for downlinks, with the remaining two MHz allocated for use in the United States. Using five kHz channels, this allocation can yield a maximum of two sets of 400 links capable of carrying a nominal 400 simultaneous conversations. As shown in Figure 4, each channel provides one-way communication to and from the satellite (the uplink and downlink respectively). Hence, a connection between users A and B (Figure 4a) requires the use of two five kHz links. Since the two links used are omnidirectional, the arrangement in Figure 4a allows A to talk to B, but not the reverse (simplex connection). However, since these are radio channels assigned under the control of the system, their assignment can be changed instantly if required, allowing B to talk to A (Figure 4b). A or B can initiate this changeover either by activating the "push to talk" button on their terminals or simply by beginning to speak (voice activation). This mode of operation is defined as half-duplex; although it requires a certain degree of user awareness, it is the standard for all radio communications employed to date.

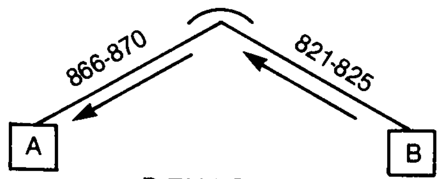
A full-duplex connection (that is, one in which both parties can talk simultaneously) requires one of the arrangements shown in Figures 4c and 4d, which use two sets of uplink and downlink channels. Since SHF channels require much less power and can be provided in relatively large numbers (due to a larger SHF frequency allocation), the latter connection is clearly much more efficient from the space segment (satellite and spectrum) point of view. Unfortunately, however, the use of SHF requires considerably higher sophistication and cost in both the user terminal and the antenna. This demands a user trade-off between airtime charges and terminal equipment costs that will have to be resolved on an application basis. Fortunately, this trade-off analysis will be limited only to the case where the user terminal B is a user base-station involved in dispatch or other functions which require that one side of the connection be fixed rather than mobile. Mobile SHF terminals are totally impractical due to the cost and size of the antenna required.

FIG. 4a



A TALKS TO B

FIG. 4b



B TALKS TO A

FIG. 4c

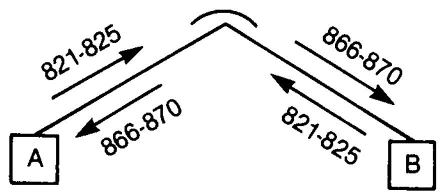


FIG. 4d

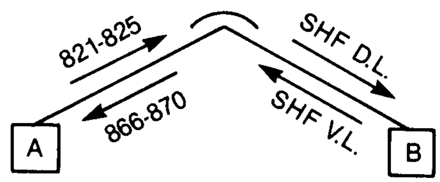


FIG. 4 MSAT TALKING PATH CONNECTIONS

The three basic connections discussed are used in different combinations within the MSAT system to derive all the possible interconnections required by all the services offered.

The two sets of 400 UHF links available must be further subdivided into smaller groups in accordance with the satellite coverage ultimately chosen. If the two-beam system of Figure 2 shown on page 22 is adopted, the channels would be split equally, allowing each beam to operate with two sets of 200 UHF channels. This split is essential to ensure that the same channel is not simultaneously assigned to two different conversations, one in each beam. Such an occurrence would result in interference since the beam signal overlap is not totally cut off, as indicated for simplicity in the diagram, but in fact fades gradually and can be received intelligibly over most of the adjacent beam. If the beam pattern of Figure 3 shown on page 23 is adopted, channels available in beam 1 can be repeated in beam 4, and potentially as close as beam 3 due to the physical separation involved. Under this arrangement, the reuse of channels would increase the theoretical effective capacity of the system by factors of 1.33 and 2, respectively. In practice, the effective capacity increase will be smaller, due to traffic inefficiencies and control complexities involved in multi-beam systems.

User terminal equipment

A variety of user terminal and antenna equipment will be needed in order to satisfy all requirements for mobile, portable, transportable and fixed user stations. In addition to the mobility factors, mobile user antennas are further affected by the type of mobile application they are to serve; such as land, air or sea applications. Air and sea applications will typically require a higher degree of sophistication and cost, due to the special interference problems inherent in these applications. In addition, the maritime application faces unique antenna platform stabilization problems. Similarly, mobile antennas of higher sophistication will be required for applications in northern locations of the country where the look-up angle to the satellite will be very low and, as as result, the signal is subjected to appreciable terrestrial interference.

More detailed information on terminal equipment is provided in Appendices 1 and 5.

MSAT SERVICE

Introduction

The main applications for MSAT will be in rural and remote regions where wide-area coverage and extended range are essential. Examples can be found in the following areas: trucking, mineral exploration, forestry, law enforcement, coastal and inland shipping, aircraft communications, national paging, environmental sensing, remote monitoring and control of utilities, and emergency relief.

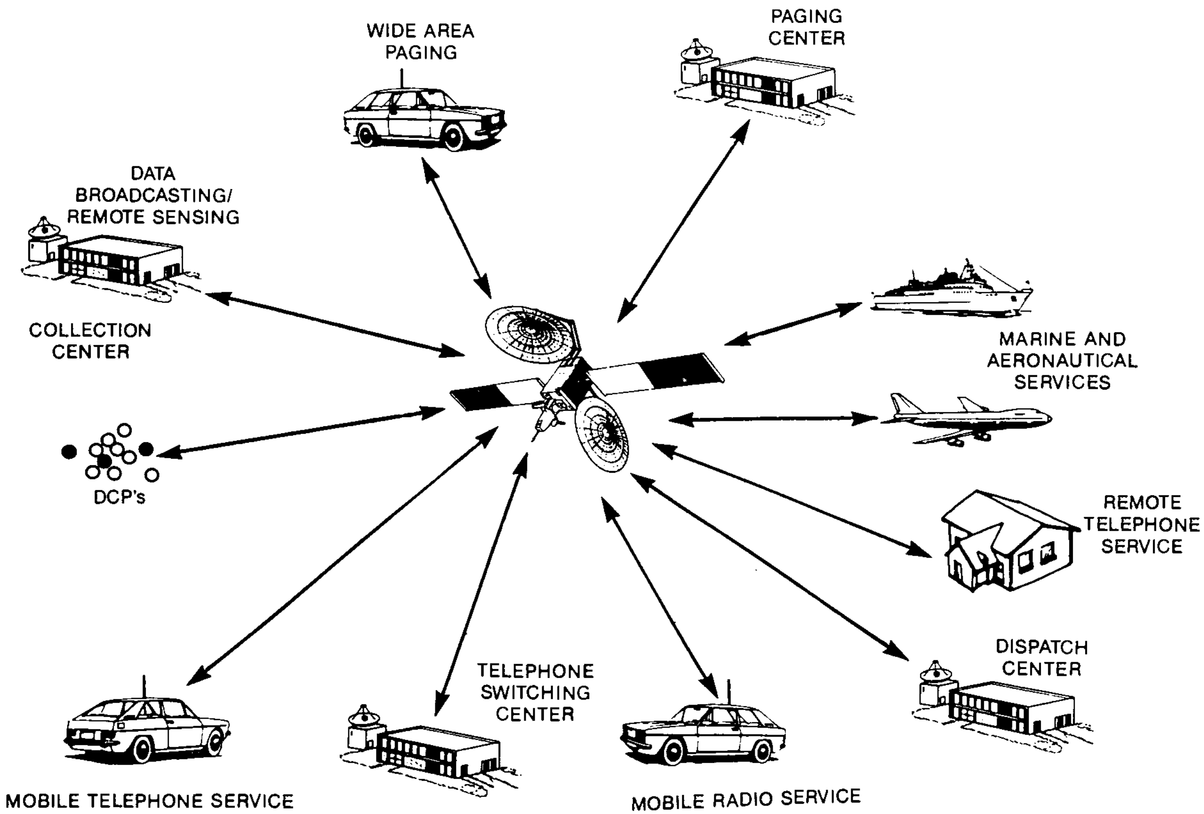
The services likely to be offered initially on MSAT include mobile radio, mobile telephone, wide-area paging, and data acquisition and control (DACS). Maritime and aeronautical services will be provided, as well as conventional telephone service to locations that, for technical and economic reasons, cannot be served by the fixed terrestrial and satellite infrastructures. Figure 5 illustrates the variety of services. It is anticipated, however, that as the service evolves there will be a gradual movement away from voice and towards data communications. For many applications, data communication through text display terminals is just as effective as voice communication and offers the additional benefits of improved transmission efficiency and privacy.

The main services and capabilities planned presently are summarized in the following paragraphs.

Mobile radio service (MRS)

The MRS is basically a mobile dispatch service operating in the Demand Assignment Multiple Access (DAMA) mode. Although MRS serves organizations or groups of users each with its own limited business and social interests, MSAT subscribers will be able to communicate with any MRS terminal by choosing the appropriate "class of service" option. The MRS service will not normally be connected to the PSTN, although the base station can be attached or patched to the PSTN on an individual line-basis. Features such as group calling and selective calling will be offered and the service will be available in both half- and full-duplex modes.

Figure 5: MSAT service concept



Access to end-user base stations (headquarters) will be through either privately owned base-station terminal equipment or common-user base stations connected by land lines to user headquarter locations.

Mobile telephone service (MTS)

From a user's point of view, the MSAT MTS will be very similar to the cellular radio telephone services offered in North America, operating in the DAMA mode. MSAT mobile telephone service subscribers will communicate with each other directly through the satellite system, while interconnection to the PSTN will be accomplished via gateway stations whose number and location will be chosen to optimize land line charges and routing. In general, each gateway will be homing in on a predesignated telephone exchange in its vicinity. A number of custom calling features will be available and all communications will be full-duplex.

Data acquisition and control service (DACS)

DACS is designed for the collection of sensor information and the remote control of devices. It will offer both polled and event-triggered communications.

The majority of the anticipated applications are expected to require the polling mode with a predetermined polling cycle. The CCS will send periodic polling messages in accordance with a predetermined polling list residing in memory. Messages received will either be transmitted directly to a designated station or stored in memory for retransmission at a later time. Although polling operations will not employ the DAMA system, applications requiring random access of sensors and control devices as well as event-triggered messages from sensors or control devices will be completed using DAMA facilities.

Paging services (PS)

The MSAT paging service (PS) is a one-way service intended to serve pagers associated with mobile terminals. Paging messages will be delivered directly only if the user is in, or very close to, the MSAT-equipped vehicle. To ensure that messages are not lost when the recipient is away from the vehicle, two optional back-up arrangements will probably be offered. Paging operators may store messages in their facilities for retransmission, or mobile terminals equipped for paging may receive and store messages for subsequent retrieval by users. In all likelihood, paging services will be implemented using dedicated paging channels.

Data capability

The MSAT system will have a data transmission capability of up to 2.4 kbps with a bit error rate of 10^{-4} to 10^{-6} using suitable error correction techniques. Although data-only terminals will be provided for DACS and other applications, including digital-only dispatch, both MRS and MTS will be capable of handling alternate voice and data. Therefore, the MSAT system will have flexible data capabilities similar to those of the PSTN.

"Thread of life" fixed applications

Provision of MSAT services to fixed terminals is technically feasible. This kind of service is not, however, generally required and would, in fact, contradict the intended primary use of both the MSAT system and the spectrum allocated to it. There do exist, however, certain situations in which it is proposed to provide communications between fixed terminals if required. For example, users with more than one base station may require base-to-base communications in order to improve the efficiency of their mobile communications. Point-to-point data transmission in some remote areas also cannot be served economically except by this means. Finally, MSAT could be one of the systems available to satisfy the lack of telephone service experienced by a considerable number of Canadians.

Numbering schemes

Several numbering schemes will be employed to suit the various MSAT services. MTS will employ a standard North American numbering scheme. MRS will employ a numbering scheme composed of a "user identifier" followed by a "unit identifier." DACS will employ variations of the two-tier identifier scheme employed in MRS.

Class of service identifiers

The CCS software and hardware will be capable of handling a large number of class-of-service identifier marks to offer flexibility in implementing special service features (such as custom calling services) to define individual user community-of-interest bounds and to deal with priority and emergency services.

CHAPTER 4

PHASE B RESULTS

CHAPTER 4 - PHASE B RESULTS

GENERAL

This section discusses and analyses the results of the activities undertaken during the definition phase of the MSAT Program. The results are presented in four sections, to accord with the list of objectives given in Chapter 2.

- System and service definition
- Market definition and development
- Economic viability and benefit evaluation
- Telecommunications policy: spectrum management and institutional arrangements

For additional information, reference should be made to the relevant appendices. For detailed results of any particular area, the reader is directed to the appropriate references.

SYSTEM AND SERVICE DEFINITIONS

System

Although the space segment presents many technical challenges, most of the crucial research and development effort in the MSAT system was centred on meeting the stringent requirements for the ground equipment (ground segment). Among the foremost of these was the development of a mobile antenna that would provide the maximum possible gain, while being confined within extremely narrow limits for physical size, appearance, and cost. These criteria are essential in order to guarantee mobility and affordability at the end-user level.

The very limited UHF spectrum available for satellite communications made it necessary to investigate and refine sophisticated modulation and coding techniques that were in contradiction to the obvious requirement for simple and affordable end-user mobile terminals.

Because of spectrum constraints and the need to provide a country-wide service with unlimited user access, complex network management and control procedures and equipment were essential.

Clearly, a number of the ground segment design parameters could be relaxed if correspondingly higher demands were to be imposed on the space segment design. It was therefore necessary to analyze the spacecraft limitations at the outset.

Space-to-ground segment trade offs

Spectrum considerations

The shortage in available spectrum frequency could theoretically be accommodated by extensive reuse of the spectrum. This subject has received considerable attention in Phase B, leading to the following conclusions:

- the development of large deployable antennas, capable of supporting numerous spot beams, would entail an unreasonable technological and economic risk for the first-generation system;

- effective capacity improvements, possible through the use of multi-beam systems, would be much smaller than expected for most beam patterns considered.

Power considerations

Improvements in the quality of mobile communications can be achieved either by increasing the effective radiated power (ERP) of the satellite or by increasing the mobile antenna gain.

In the scenario of increased ERP, the added cost is essentially proportional to the end-of-life capacity of the system and is entirely borne by the satellite owner and operator at launch time.

In the increased mobile antenna gain scenario, the added cost is distributed over all end-users and its magnitude and timing are proportional to the number of users and the rate of market penetration.

For the market penetration profiles projected for Canada, it would appear that a marginal overall cost advantage would result from shifting the burden to the mobile antennas.

It was concluded, therefore, that no significant improvement on spectrum utilization can be obtained by increasing the sophistication of the space segment and that inexpensive high-gain satellite antennas are essential to the overall economic viability of the service.

Ground segment considerations

The stringent system and cost requirements of MSAT affect primarily the design of the mobile terminals and antennas and, to a lesser degree, the design of such common control elements as the CCS, gateways and multi-user base stations.

MSAT terminals

It was recognized early in the evolution of the MSAT system that use of some spectrum-efficient modulation techniques would be required. The Department of Communications thus embarked on a research program aimed at assessing the suitability and potential of ACSSB and PELPC/DMSK. In parallel, a Narrow Band Frequency Modulation (NBFM) terminal was also developed.

As the MSAT development program progressed, it became apparent that the NBFM terminals using 30 kHz of bandwidth would not be appropriate because of the spectrum shortages. Although an NBFM prototype had been developed and tested successfully, all efforts were concentrated on ACSSB and PELPC/DMSK. The elimination of NBFM terminals further complicated efforts to design a cellular-compatible mobile telephone terminal.

Both ACSSB and PELPC prototype terminals, using five-kHz bandwidth, were developed and tested with varying degrees of success.

The performance of the ACSSB prototype was inadequate; it has since undergone design and component changes to bring its performance within the original specifications.

The PELPC prototype provided adequate performance under ideal conditions. It requires certain improvements, presently underway, to make it compatible with the non-linear microphones prevalent in the PSTN and to reduce its sensitivity to background noise.

In general, the terminal prototype development demonstrated the basic feasibility of MSAT terminals within established performance and cost targets. Detailed listings of terminal types and projected costs are given in Appendix 1.

MSAT fixed and mobile antennas

The MSAT communications system requires a number of antenna types. In order to realize space segment power efficiencies, effective antenna gains of eight dBi or better are desirable; the minimum acceptable antenna gain is four dBi.

Antennas used for fixed and transportable terminals do not pose any problems since such antennas already exist with effective gains of 8-12dBi and are presently selling in the range of $300-$400. These antennas are typically directional and would be used for UHF base stations, for transportable terminals and for sensor and remote control applications.

Mobile omnidirectional vehicle antennas with a four dBi gain have been studied extensively in both Canada and the United States. A number of prototypes have been tested by the MSAT Program with generally satisfactory results. Their $300 to $400 cost is within the original target.

Mobile vehicle antennas with higher gain would require the use of tracking techniques. A number of mechanically tracking antennas have been investigated; although their cost is reasonable (in the area of $800), their physical appearance and size render them unsuitable for land vehicle mount. Research efforts are presently directed at electronically tracking antennas, which offer excellent physical characteristics and good performance. Typically, these antennas employ phased-array techniques. To date, however, the cost of such antennas is well outside the price target for a viable service offering and cost reduction efforts are underway in both Canada and the United States.

There is also a substantial demand for airborne and shipborne antennas. These antennas must conform to special and stringent standards and have been anticipated to cost substantially more than the types previously discussed. To date, a number of possibilities have been examined, but the development of practical antenna designs requires further effort.

Although the feasibility of all fixed and four-dBi gain mobile antennas was demonstrated adequately, considerable effort is still required for the development of eight-dBi gain antennas, as well as airborne and shipborne antennas. A high priority has been assigned to this activity in the 1985-1986 development budget for Phase C/D. Further details on antenna design activities and results are given in Appendix 1.

Central Control Station (CCS)

MSAT satellite station keeping and the communications control functions will be performed by the system's CCS. Specific functions assigned to this station are DAMA control, network management and maintenance.

Studies have verified the original assumption that centralization of these functions would lead to a more efficient and reliable system organization. Gateways, base stations and terminals are treated as peripherals with varying degrees of intelligence. The intelligence to be engineered into each peripheral is dependent on the type of interface with the central control.

There are few technological challenges associated with the design and implementation of the CCS, but extensive effort is required in the areas of system organization and programming. The magnitude of the task is comparable to that of large software-controlled digital telephone switches. Although the MSAT peripheral interfaces are well-defined, intricate handshake routines are required for request, completion and signalling.

During Phase B, the functional aspects of the CCS, such as the DAMA and network management functions, were defined in sufficient detail to obtain order-of-magnitude estimates of the development costs and development intervals required.

Equipment configurations were considered but not finalized. It appears that the hardware sophistication required will be similar to that of a DMS-100 telephone exchange; in fact, a modified DMS 100 would be one of the hardware options available. However, many new peripherals would have to be designed specially for the MSAT system. Software development is estimated to require approximately 75 person-years, over a period of at least three years.

It has been estimated that the total cost of the CCS would be in the vicinity of $15M.

Further details on the DAMA and network management definition activities are given in Appendix 2.

Gateways and multi-user base stations

Major exploratory development contracts were commissioned for the definition and cost evaluation of these base stations. Although they are technologically straightforward, it was important to arrive at cost-effective realizations due to the potentially large numbers that may be involved in a fully developed MSAT system. The original proposals met all the operational specifications but exceeded the commercial viability price targets.

Cost reductions arising from decreased but adequate duplication and the use of more cost-effective subsystems have led to revised models that could be manufactured within the upper limits of the original targets. Further refinements and simplifications will be pursued during Phase C/D. Study details are given in Appendix 1.

Space segment considerations

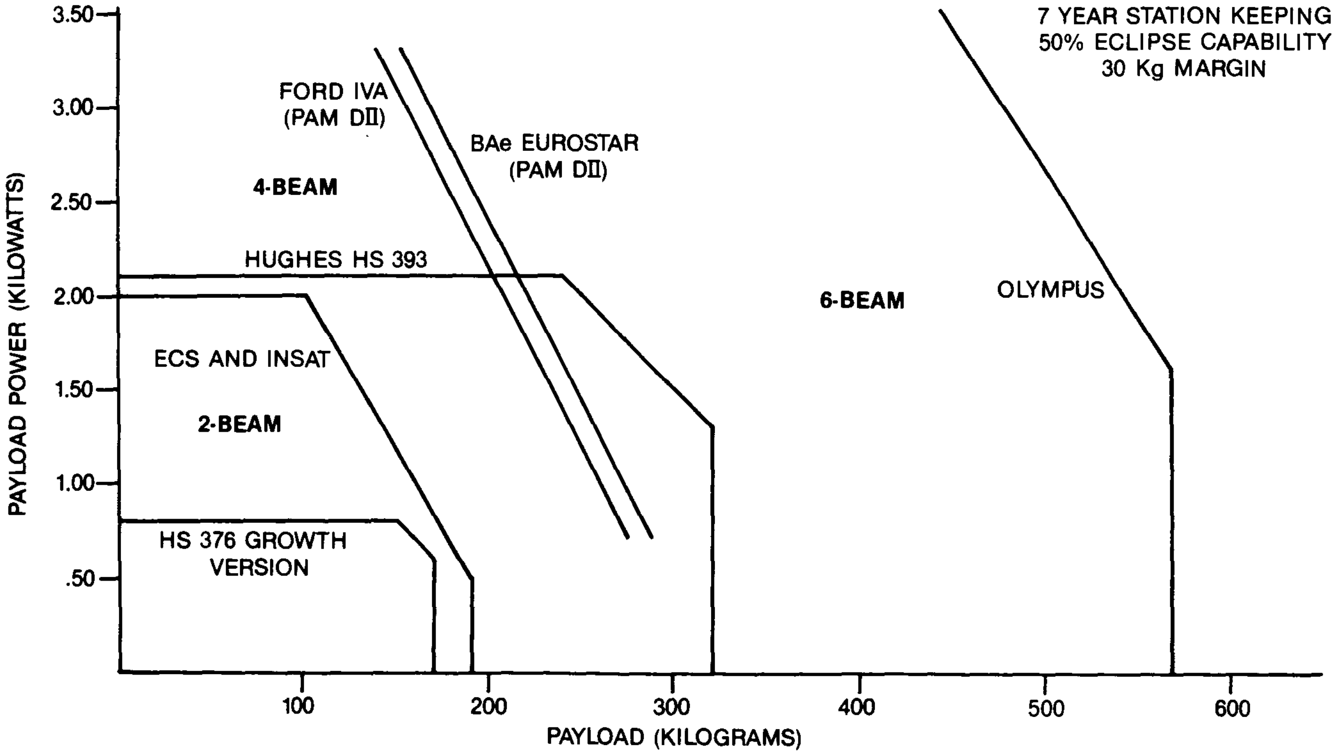
Spacecraft selection

A number of existing buses was investigated for several system sizes. For a two-beam system the Hughes HS-376, the BAe ECS and the Ford INSAT were considered. The Hughes HS-393, the BAe EUROSTAR and the Ford Intelsat IVA were evaluated for a four-beam system. The SPAR-BAe OLYMPUS (previously known as L-SAT) was considered for a six-beam system.

Figure 6 shows the results of the investigation under normalized traffic conditions.

It was concluded that an adequate bus selection exists for all the MSAT system configurations studied.

Figure 6: Capability of potential MSAT buses



Spacecraft antennas (reflectors)

The following are the four different candidate-deployable structures that have been investigated and found adaptable to the MSAT mission.

- The deployable truss structure built by Harris. It is a derivative of the design used in the TDRSS spacecraft. Its main attribute is a light compact assembly.

- The wrap-rib reflector built by Lockheed is the same concept as the one flown on the ATS-6 spacecraft. Mounting is at the centre hub only and edge mounting is precluded.

- The Convair reflector built by General Dynamics provides good structural rigidity but is relatively heavy.

- A new concept under development by the European Consortium of Aerospatiale and Thomson CSF is expected to offer good rigidity on a nine-metre diameter assembly engineered to MSAT requirements.

These reflectors are shown in Figure 7.

Payload

A number of critical payload subsystems were specified and preliminary development was carried out by SPAR. Development of these components was necessitated by the need for the MSAT satellite to perform special functions and the effort to keep payload weight to a minimum.

The following are some of the main subsystem prototypes developed and tested.

- High-power (100-watt) amplifiers of low weight were developed and tested successfully against the preliminary specifications. By satellite standards, these are large amplifiers not previously available.

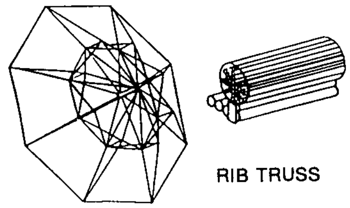
- Highly compact power converters were developed and tested successfully. These converters are required in conjunction with the high-power amplifiers and represent a major improvement over any power converter previously developed by SPAR.

Figure 7: Reflector alternatives

HARRIS

The deployable truss structure built by Harris is a derivative of the design used on the TDRSS spacecraft and provides for a light compact assembly.

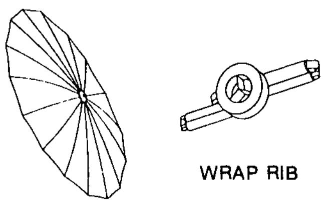
Deployment is controlled via a single hub-mounted electric motor with linkages to synchronize rib deployment. Mounting is at the centre or at the edge. Edge mounting requires either rib strengthening or additional truss members. The reflector mesh is knit of gold-plated molybdenum wire supported with graphite string.



RIB TRUSS

LOCKHEED

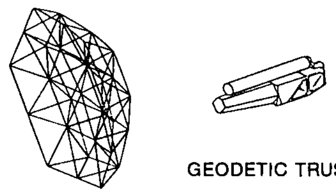
The wrap-rib reflector built by Lockheed is the same concept as that flown on the ATS-6 spacecraft. The graphite ribs bend radially around a central hub and the induced bending stress within the ribs provides the deployment force. As an option, a damping mechanism can be fitted to provide a controlled deployment. Mounting is at the centre hub only; edge mounting is precluded. The reflector mesh can be either gold-plated molybdenum knitted wire or a copper-plated dacron weave and is attached directly to the contoured ribs.



WRAP RIB

CONVAIR

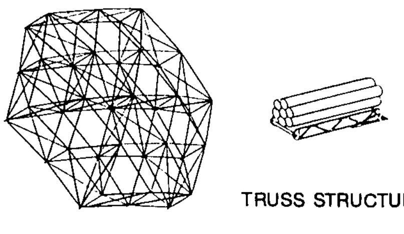
The Convair reflector built by General Dynamics comprises graphite tubes assembled to form a geodetic truss structure. Deployment is achieved by the use of steel carpenter springs at the centre of each inplane strut; damped controlled deployment is optional. The homogeneous nature of the structure allows mounting to any part of the reflector, centre or edge. The deployed structure is stiff but relatively heavy. Reflector mesh is knit of gold-plated molybdenum wire, supported with kevlar string.



GEODETIC TRUSS

AEROSPATIALE

This concept is being developed by a European consortium comprising Aerospatiale and Thomson CSF. The main structure is spring-deployed to form a multiple-truss assembly of graphite tubes. The nature of the structure allows either edge or centre mounting with good stiffness characteristics. Reflector mesh is knit of gold-plated molybdenum wire developed in France. The reflector assembly being developed is nine metres in diameter with performance based on specific MSAT requirements.



TRUSS STRUCTURE

- Special UHF components such as front-end amplifier/receivers, oscillators and feed networks had to be developed.

A number of other components and subsystems were also developed to provide the specialized functions required by the MSAT payload.

Service

General

It was recognized at the start of the definition phase that the long lead-period to the projected launch of a mobile satellite afforded an ideal opportunity to generate a meaningful, productive dialogue with potential end-users and service-providers. Scheduled for discussion were service definition, market demand and service regulation. Since a constructive approach to market demand projections and service regulation issues requires a well-defined service offering, most initial efforts were directed towards the selection and definition of services to be offered on MSAT.

Several distinct interfaces were defined and implemented to ensure maximum efficiency and optimum results.

Service-providers and large user entities such as governments and associations were invited to participate in formal working group sessions. Six major working groups were established between the DOC and the common carriers, the Canadian Radio Common Carriers Association (CRCCA), provincial governments, the federal government user departments, the Canadian Petroleum Association and Telesat, respectively. These groups held a series of one- to two-day working sessions throughout the definition phase and made important contributions in the definition of most service and market development areas. In addition, these sessions resulted in a clear understanding of the respective requirements and expectations of the participants, so essential to the development of the MSAT Program.

The user public was introduced to the MSAT Program at an early stage through numerous public briefings and seminars. Over 400 public- and private-sector organizations sent about 600 attendees to these briefings. Approximately 50 percent of these organizations subsequently expressed interest in various MSAT service offerings.

The interested organizations provided a large and diversified base for detailed service application discussions that led to an improved definition of services for the system. In addition, the attention paid to individual user needs reassured potential users of the intention of both the DOC and Telesat to arrive at user-friendly and cost-effective service offerings.

The Department worked extremely closely with Telesat throughout Phase B to ensure that end-user and service-provider requirements were properly interpreted and accounted for. This close interface served the dual purpose of catering to user needs and providing service, demand and cost information, vital to a proper commercial viability assessment by Telesat.

The following paragraphs highlight the main service considerations and parameters involved in the service definition area and the basic characteristics of the MSAT service offerings.

Service considerations and parameters

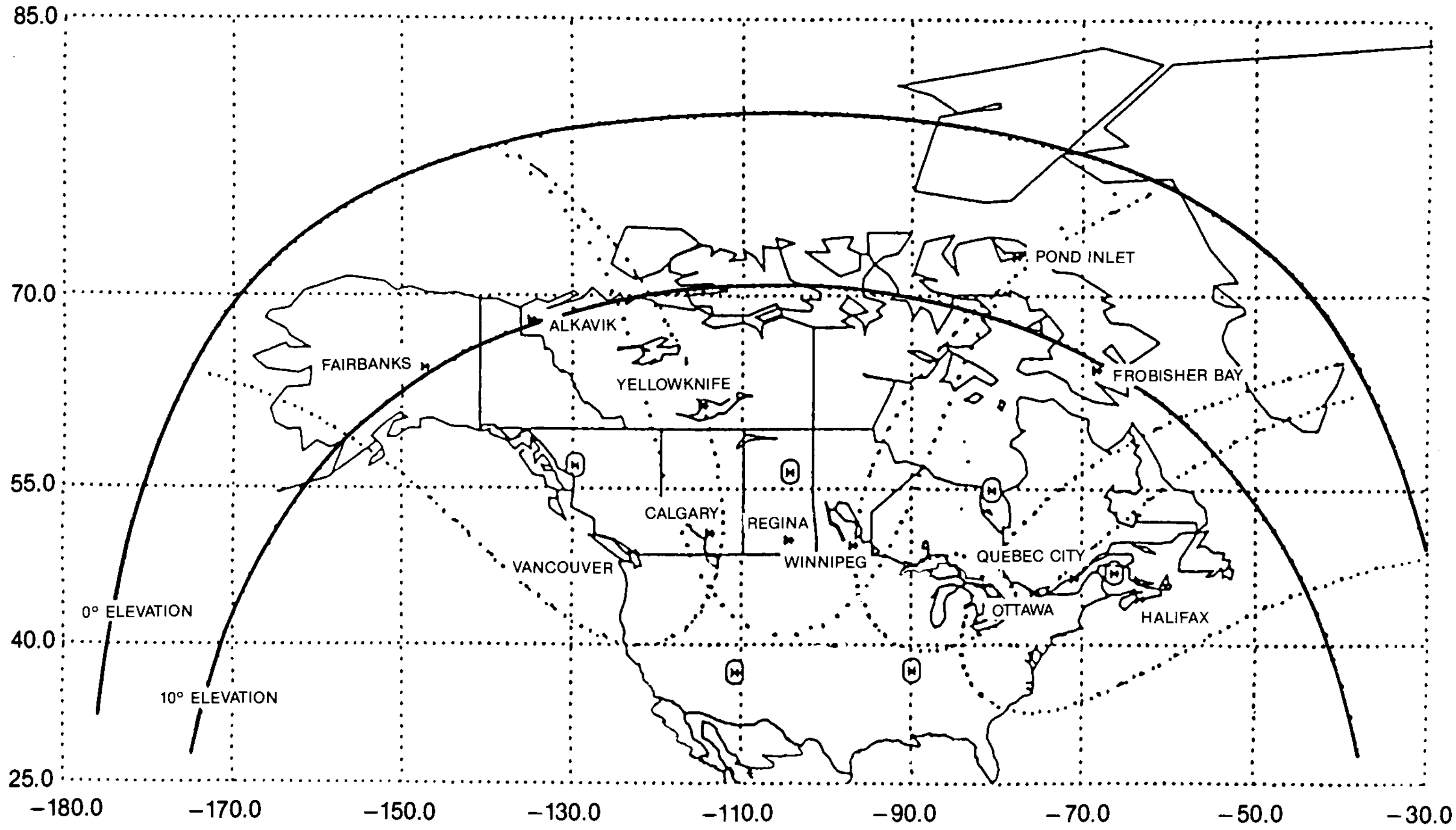
<u>Coverage</u>

The optimum coverage is dictated by the positioning of the satellite. Longitudinally, there exists some freedom in the placement, the only limiting factors being interference with other geostationary satellites and the use of slots presently assigned to Canada. However, the satellite would be in the equatorial plane, as are all geostationary satellites. Hence, the zero-elevation angle contour of the coverage, as seen from the ground, may be shifted along the east-west axis but its northern extreme is fixed at about 80° North latitude.

Figure 8 shows the 0° and 10° elevation angle contours for a satellite located at a longitude of 106.5° West. Although the actual contours shown have been computed on the basis of a four-beam Canadian coverage, the overall elevation contours are certainly not dependent on the beam configuration employed.

Reliable mobile communications become gradually more difficult to sustain as the satellite's angle of elevation decreases. To

Figure 8: MSAT coverage



predict system performance at various elevation angles, the DOC undertook an extensive simulation program using helicopters and the MARECS satellite.

The results of these simulations are listed in Appendix 4.

Basic service considerations

It was decided early in Phase B that the DAMA mode for channel assignment would be the main operating mode for the system. Various service considerations were examined that could affect the organization of the DAMA.

An initial question was whether all types of MSAT services could be provided using a common pool of randomly assigned channels or whether there would have to be preassignment of channels to some individual services.

After examination of the call processing procedures and protocols required for MRS, MTS and DACS, it was concluded that these three types of service would have to be assigned separate groups of channels. The mix of these types of service cannot possibly be predicted in advance with any reasonable degree of accuracy and will actually fluctuate on a daily and hourly basis during normal operation. It was therefore considered necessary to design the system to be capable of varying the number of channels assigned to each service on a fully dynamic basis, as dictated by the prevailing load requirements.

Consideration had also to be given to the need for a certain number of channels to be capable of being permanently assigned to a given user for indeterminate periods.

Mobile radio services, as opposed to telephone services, have been traditionally obtained through systems serving narrow community interests. In other words, most users have been served by privately owned or leased systems providing service to groups of stations. Often these groups of stations are operated for the sole benefit of one or more major customers. Interconnection of one such user group with another is infrequent. As this characteristic of mobile radio service is not likely to change appreciably with the introduction of MSAT services, the system must be capable of "private network" operation.

The private network mode of operation would be achieved in MSAT by preassigning a distinct number of channels to each major user and ensuring, through appropriate class marks, that these channels could not be accessed by other users unless authorized. The reverse mode of operation may or may not be necessary; that is, a private network customer may be allowed to access users served under the basic DAMA mode, if the appropriate subscription to the service has been arranged.

DACS involves a number of operational variations; thus it would have to be offered on a dedicated group of channels. It would also have to employ techniques such as polling, timed access and event-triggered access. This would require a considerable degree of channel allocation complexity.

Service parameters

A tentative set of service parameters has been defined in Phase B and is listed below by service category.

DAMA MRS:

- Two-way, half- or full-duplex voice and data communications
- Unlimited station access within the MSAT coverage
- Interface to fixed and other mobile networks (through special arrangements)
- Inherent data transmission capability up to a maximum rate of 2.4 kbits
- MSAT, MRS/standard-access protocol
- Transparency to data message formats and protocols
- Total RF channel bandwidth (including guardbands) of 5 kHz transmit and 5 kHz receive
- MSAT system standard grade of service (to be determined)

Private network - MRS:

- Two-way, half- or full-duplex voice and data communications
- Access limited to customer's own group of stations
- Interface to fixed and other mobile networks (through special arrangements)
- Inherent data transmission capability up to a maximum rate of 2.4 kbits
- User-defined network access protocol
- Transparency to data message formats and protocols used in customer's MRS network
- Total RF channel bandwidth (including guardbands) of 5 kHz transmit and 5 kHz receive
- User-controlled grade of service

Mobile telephone system (MTS):

- Two-way, full-duplex voice and data communications
- Unlimited access within MSAT coverage
- Unlimited interconnection to PSTN (contractual agreements required between each entity interconnecting and the appropriate telco)
- MSAT MTS standard-access protocol
- Transparency to data message formats and protocols; data rates of 2.4 kbits
- Total channel bandwidth (including guardbands) of 5 kHz transmit and 5 kHz receive
- MSAT system standard grade of service (to be determined)

DACS:

- Two-way data transmission capability
- Access to data processing stations
- Polled (interrogated), timed-access or event-triggered operations
- Data rates of up to 2.4 kbits
- Fixed-message formats
- Specialized sensors and terminals operating in digital mode

Service costs

Service costs cannot be defined positively until arrangements for commercial service have been finalized and the participating service providers apply for rate approval. However, target costs were set during Phase B and were used both as the basis for the viability and benefit studies and for allowing potential end-users to perform preliminary evaluations of the cost-effectiveness of the services. Although the list of projected costs is quite extensive (see Appendix 5), only a few key entries exist. These were originally defined as follows.

- Average retail price of mobile terminals and antennas: $4,500
- Monthly fixed network access charges: $25-50
- Airtime: $1.50-2.50/minute, depending on type of service

The final Phase B results indicate that these targets can be met and in some cases exceeded. Appendix 5, in addition to listing all price targets established, contains details on cost projections resulting from the relevant studies.

Service applications

The MSAT system and the communications services to be offered through it have evolved over a two-year period, primarily through a process of consultation with the user public.

This consultation took place as part of the activities of the Post Launch Communications Program (PLCP) and provided some major insights on service requirements.

For instance, though it was originally believed that the system would cater predominantly to voice communications and that data communications would be limited to one to three percent of the total, user response indicated a much larger data ratio. Moreover, users demonstrated great interest in a variety of data communications modes requiring short bursts of messages along with store-and-forward and polling techniques.

It became apparent that the MSAT system would have to be configured to perform as a combined voice and data switch. In addition, since the system is still at an early stage of evolution, many additional applications, requiring new service features, could conceivably emerge prior to the launch. For this reason, the MSAT CCS will include the latest software and hardware features and capabilities employed by the most sophisticated digital switches and will allow for relatively easy introduction of new service features.

The following user sectors expressed the greatest interest in the MSAT services:

- trucking,
- rail and bus transport,
- aviation and sea transport,
- oil industry,
- mining,
- oil and mining service industry,
- commodity handlers such as grain buyers,
- miscellaneous sales distributors,
- utilities such as hydros and pipelines,
- natural resource management such as forestry and fisheries,
- native groups,

- law enforcement agencies,
- municipal agencies such as school boards,
- governments, both federal and provincial (over 50 departments have expressed the need for approximately 150 different applications for MSAT services).

As expected, most applications come from rural and remote areas and underserved sectors where mobile and transportable communications are either extremely poor or non-existent.

From these applications has emerged an unexpectedly large number of entirely new and specialized applications for MSAT. Most are digital in nature and include monitoring of sensors for industrial control, point-of-sale terminals, oil well monitoring and inventory control. The potential in this category appears extensive and the requests received to date probably represent only a small sample of the total.

In addition to the unique nature of many of the applications, a high-cost elasticity is also exhibited: that is, the benefits received from the service -- improved productivity and sales, protection of life and property, or improved law enforcement -- would easily justify the MSAT equipment and service costs.

The number and variety of the applications proposed by users have exceeded original expectations and seem to suggest that the market penetration indicated elsewhere in this report may be quite conservative.

MARKET DEFINITION AND DEVELOPMENT

General

The definition of the potential MSAT market has proven both a difficult and crucial aspect of the overall program viability. Assessing the market potential of a new and novel service offering five years prior to its introduction poses some complex marketing and design problems; and yet a significant misinterpretation of the existing potential could prove to be catastrophic for the space segment provider due to the large initial investment involved.

During Phase B, the potential market for MSAT services was the subject of numerous formal studies (see Appendix 6). They have been supplemented by information generated by other Phase B studies and their results adjusted wherever necessary to account for direct user inputs and to provide a safety margin against the possible migration of users to other offerings that might be developed in the next five years.

The resulting baseline market forecast has been used as the basis for the commercial viability and benefit studies carried out during Phase B (Figures 11 and 12 on page 59); it is considered to be a conservative estimate that could be met or surpassed in actual practice. The following paragraphs highlight the market research carried out and the several factors taken into account in order to arrive at what has been defined as the baseline market forecast.

Market definition

Market analysis parameters

The MSAT market has been determined by defining two parameters: the number of terminals and the average monthly usage per terminal.

Many types of terminals and services are planned for MSAT, each with considerably different usage profiles. To facilitate market analysis, it was decided to express the MSAT market in "equivalent" mobile radio terminals operating in the voice mode with an average usage of 150 minutes per month. This approach provided a relatively simple market profile, although it is recognized that it does not give a true picture of the actual number of terminals and their mix. Most of the MSAT services are expected to have a lower monthly usage than MRS, for example, and the actual number of terminals in service will be generally higher than the "equivalent" terminals shown in the market penetration curves.

The likely MSAT share of the mobile market was assessed by considering such factors as the degree of need for MSAT services, the cost elasticity of these services, and the effect of competing technologies.

Market forecasts

The potential market

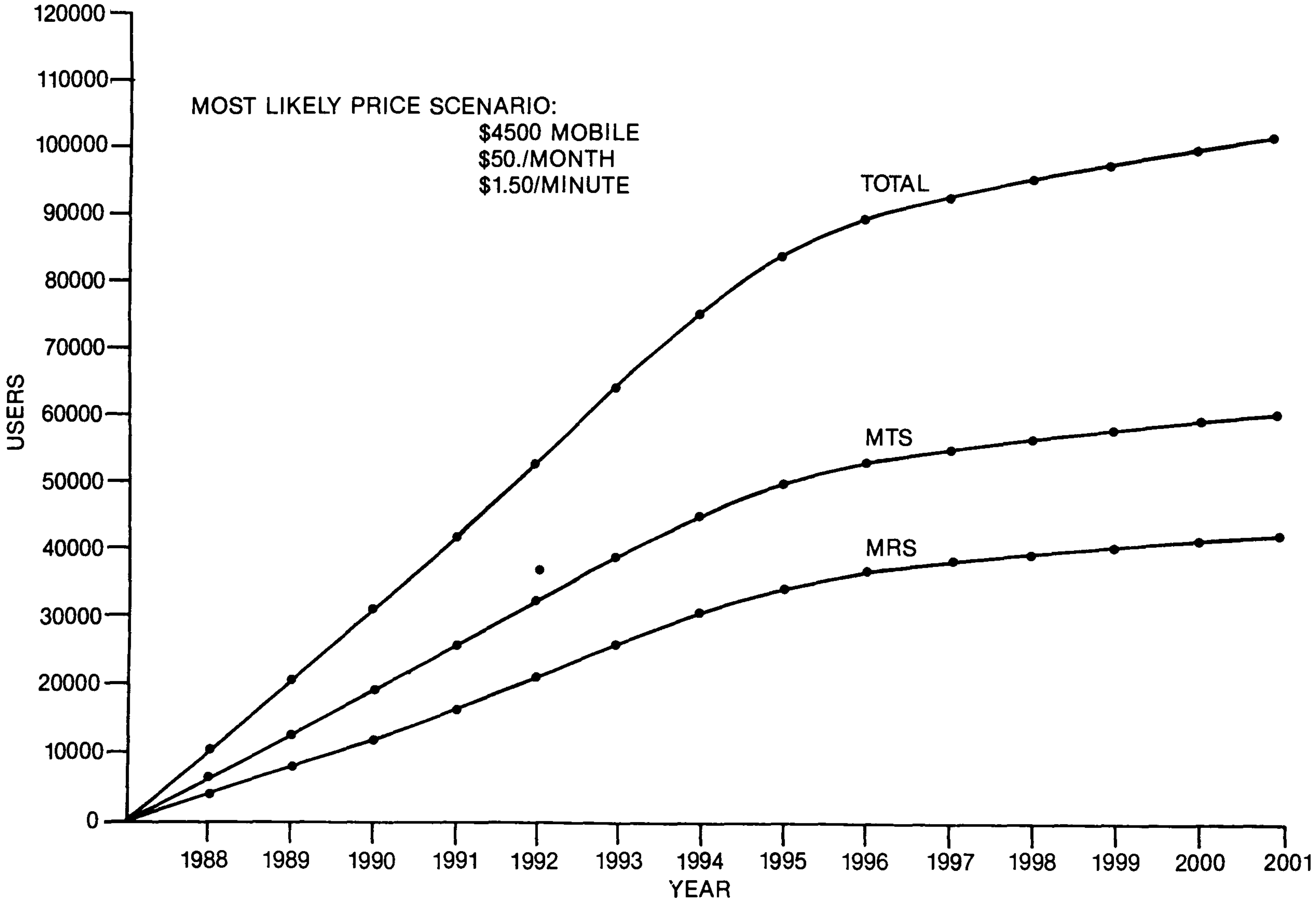
Woods Gordon produced their market forecast for MSAT services by first identifying the potential market and then carrying out a demand analysis to determine how much of the potential could be captured by MSAT. They estimated the number of mobile radio and mobile telephone units that would be in service between 1983 and 2001 by projecting the DOC's licence data covering the 10 preceding years. Projections were based on industry sectors divided on a regional basis. From just over 500,000 units existing in 1983, it was estimated that there would be over one million units by 2001. Removing those units operating in systems wholly confined to metropolitan areas left an MSAT potential market of 420,000 in 1983, growing to 920,000 by 2001.

The potential market identified by extrapolation from existing usage does not take into account suppressed demand or new applications made possible by MSAT. Woods Gordon conducted a separate analysis of this potential, including such services as wide-area paging, truck cargo monitoring and intercity dispatch, rural or remote telephone, and data collection platform readout. The total number of units identified ranged from a low estimate of 21,000 to a high of 70,000.

All these potential units would not, of course, become candidates for MSAT the day it was launched. The decision to transfer from existing facilities would be made in many instances when a mobile became obsolete or had failed and was to be replaced, or when additional units were required. On the basis of a seven-year average life span for a mobile unit, an estimated 95,000 mobiles would be candidates for conversion to MSAT in 1988.

After the initial surge, the annual growth of terminals would diminish in percentage, if not in actual numbers. Thus, by the end of the 1990s the growth rate would be of the order of 17,000 terminals per year to 100,000 terminals in the year 2001 (see Figure 9).

Figure 9: Woods Gordon market forecast



In addition to the overall MSAT market potential, Woods Gordon provided the results of their sensitivity survey indicating the percentage of the potential market captured if the services were to be priced under several pricing alternatives. The range of market penetrations obtained is shown in Figure 10.

The so-called baseline market curve was derived by using the pricing assumptions given in the "Service costs" section and by applying adjustment factors as required.

The degree of need for MSAT services

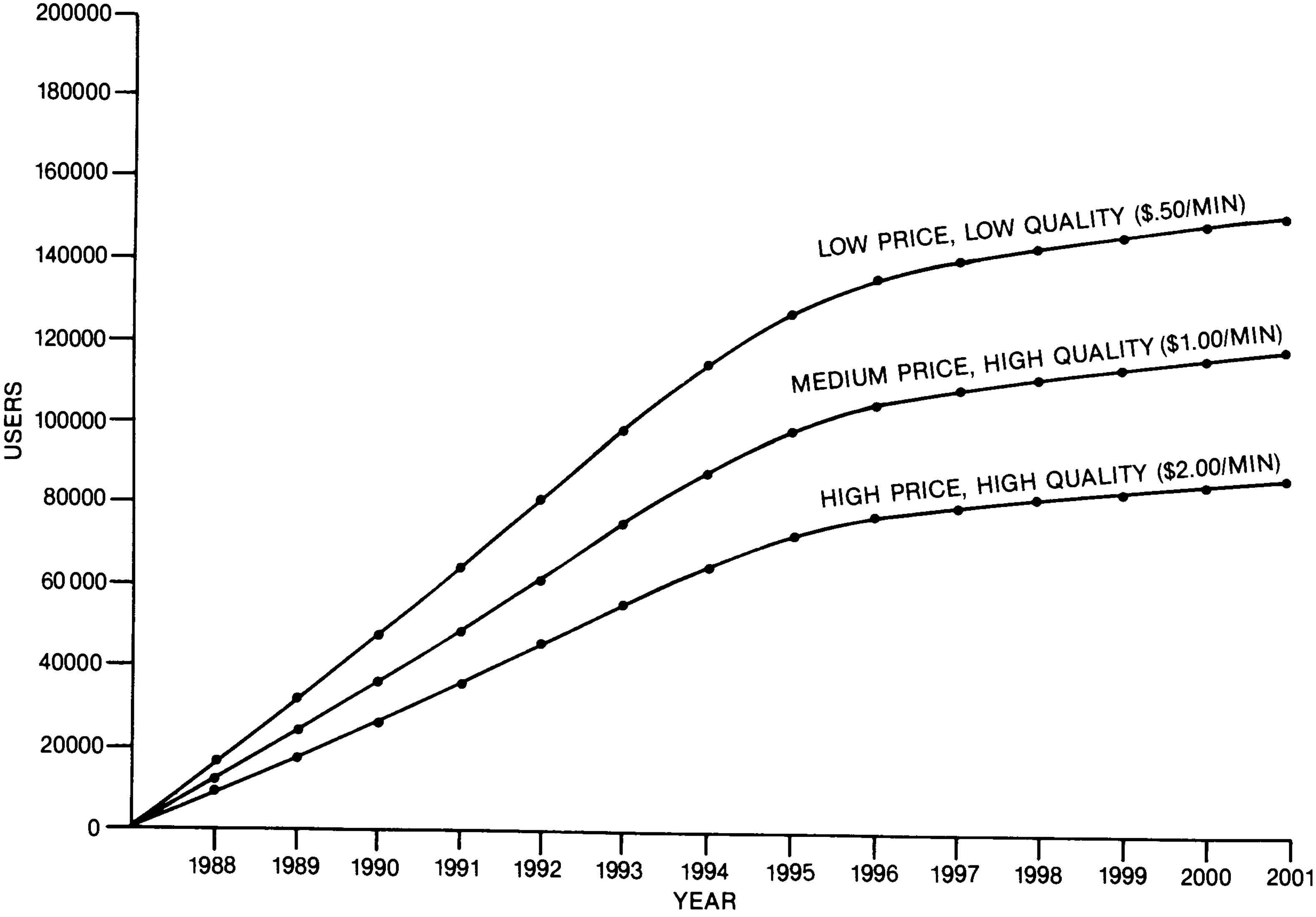
A user requirements study was done to investigate whether mobile communications users would benefit from some of the main attributes of a satellite system. These include wide-area coverage, country-wide accessibility, high reliability, and predictable performance. The study found that these attributes rated highly amongst potential users. The major technical limitation of present systems is inadequate range; typically a maximum of 80 km, reported by 49 percent of users. The second major problem relates to noise, interference, and distortion. Lack of interconnection with associated systems was another problem cited. Users needing mobile service in many remote areas noted the lack of coverage in large areas of Canada. Reliability has been stated to be a particular problem for users who must rely on HF radio systems.

Users also identified a number of new services that they would find useful: automatic vehicle location/identification, access to an emergency channel, data transmission, wide-area paging, data collection, facsimile, and teletype. Data transmission already is a growing service; 13 percent of mobile telephone users and 33 percent of mobile radio users now have that capability. A further 41 percent and 30 percent, respectively, indicated an interest in acquiring it.

Target market and pricing of existing services

The target market for MSAT services includes all users of mobile services who need to operate beyond the range of their base stations. This excludes users operating exclusively in metropolitan areas, but includes a small percentage of urban users who venture into surrounding rural areas or roam between cities.

Figure 10: MSAT market penetration vs. price and quality – Woods Gordon



In addition to the many land mobile users in rural and remote areas, the target market includes vessels in coastal waters up to the 200-mile limit and aircraft in various aeronautical applications.

Present mobile service is divided into two basic types: mobile radio and mobile telephone. MRS is generally of a dispatch nature, limited to operations between a base station and a mobile. In some cases the system is privately owned and operated; in others the base station services are leased from the radio common carriers (RCCs). MTS is interconnected to the PSTN and provides access to or from the telephone system. All the major telephone carriers offer either operator assisted or automatic MTS, although not all systems are compatible. Certain telephone companies also provide radio dispatch systems and dial-access private radio systems. With the advent of cellular mobile telephone service (CMTS), one government-selected non-telco, CANTEL Cellular Radio Group Inc., is authorized to provide interconnected MTS across Canada under certain licensing conditions.

The price structure and price ranges in today's mobile communication environment vary. Service charges range from $10.00 to $77.00 monthly for service and equipment rental. Airtime charges for mobile telephone service range from $0.25 to $0.75 per minute.

<u>New competing services and technologies</u>

Urban cellular MTS has been implemented in the major Canadian metropolitan areas by both the telephone companies and CANTEL, the latter licensed by the DOC as a non-wireline common carrier. Service was introduced in Toronto, Montreal, and Vancouver in July, 1985, and will be provided in some 20 metropolitan centres within the next three years.

Major expansion of MTS to provide coverage of rural areas is underway or planned by some telephone companies. Present coverage varies considerably across the country. Parts of the Atlantic provinces appear to be well served. Major expansion is underway or planned in Alberta, British Columbia, and Saskatchewan. Alberta coverage is most complete; Alberta Government Telephones has over 50 percent of the total mobile telephone subscribers in Canada. Only the Manitoba, Ontario, and Quebec telephone companies do not appear to have any major expansion plans for additional rural coverage.

Other technologies competitive to MSAT include International Marine Satellite (INMARSAT), Prosat, Stationary High Altitude Relay Platform (SHARP), fixed satellite thin route service, Radio Automatic Channel Evaluation (RACE), HF low-cost data terminal and Personal Radio Communications Systems (PRCS). INMARSAT and Prosat services could compete with MSAT in coastal waters and possibly in aeronautical applications. However, as service costs at the time MSAT comes into service could be considerably higher than that projected for MSAT, minimal impact is expected.

SHARP is a unique technology competitive to MSAT based on aircraft carrying transponders at an altitude of 21 km and therefore capable of providing wide-area mobile communication coverage. The aircraft would be powered by a high-energy microwave beam transmitted from a ground control station, or by solar cells and on-board batteries. However, the concept is currently at a very early research stage, and technical feasibility has not yet been demonstrated. Since many SHARP aircraft would be necessary to cover Canada, cost effectiveness compared to satellite service also remains unproven. This system would probably not be capable of offering ubiquitous coverage over the Canadian land mass and coastal waters.

Fixed satellite thin-route service, such as that offered by the Spacetel, Skyswitch, or Sparcom terminals, is an alternative to any fixed-service application of MSAT where traffic and data rate warrant it. However, for low-traffic, low-data-rate fixed services, MSAT is expected to be more cost-effective because of the much lower projected cost of earth stations.

RACE and HF low-cost data are HF dependent and reliability is in question due to aurora borealis effects.

The PRCS target is the consumer market, with the general public as end-users. Coverage area is very restricted. As PRCS serves a different market to that of MSAT, this technology should have little or no impact on MSAT market demand, other than perhaps to stimulate demand for the more extensive mobile service and coverage offered by MSAT.

Final market profiles

After modifying the Woods Gordon results to allow for the effect of the factors discussed above, the final market penetration projections for equivalent terminals and total airtime were developed as shown in Figures 11 and 12 respectively.

These projections, referred to as the baseline market forecasts, were used widely as the basis for the Telesat commercial viability study, the various benefit studies and the commercial proposal submitted by Telesat.

Further details on market-related studies are contained in Appendix 6.

Market development

One major objective of Phase B has been the development of a broad market base sufficient to support a commercial MSAT service offering.

To this end, the DOC initiated a major program known as the PLCP. It was originally designed to offer trial service to interested users, for a limited period of time, using the government-owned demonstration system, followed by interim service until such time as the private sector made available a commercial MSAT system.

Soon after the inception of the Program, it was realized that the close contact developed with potential users offered an ideal opportunity to obtain first-hand data on projected usage that would supplement, and in many cases improve upon, the results of market studies. At the same time, customer requirements and comments on the proposed services resulted in the refinement of the originally proposed services and the introduction of new ones. Thus, the Program developed into a major tool for both market and service development.

During Phase B, the trend towards reduction of direct federal government involvement in such programs as MSAT led to the abandonment of the demonstration system concept in favor of a commercial system. The PLCP was retained and then assumed an

Figure 11: Adjusted MSAT market forecast

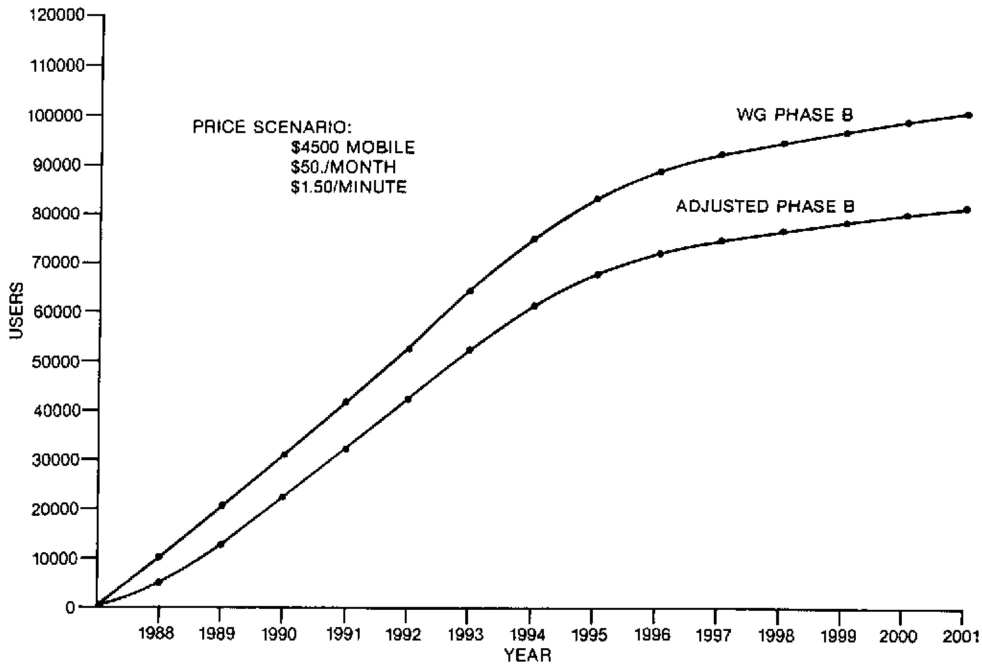
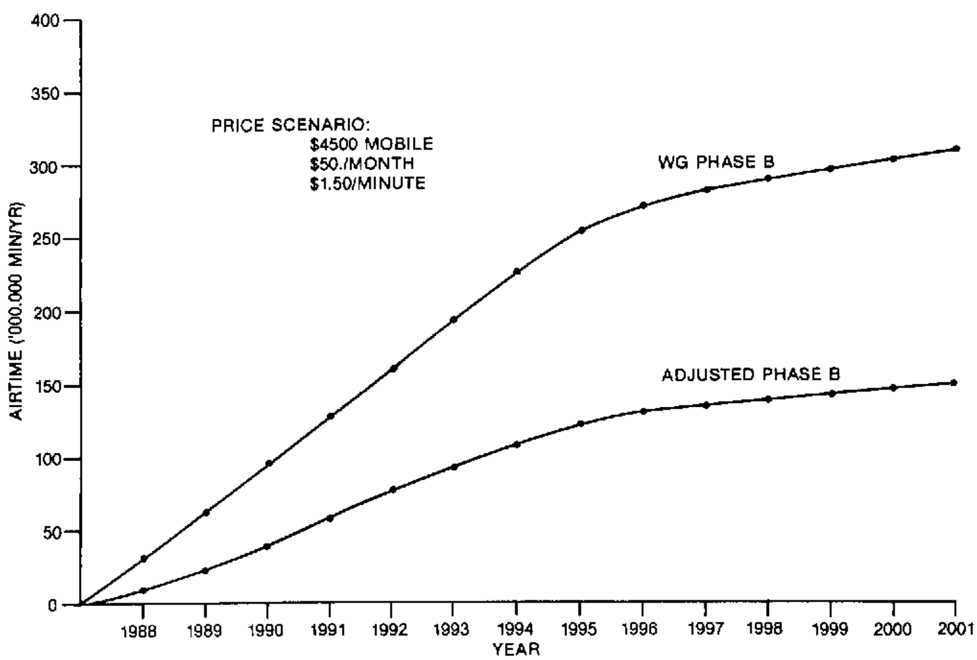


Figure 12: Adjusted MSAT airtime forecast



added importance in that the identified users became the most likely backbone clientele for the first-generation commercial system.

The highlights of market development through the PLCP and related activities follow.

Trials and experiments

The Department of Communications is sponsoring a program of trials and experiments available to help individual users, service-providers, manufacturers and government organizations assess the technical and economic viability of MSAT services in their operations. The detailed description and rules applying to the program have been published in a document entitled MSAT Users' Guide.

Under this program a user with a valid MSAT application could apply to the DOC for a limited amount of airtime and equipment to conduct operational tests for a specified period. The Department would contract and pay Telesat, as the space segment service provider, for the cost of airtime and would also pay the appropriate service-providers for the equipment leases. The user would, in return, cover the costs of carrying out the operational tests and viability assessment of the services.

The offer for the DOC-sponsored trials closed in August 1984; by that time 175 organizations had submitted proposals for trials on a large spectrum of MSAT applications. The total commercial demand of these applicants alone is projected at nearly 25,000 terminals of all types (see Appendix 6).

This represents a sizable market base, which will contribute greatly to the commercial success of MSAT. The Department of Communications intends to further promote this user base during the implementation phase of the MSAT program. The Department, in conjunction with Telesat and the users, will perform the detailed planning of the trials and the transition to commercial service. In so doing, the DOC expects to arrive at application refinements that will enhance the marketability of the MSAT services. Concurrently, efforts will be directed at promoting the use of MSAT to thousands of organizations that have not yet indicated interest but have needs similar to those of organizations approved for participation in the program of trials. Finally, it is hoped that Telesat will be successful in preselling MSAT services to a number of key user organizations and service-providers.

ECONOMIC VIABILITY AND BENEFIT EVALUATION

One main issue that had to be resolved, beyond a reasonable doubt, during Phase B was the overall viability of a commercial MSAT system and services and their impact on the Canadian public.

Numerous individual studies conducted for this purpose were aimed at collecting information in the following three areas.

- The economic viability of MSAT commercial services from the perspectives of the telecommunications companies that would provide the services and the manufacturers that would produce the required MSAT equipment.

- The value of the MSAT services to the user public, from an economic and service point of view.

- The overall value of the MSAT Program to Canada. The specific issue was whether the net benefits to be derived would justify the economic and human resources required by both the private sector and the government.

Commercial viability

To establish the commercial viability of MSAT, the following steps had to be executed.

- Estimation of market potential for the MSAT services and the way this potential would vary if the price to be paid was adjusted within a certain range (elasticity of the market).

- Estimation of the impact of MSAT on the manufacturing industry.

- Estimation of the impact of MSAT on the telecommunications service providers and, in particular, Telesat, which as the designated satellite owner and operator, would have to invest heavily in satellite procurement several years before the launch.

The studies intended to cover these commercial viability aspects were the market study by Woods Gordon, already discussed in the Market Forecast section, a manufacturing impact study by Woods Gordon, an impact study for the CRCCA by KVA Communications and Electronics Co., an opportunity assessment that the CRCCA conducted itself, and finally an overall commercial viability study conducted by Telesat. The results of these studies are summarized in Appendix 6.

The Telesat commercial viability study took into account the findings of the other studies mentioned above and developed a framework of economic and technical factors that would result in a commercially viable service offering. In general, the individual study results reinforced the preliminary findings of Phase A and showed that there is a strong market potential for the services, that radio common carriers will stand to make sizable revenue gains by marketing the services, and that the member companies of Telecom Canada would realize small incremental revenue gains (due to their large size) that would be sufficient, however, for them to enter into the marketing of MSAT services.

Telesat Canada combined the findings of the earlier studies with other inputs and arrived at an overall assessment, primarily from a satellite carrier's point of view, of the opportunity presented by the implementation of an MSAT system. It was concluded that such a project would represent a major long-range opportunity but that short-term cash flow would be negative for a number of years if the large initial investment was taken into account (between $250 and $300 million depending on the implementation option chosen). Telesat concluded that in order to be able to proceed with the project it would require financial support in the form of a repayable loan and/or outside investment in the form of equity.

User benefits

Establishing the benefits to be derived by the user public is an essential process for government-sponsored projects, particularly in the current Canadian economic climate. There are two ways of measuring such benefits. The formal method first establishes the individual benefits, such as increased efficiency through better communications, increased safety, more reliable communications, and direct savings in telecommunications costs.

Dollar values are then assigned to these benefits. The assignment of dollar values can be quite accurate in the case of direct cost savings, for instance, but can only be considered statistical in nature when dealing with such advantages as increased safety. The second way of assessing user benefits is by gauging the interest that potential users express in the proposed services. In the case of MSAT, both approaches were pursued and gave rise to some very positive results.

Wescom Communications undertook two formal studies assessing user benefits, entitled The Qualitative Description of the Social Impacts of MSAT and Study to Evaluate the Quantitative Social Impacts and Additional User Benefits of MSAT. These showed that the total combined user benefit will be in the order of $1.16 billion (see Appendix 6).

In addition, the DOC had the opportunity to assess the user mood towards MSAT services through the PLCP and through the working groups established between the DOC and such major users as federal government departments, provincial governments and major private-sector associations. As indicated by the overwhelming acceptance of the user trials and numerous letters of support received as a result of the public policy consultation process, the majority of these organizations saw important advantages in the areas of safety, medical emergency, increased efficiency of operations, improved communications and direct savings in their communications costs.

Impact on industry

Throughout Phase B, the DOC has been concerned with defining the MSAT system and services so that they would have a positive impact on industry. This became especially true with the reorientation of the Program to a commercially viable first-generation venture and the appointment of Telesat as the space segment service-provider.

This positive industry impact objective has been reflected in the numerous specialized technical and non-technical DOC contract studies in Phase B to measure the impact on the participants in the various sectors of industry: all common carriers and radio common carriers, Telesat, space and mobile manufacturers, and user industries. Studies were also done to estimate the benefits to investors. The impact on each relevant industry sector has been summarized in the appropriate part of this report with details given in Appendix 6. The overall impact is as follows:

- Notwithstanding market forecasting, regulatory and institutional concerns, the major Canadian common carriers perceive MSAT as having a positive impact on their operations in that it appears a viable economic undertaking and would require relatively little capital investment on their part.

- Radio common carriers would stand to benefit substantially from the provision of MSAT services assuming favorable treatment of institutional, regulatory, compatibility, competition and other concerns.

- Conditional on some initial assistance or preselling of services, given the large start-up capital investment required, Telesat perceives MSAT as a major business opportunity provided that a joint venture with a United States provider of mobile-satellite service is arranged.

- Assuming federal government assistance in defraying some of the costs of research and development, significant additional domestic and export sales revenues and business expansion could be realized for 31 Canadian manufacturers that have indicated interest in developing and producing MSAT component equipment.

- Considerable benefits relating to reduced costs, improved service and operating efficiency are expected to materialize in a number of major Canadian industries such as forestry, forest-fire fighting, coastal fisheries, emergency medical services, utilities, highways, mineral exploration and production, law enforcement and railways.

The general impact on Canadian industry could therefore be expected to be very favorable and the return to investors could be very significant. In conclusion, the program will be a highly desirable one for industry from all points of view.

The overall socio-economic analysis of MSAT

For this study, Econanalysis integrated the results of the various social and economic studies already discussed in terms of the following objectives.

The primary objective of the study was to measure, in a systematic and consistent fashion, MSAT's contribution to the net economic wellbeing of Canadians. The key issue was whether MSAT would be likely to use Canada's scarce resources efficiently. This was measured by the net present value (NPV) of its incremental net economic benefits discounted by the social discount rate. Only if this NPV was positive could MSAT claim to improve net economic wellbeing.[1]

A second objective was to measure MSAT's financial attractiveness to the private investors, namely Telesat, the service providers, and the manufacturers. The key issue from their perspective was whether the expected after-tax returns would be sufficient to offset their capital costs. This was measured by the NPV of their respective net cash flows. If these NPVs were positive without any government financial assistance, none should be required.

A third objective was to determine what financial assistance, if any, is justified on financial and economic grounds. As a rule, financial assistance to private investors is warranted only when the NPV of net economic benefits to the country is positive, but one or more of the NPVs of the net financial cash flows to private investors (Telesat, the service-providers, or the manufacturers) is negative.

The results of this analysis were very positive for the MSAT project as a whole, indicating NPV net benefits to the country of $1.16 billion and to the key MSAT investors of $146 million. Individually, it was concluded that Telesat's NPV would be

---

1. The calculation of an NPV and its use as an investment criterion are explained in Appendix 6.

positive at $32.8 million while that for service-providers and manufacturers would be $58.4 million and $54.6 million respectively. It was noted that although the Telesat NPV would be positive in the long run, making a federal government subsidy unnecessary, the initial high start-up satellite costs would result in a negative cash flow in the first few years; hence some form of repayable financial assistance would be warranted.

TELECOMMUNICATIONS POLICY: SPECTRUM MANAGEMENT AND INSTITUTIONAL ARRANGEMENTS

General

The absence of mobile satellite spectrum allocations and co-ordination has been a persistent major issue in MSAT Phase B. In fact, the availability of spectrum has been a preoccupation in the various Canadian mobile satellite programs primarily because both suitable frequency allocations for this new service and proper co-ordination of frequency use were needed. These requirements are dictated by domestic and international law to avoid interference with other systems.

Other concerns arose as a result of the spectrum requirements. In earlier Canadian mobile satellite planning, it was realized that if no spectrum were allocated to mobile satellites, technical systems planning could be jeopardized. The required changes to the table of allocations might never materialize because of objections to Canada's MSAT spectrum allocation and co-ordination proposals from other countries, particularly the United States. In such an event, resources devoted to planning would be wasted.

Changes in allocation of this magnitude, that is to accommodate an entirely new class of service, made to Canada's table without a corresponding change to the international table would have been essentially meaningless, because MSAT could cause interference problems over a large portion of the North American continent. The longstanding co-operative United States/Canada spectrum management processes spread over many other parts of the frequency spectrum could be jeopardized in such an instance.

As Canada's definition of MSAT proceeded in Phase B through internal DOC system design and program and policy analysis as well as through widespread consultation with industry and government, concern naturally arose as to the part that potential investors and others would have in making MSAT a reality. Canada's efforts to define institutional arrangements for the service opened up issues both in Canada and the United States as to the respective roles and requirements for the various participants. Fears similar to those about jeopardization of technical systems design investment began to be voiced about commitment of resources and money to particular institutional arrangements in the absence of successful spectrum arrangements.

The emergence of the limitations in spectrum and the difficulties in co-ordination produced a very important change in MSAT technical design. System designers and management began to look seriously at the use of only those technologies promoting optimized traffic-handling capability on each satellite mobile radio channel to be provided.

It proved not only a case of choosing existing spectrum-efficient technologies consistent with cost and therefore price to achieve this vital objective; also highlighted was the development of new technologies, such as modulation methods for mobile radio channels and mobile antennas for vehicle mounting.

The uncertainty about spectrum allocation and co-ordination remained at the end of Phase B, but the problem was becoming the subject of intensified discussion with the United States and the international telecommunications community to attempt to resolve some of the difficulties and speed up the entire process.

An extremely important conclusion was reached in Phase B: spectrum management has been shown to have an unavoidably powerful domino effect on the technical design, systems planning and institutional arangements for the system. It will have to be given the ongoing importance it deserves in program implementation during MSAT Phase C/D.

The details of both spectrum management and institutional arrangements matters are contained in Appendix 7.

MSAT spectrum management issues in Phase B

Apart from the DOC and Transport Canada organizational units responsible for spectrum allocation and co-ordination activities, the organizational groupings listed below, together with the MSAT Program Office, were actively involved in the MSAT spectrum allocation and co-ordination processes during Phase B:

- the federal government MSAT Planning and Implementation Committee (PIC),
- the DOC MSAT Policy Steering Committee,
- the DOC MSAT Spectrum Co-ordination Committee (SCC),
- the Canadian ITU/WARC Interdepartmental Committee (CIC),
- the DOC/FCC Technical Liaison Committee.

The work done by these committees in conjunction with the normal operations of the public service spectrum policy and implementation units is reflected in the following parts of this section. It provides relatively brief presentations of the MSAT spectrum allocation and co-ordination issues.

Spectrum allocation

As indicated above, the advent in the 1970s of mobile-satellite program planning has been primarily characterized by a lack of any specific international or domestic Canadian spectrum allocation; hence there were no official Canadian or international frequency listings in the respective tables of frequency allocations. Considerable Canadian spectrum policy effort was exerted in getting the UHF 800 MHz spectrum conditionally allocated to world frequency Region 2 through internal DOC public policy processes and the WARC '79 proceedings. The necessary changes were made to the Canadian and international table of frequency allocations. The next issue then became the need to co-ordinate the use of the spectrum in Region 2.

At the same time as the co-ordination of the mobile-satellite allocation at WARC '79 was getting under way in Phase B of the MSAT Program, the United States began to show an interest in mobile satellites. In more or less the same time frame, the Canadian plans changed substantially to provide for a commercial rather than a demonstration first-generation MSAT. Part of the Canadian planning included the concept of a joint Canada-United

States system. It was realized as a result that the UHF allocation would be insufficient for both Canadian and United States first-generation needs, not to mention any second-generation systems.

Late in Phase B, it also began to appear as if planned Canadian use of the very limited UHF spectrum available at 800 MHz for MSAT, even for a first-generation system, would be subject to long and arduous negotiations between the Canadian and American governments, with adverse input from the cellular and terrestrial mobile lobby in both countries. This lobby understandably did not want to lose its reserve UHF spectrum allocation to an untried system. The public safety lobby in the United States was also opposed to the use of the allocation on the grounds that it was wasteful and that there were other more vital communication needs yet to be filled.

By the end of Phase B, it had become apparent that there could conceivably be agreement on the use of this spectrum for a relatively small first-generation system, possibly a joint one between the United States and Canadian industry; it was, conversely, quite clear that, no matter how successful the discussions were, there would simply not be enough UHF spectrum for a second-generation system.

As a result, the search for more spectrum began again and because of both Canadian and American industry consensus, attention was directed elsewhere in the spectrum, namely to the L-band at 1.5 GHz. As in the case of the original UHF allocation, no broad mobile satellite class-of-service allocation existed and the long and difficult process of changing the international and domestic tables of frequency allocations had to put in hand once again. The primary vehicle planned for this exercise is the mobile WARC in 1987. Steps have been taken to have this matter on the agenda for that conference.

It is assumed that the new L-band allocation will be conditionally successful in 1987 as was the case with the UHF 800 MHz proposal at WARC '79. Co-ordination would in due course be required before the frequencies could be actually used for MSAT. As in the UHF case, there exists a lobby opposed to the allocation, that of the international aeronautical community, which for some considerable time has had its own plans for an aeronautical mobile-satellite system. Just as for the cellular and terrestrial mobile lobby in the UHF case, this L-band lobby does not want to lose any part of its allocation to land mobile-satellite service.

A further complication in the search for L-band spectrum for land mobile-satellite service lies in the speed with which the infant INMARSAT Organization has caught up with MSAT and the aeronautical mobile-satellite plans to initiate mobile-satellite services in order to bolster revenues. This represents yet another similar service searching for developed spectrum, albeit for a different segment of the market. INMARSAT's position is enhanced by its already being in L-band and successfully providing maritime mobile-satellite service worldwide with Canadian government and industry participation.

Clearly, considerable ongoing work is needed to ensure that sufficient spectrum will be available well in advance of the implementation date for the MSAT system. Intensive consultation must therefore continue if the various parties involved in the program are to have sufficient notice on which to base their major corporate decisions.

Spectrum co-ordination

MSAT spectrum co-ordination within Canada

In May and June 1984, the DOC released for public comment through the Canada Gazette specific Canadian sub-allocation spectrum policy proposals for L-band and UHF at 800 MHz respectively. These proposals resulted from the complex and detailed ongoing Canadian spectrum policy analysis process. This had taken into account the alteration to the Canadian table of frequency allocations after WARC '79 to allow for, amongst other things, the UHF co-primary allocation in reserve of the mobile class of service with that of mobile-satellite service at 800 MHz. In all, 23 different entities responded and provided valuable input to the spectrum policy process.

The Department of Communications is in the process of formulating a policy on MSAT spectrum to reflect not only the Canadian public perspective but also the co-operative spectrum-sharing arrangements. The FCC rulings on mobile-satellite systems will also be taken into account. It should be noted that the FCC is in the process of publicly evaluating mobile-satellite policy from the standpoints of spectrum policy, institutional arrangements and possible joint mobile-satellite operation between American and Canadian industry.

The international spectrum co-ordination for MSAT at 800 MHz

The basis for international co-ordination rests with the post-WARC '79 alteration of the international table of frequency allocations to take account of mobile satellite, as was the case with the Canadian sub-allocations to the spectrum allocated to mobile satellite through the revision of the corresponding Canadian table after WARC '79.

Canadian MSAT spectrum co-ordination with the ITU/ International Frequency Registration Board (IFRB) required major DOC effort to attempt to provide for the implementation of the WARC '79 decision, which required co-ordination between countries in world frequency Region 2 of any proposal to use the band for specific mobile satellite service. For MSAT, Canada initiated the co-ordination process under ITU Radio Regulation Article 14 with the ITU/IFRB early in Phase B.

Because MSAT was a satellite system, an additional level of co-ordination prescribed by the ITU radio regulations was also required, this time under Article 11, which is devoted exclusively to co-ordination of spectrum for any communications satellite planned.

The procedure in either case called for an Advance Publication of Information (API) to which is attached respective appendices containing prescribed data of differing levels of detail. The ITU publishes the documents worldwide and invites comments to the IFRB which in due course indicates if any country believes that the proposal may cause interference problems. Efforts are then directed to internationally resolving the difficulties enumerated.

In the case of the co-ordination under Article 11, Canada submitted an API to the IFRB in January 1983, together with the relevant appendix containing such data as was available at the time. The API was published in April 1983, and comments were received by June of that year. The USSR was the only country to register objection to Canada's proposal on the grounds of problems with the telemetry, tracking and control (TTAC) allocation Canada had proposed in L-band. Due to the evolving MSAT design configuration, a corrigendum to the API was sent to the IFRB in March, 1984.

The requisite API information on the general configuration together with some system detail was to have been sent to the IFRB in due course. At the end of Phase B this information was not available, primarily because Telesat did not have the necessary information to finalize MSAT configuration plans. This occurred because of the evolution of the Canadian plans including the dropping of the L-band TTAC requirement. Another factor was the need (for cost-effectiveness reasons) to enter into a co-operative arrangement with the corresponding mobile-satellite carrier(s) in the United States at a time when absolutely no decisions had been made about mobile-satellite service in that country. The regulatory process in the United States had not yet run its course in regard to that country's mobile-satellite spectrum allocations, the choice of mobile-satellite carrier(s) or even the actual system configuration. Hence at the end of Phase B, the Article 11 co-ordination with the IFRB was still in abeyance for reasons mainly beyond Canada's control.

The special co-ordination required under Article 14 covering the detailed information about the MSAT satellite spectrum was initiated with the IFRB in December 1983 under cover of the API sent in January 1983. Because of administrative delays in the IFRB, the Canadian spectrum proposal was not published for international comment until March 1985 and only one country, the United States, registered an objection by July 1985. It advised that its regulatory process had not been completed and that it could not therefore respond to the proposal at the time. At the end of Phase B this situation remained unchanged; just as in the case of Article 11 co-ordination, Article 14 co-ordination could not be completed for reasons beyond Canada's control.

A major conclusion of Canada's attempts at MSAT co-ordination is that success in this area is strongly dependent in the final analysis on the achievement of the relevant spectrum-sharing agreements between the Canadian and American governments.

The DOC had furnished several technical studies on mobile-satellite and MSAT for joint FCC-DOC study, using permanent technical spectrum co-ordination machinery established between Canada and the United States. Other Canadian-American meetings were arranged between the DOC and, for example, the National Telecommunications and Information Administration (NTIA). Meetings had also been arranged by the DOC's MSAT Program Office with NASA during Phase A and this contact was maintained in Phase B. NASA had petitioned the FCC for a ruling on mobile-satellite services in November 1982 and had signed a co-operative arrangement with the DOC on mutual sharing of mobile-satellite service development.

Both the MSAT Program Office and Telesat held discussions in the course of Phase B with prospective United States mobile-satellite carriers Mobilsat and Skylink, which were two amongst a number of such entities to apply to the FCC for licences to provide the service in the United States. In January 1984, the DOC responded to an FCC request for comments on the licence applications of these two companies.

In May 1984, the DOC and FCC top-level managers discussed mobile-satellite co-ordination at one of their periodic meetings on the Canada-United States frequency sharing arrangements. They agreed on support for expeditious development of commercial mobile-satellite services and timely resolution of the spectrum issues.

In January 1985, the FCC issued an NPRM for public comment proposing mobile-satellite service at 800 MHz and calling for service applications from American business interests. Twelve applications were received with some for and some against a joint venture between the yet-to-be-selected United States mobile-satellite carrier and Telesat. An FCC ruling is expected sometime in 1986 and the spectrum and institutional arrangements for the United States will probably be stipulated at that time. Assuming a positive outcome for mobile-satellite allocation and for co-operation with Canada, the existing Canadian-American frequency-sharing arrangement should be revised to reflect the spectrum planning required to alleviate all the uncertainties Canada has been experiencing with the United States in regard to MSAT spectrum co-ordination.

Mobile WARC '87

Allocation for land mobile applications at L-Band will have to be agreed upon in the up-coming WARC '87. Based upon the decisions reached at that time, Canada will have to co-ordinate spectrum with other interested administrations in a process similar to the one followed for the 800 MHz spectrum.

Spectrum conservation

In an August 31, 1982 policy paper on MSAT spectrum and institutional policy issues, the DOC called for public comment on a number of mobile-satellite service matters of vital concern to Canada. One such matter was the impact of technological developments in spectrum conservation on the first-generation MSAT to operate at 800 MHz in the UHF band. Discussion in the paper centred around a narrowing of the mobile radio channel bandwidth to 5 kHz, with 45 MHz duplex RF spacing to be achieved using specific modulation techniques that are dependent on technological advances and the use of standard RF uplink and downlink carriers connecting with the satellite.

MSAT institutional arrangement issues in Phase B

The development of Canadian institutional arrangements for MSAT in Phase B was initially accomplished through a process of wide-ranging consultation with the participants of the PLCP working groups. Those consulted were the prospective federal government users, the CRCCA, Telecom Canada and the provincial governments. Later, when reasonable proposals had been devised, the arrangements were thrown open to public comment via the Canada Gazette.

The particular institutional arrangements given a detailed analysis in Phase B were the following:

- nomination of the satellite carrier and space segment manager,
- rate regulation and licensing of the space segment service,

- nomination of the providers of end-user service,
- rate regulation and licensing of the end-user services,
- competition in the provision of end-user hardware and services.

As a result of the early efforts at consultation in the PLCP working groups, a general philosophy was adopted in the actual formulation of specific institutional arrangements: avoidance of conflict with existing policies and regulations wherever feasible while ensuring that the needs of the various participants in the provision of MSAT were to be met insofar as humanly possible.

As a result of this overall guideline, an early institutional decision was made that Telesat would be the satellite carrier and the space segment manager. Proposals were that the common carriers and RCCs would be free to offer MSAT end-user mobile services interconnected to the PSTN; rate regulation and licensing of the space segment and end-user services were to be done within the already-existing structures and processes in the DOC and the Canadian Radio-television and Telecommunications Commission (CRTC). This latter automatically meant that existing rules for competition in the provision of end-user hardware and services would be the benchmark that would apply as a minimum to MSAT. Any advancements between then and launch time would have to be taken into account later.

As a consequence of the extremely comprehensive MSAT consultation process, the many original institutional questions were narrowed down to relatively few contentious issues. In order to subject these issues to further debate, they were included in the form of proposals in the DOC policy discussion paper, Telecommunications Policy Proposals for Mobile Satellite Service, opened up for public comment through the Canada Gazette on August 31, 1984. The proposals covered were as follows:

- The extension to MSAT of earth-station licensing policies effective April 1986, allowing the public to hold a radio licence to own an earth station contingent on contractual arrangement with the operator of the service.

- Sub-allocation of dedicated spectrum to certain MSAT services in accordance with the realities of the marketplace, with the balance of the spectrum to be open to the first-come-first-served principle.

- Joint venture with the United States provider(s) of MSAT services so that North American standardization of frequency channelling and mobile terminal configuration could be realized, as well as compatibility between MSAT services.

- In regard to MSAT services the following proposals were made:

  - for mobile satellite radio service (MSRS), the DOC did not intend to limit access, although for such a service in remote areas for which MSAT is best suited, the RCCs would be most likely to satisfy the needs of the small users to be encountered in these areas;

  - for mobile satellite telephone service three scenarios were presented: service provision only by Telesat, service provision by the major telephone companies, or arrangements similar to those for cellular service (in which Telecom Canada and a consortium representing the RCCs are permitted to provide service), except that Telesat would compete with the others permitted to provide the service;

  - the DOC would not prohibit mobile-satellite fixed remote telephone service as an interim measure pending extension of regular fixed satellite telephone services to satisfy the need filled by MSAT.

- The DOC proposed not to support to the extent practicable for Canadian research, design and industrial personnel, technology and facilities to be used to maximize Canadian content in the space and terrestrial components and to optimize economic benefits to Canada.

In reply to the DOC policy discussion paper on MSAT, some 50 sets of comments were received; while there was overwhelming support for MSAT, suggestions were offered on the individual issues raised in the paper. A DOC policy was in preparation at the end of Phase B.

CONCLUSIONS

CONCLUSIONS

As documented in this report, the original MSAT Phase A concept was the subject of numerous carefully designed analyses in Phase B in the fields of engineering, services, market development, economic viability and benefits. Telecommunication policy was also studied specifically in regard to spectrum management and institutional arrangements. The following important conclusions can be drawn about MSAT definition.

MSAT is far from being a purely theoretical product of government researchers divorced from the mobile and telecommunications industries: system definition has been done throughout with full and active support from market-oriented, profit-centred business users of these services. Support has also been sought from providers of fully commercial mobile and satellite communications services and from providers of telecommunications services. The participation of other interested parties in industry and government was also solicited in Phase B.

The first criterion of the system definition has been that MSAT must be readily marketable and accessible to users and that it must be technically and economically feasible in a fully commercial environment.

MSAT has been shown by the satellite service provider, Telesat, to be a realizable major business opportunity; it has also been shown to provide favorable investment opportunities for the other commercial interests involved. These conclusions came from in-depth market analysis which forecast a relatively high volume of prospective users and through a clear demonstration that the concept was economically viable in its own right and of significant benefit to Canadians. Telesat's perception of MSAT as a major business opportunity is, however, predicated on its obtaining some bridging financial assistance in launching the capital-intensive satellite and putting in place the costly ground segment. It is also predicated upon Telesat being able to enter into a joint venture of some kind with the mobile satellite provider in the United States.

The PLCP in Phase B proved a powerful means of generating public awareness of the cost-effective communications capabilities of MSAT. It also enhanced the marketability of the system to potential users by inviting them to evaluate the merits of the system. The PLCP showed that MSAT would be a boon to users in that it would supply high-quality, wide-area, readily accessible, cost-effective communications in regions of Canada where today no such services normally exist on an economical basis. Under the PLCP, the DOC will sponsor over 150 organizations which have actually submitted proposals for specific trials and experiments and will pay the cost of airtime and equipment leasing for a short period, provided applicants agree to conduct viability assessments at their own cost and pay other operational costs involved.

MSAT will therefore, in the final analysis, provide marketable and fully usable services; the system has been shown to appeal to a wide variety of users in federal, provincial and municipal governments and in industry. It is perceived by industry as a potentially indispensable tool in work areas such as utilities, public safety and emergencies, law enforcement, transportation and distribution, mineral extraction and exploration, industry services, forestry and conservation, construction and many other major applications. The reason for MSAT's appeal is that, from the start of Phase B, practical business and government users actually operating in these work areas provided considerable input on what would make MSAT of real value in the field.

The satellite communications characteristic of MSAT will be put to optimum use in the field -- in rural or remote areas where high quality, reliable, wide-area service is needed and yet cannot be economically provided using current terrestrial mobile communications. MSAT is not designed to compete with the industry's strongly entrenched metropolitan terrestrial mobile or fixed services infrastructure. It hence poses no threat to the viability of existing Canadian mobile services.

MSAT will enable potential users to realize extremely efficient mobile telecommunications services that were only a dream until now. For example, while "voice" mobile communications services remain in greatest demand, some novel and advanced applications will now be available, such as monitoring of sensors for industrial control, point-of-sale terminals, oil well monitoring and inventory control.

Adequate satellite-complex and critical payload options are available for all possible MSAT configurations and their costs have been calculated. A CCS will be employed for satellite station-keeping, mobile channel switching, network management and maintenance; functional design and cost analysis has already been effected. The CCS can allow for the mixed selection of mobile radio channels -- randomly for maximum efficiency as traffic levels dictate (demand assignment) or on a dedicated (or preassigned) basis for privacy or for assured full-time availability. In practice, mobile telephone, mobile radio and DACS services will be preassigned separate groups of channels. Dynamic variation of the number of channels assigned to each group will be possible, so as to reflect the vagaries of the marketplace.

From a technical standpoint, the engineering of the basic MSAT system configuration is not expected to present any insurmountable problems. Considerable time and effort will be required, though, to program the combined voice/data multiplex switcher. More research is needed to define the mobile channel modulation techniques for maximum spectrum efficiency and economic feasibility. Also to come is an economical and practical solution to the engineering of the mobile vehicle antenna for MSAT.

Two aspects of telecommunications policy were given in-depth treatment in the definition phase: spectrum co-ordination and institutional arrangements. MSAT spectrum co-ordination proved as complex, arduous or painstaking as it normally is, given the multiplicity and power of worldwide commercial and governmental entities endeavoring to protect their spectrum interests. However, in addition, specific factors in Phase B proved at odds with the normal slow pace at which international spectrum co-ordination decisions are made. These were the extremely tight time constraints in Phase B, the difficulty in consolidating exact system details so far in advance of satellite launch and the urgent need to know, for planning purposes, when the requisite changes to the UHF and L-bands on the Canadian and international tables of frequency allocations could be expected.

In particular, co-ordination of the proposed UHF band allocations proved especially difficult for a number of reasons, but primarily because Canada wanted this spectrum for the first generation satellite and also because the United States has under regulatory scrutiny plans of its own for mobile satellite in the 800 MHz band. Preliminary L-band allocations were also co-ordinated for the Canadian MSAT system; some difficulties were experienced in this regard with competition from aeronautical satellite communications for the spectrum concerned.

Attempts to renegotiate the Canada-United States frequency sharing agreements are in process to take account of Canadian mobile satellite needs. Progress is partially dependent on the outcome of the FCC internal United States mobile satellite and public safety deliberations.

The optimum channel bandwidth to be adopted as a standard for MSAT in order to conserve spectrum was given special treatment in policy studies. This, along with co-ordination and the institutional arrangements dealt with below, were covered in the DOC document published in mid-1984 entitled Discussion Paper - Telecommunications Policy Proposals for Mobile Satellite Service. A total of 4 MHz Mobile Satellite System (MSS) RF bandwidth was proposed in the 800 MHz band using 5 kHz channel bandwidth and 45 MHz RF duplex separation. Public response to the paper was very positive and comments have been reviewed; a final policy is in preparation.

In regard to the study of MSAT institutional arrangements in Phase B, six key areas were examined in a consultative process involving high-level DOC and federal government staff, as well as industry, using the consultative machinery provided by the PLCP and the Canada Gazette. The six key areas were: interconnection to the PSTN, system ownership rules, North American system compatibility, competition in services provision, rate/tariff regulation, and radio licensing.

Early in Phase B, the DOC chose Telesat as the MSAT space segment provider, a decision that later simplified considerably the analysis of the balance of the institutional arrangements. The 1984, the DOC policy discussion paper mentioned in preceding paragraphs invited comments on the following important proposals: that current radio licensing and satellite earth-station ownership rules would apply to MSAT, allowing anyone to own fixed and mobile earth stations subject to prearranged contractual arrangements with Telesat and with providers of end-user services respectively; and that North American compatibility should be achieved wherever possible. The intention was to facilitate radio licensing of MSAT and to ensure that an appropriate level of competition existed in the provision of MSAT services. The public consultation process has been successfully completed and a DOC institutional arrangements policy is being finalized.

It has been demonstrated in Phase B that MSAT is technically feasible and commercially viable. There remain some technical areas requiring further research and development but these are all at a stage where concrete positive results are attainable. MSAT promises to be attractive to investors and to provide significant measurable socio-economic benefits to Canada and Canadians. It can be made to fit with relative ease into the existing telecommunications infrastructure insofar as the requisite institutional arrangements are concerned. In fact, radio licensing and service regulation rules may not be required to deviate from present practice in order to provide for the successful implementation of MSAT. Hence, no delays in bringing MSAT plans to fruition are expected in this regard. This is regrettably not so in the case of international spectrum co-ordination as outlined below.

An invaluable business opportunity exists for international industrial and governmental co-operation between the United States and Canada in implementing a mobile satellite system. This joint venture could prove of significant benefit to both Canadian and American providers of service and to end-users. However, because of the level of interest generated on both sides of the border, important questions have arisen on the mutual allocation and sharing of the 800 MHz or L-Band spectrum for the first-generation system.

The international co-ordination of the UHF spectrum involved has already proven difficult and seems largely dependent on the resolution of United States domestic mobile satellite concerns. Other frequency co-ordination problems have arisen in regard to the use of L-band for the first and/or second generation system but the time element is not as urgent as in the UHF case. In regard to L-band, the specific co-operation of the USSR and International Civil Aviation Organization (ICAO) has been shown to be necessary before successful co-ordination can occur.

International spectrum co-ordination for MSAT is therefore the one area in the entire program requiring special high-level federal government attention in Phase C/D in order to prevent significant delay in the successful realization of Canada's plans for a mobile-satellite system.

In conclusion, the Phase B studies have shown that MSAT is capable of providing many direct and indirect benefits, such as a good return for investors, increased business efficiency and improved public safety communications in rural and remote applications. The implementation of the system is expected to result in thousands of new jobs and prove highly desirable from both social and economic perspectives. MSAT will, in short, contribute significantly to the overall well-being of Canadians.

APPENDIX 1

GROUND SEGMENT DEVELOPMENT

This appendix summarizes the results of a number of technical research contracts covering the design of MSAT antennas, mobile terminals and SHF ground stations.

The complete studies are listed in Section D of the references.

APPENDIX 1 - GROUND SEGMENT DEVELOPMENT

Based on the results obtained in Phase A of the MSAT Program, the ground segment activities in Phase B were initially defined as Earth Segment Definition and Design and Earth Segment Technology Development. The activities were redefined as Ground Segment Technology Development and Applied Research near the end of Phase B.

The contracts described below were completed during the initial stage of Phase B.

- MSAT Data Services Study, Mobile Data International, April 1983, contract no. DOC-CR-SP-83-041. This study outlined specific potential needs for types of data services and identified MSAT mobile data terminal types. The economic and operational benefits of data services were described. A statement of work for a technical definition study of four of the data service concepts identified in this study was included.

- Study of a Frequency Control System and Prototype Development of Frequency Sources and Synthesizers for the Mobile Satellite (MSAT) System Mobile Terminals, SPAR Aerospace Ltd., October 1983, contract no. DOC-CR-84-035. Phase I of this study involved a detailed system analysis of the frequency requirements of the entire MSAT system, including the effects of Doppler shift, oscillator stability, and system requirement on oscillator phase noise. The recommended approach was for the satellite to distribute a reference signal to all UHF terminals. Phase II of this study was the design, development and delivery of three prototype models of the synthesizer for use in the MRS terminals. One synthesizer was loaned to SPAR for use in the DMSK/Linear Predictive Coding (LPC) radio and one was loaned to ADGA Ltd. for use in the ACSSB radio.

- MSAT UHF Antenna Study, Canadian Astronautics Ltd., November 1983, contract no. DOC-CR-84-034. This study investigated potential antenna types for use by ground terminals in the MSAT system. Identification, specification and costing of a complete family of MSAT UHF antennas was prepared. Two prototype four-arm conical spiral antennas were developed and tested. The antennas are similar in size and shape to the conical log spiral antennas developed by the DOC's Communications Research Centre (CRC) during Phase A, with shape optimized to give better gain over $15°-35°$ elevation angles.

- MSAT Mobile Telephone Service - Definition and Development of UHF NBFM Terminals, Glenayre Electronics Ltd., April 1984, contract no. DOC-CR-84-030. The objectives of this study were to:
  a) define and describe the operation of the DAMA system controller, including the PSTN interface, and to estimate equipment costs;
  b) define the requirements of the mobile terminal and estimate the costs and the new or advanced technology required for production;
  c) define, construct and test a mobile terminal using NBFM;
  d) report on the compatibility of this terminal and the terrestrial cellular terminal, including design and cost implications of a MSAT/cellular compatible terminal.

  The study recommended a centralized DAMA system. The terminal cost was estimated at $3200 wholesale in 1000-unit quantities, with the transceiver functions representing almost 60 percent of the cost. The compatibility study concluded that two independent transceivers with a single control unit would be the most effective method.

- MSAT SHF Ground Station, SED Systems Inc., June 1984, contract no. DOC-CR-84-029. This was a definition study to prepare design specifications and develop cost estimates for the turnkey MSAT CCS, gateway stations, SHF base stations and feeder base stations. Technical and design trade-offs were performed. The cost of a CCS was estimated at $10M and the operation for seven years at $5M in 1983 dollars. Gateway stations were estimated at $3M for the initial station and $2M for subsequent stations; the operation over seven years at $600,000. The first fully redundant SHF base station was estimated at $2M and each subsequent redundant station at $1M operating over seven years at $40,000. A non-redundant station was estimated at $600,000, with seven years of operation costing $34,000. The first feeder station was estimated at $91,000 and each subsequent feeder station at $4,000 and $7,000 respectively for ACSSB and PELPC/DMSK. With the exception of the CCS, all the costs for these stations have since been revised and reduced by a large factor to account for cost reductions arising from a simpler specification and the use of more advanced components.

- Definition and Development of the UHF Ground Terminals (PELPC/DMSK), SPAR Aerospace Ltd., July 1984, contract no. DOC-CR-84-031. The major objectives of this study were:
  a) to develop a detailed specification for a UHF ground terminal utilizing PELPC circuitry to code the voice and DMSK techniques for signal modulation;
  b) to design, construct and test a development model of the terminal; and
  c) to prepare production cost estimates for the terminal.

  The development model of the terminal incorporated a frequency synthesizer developed by SPAR and a DMSK modem developed by Miller Communications Systems. The DAMA study was also followed to ensure that it met requirements.

- Development of Engineering Prototype DMSK Modems, Miller Communications Systems Ltd., October 1984, contract. no. DOC-CR-84-065. The PELPC/DMSK ground terminal built by

SPAR incorporated an LPC/DMSK modem built by the CRC/ Department of Supply and Services based on this modem design.

. Definition Study to Determine the Technical Requirements and Develop Cost Estimates for MSAT Data Services, Miller Communications Systems Ltd., September 1984, contract no. DOC-CR-84-049. This investigation identified the data services to be considered and postulated basic user requirements for each service. The general system and technical parameters influencing the design of data services were discussed. A detailed analysis of each of the service categories was described and cost estimates were developed. A computer analysis of three modulation techniques -- coherent binary phase shift keying, differential binary phase shift keying, and differential minimum shift keying -- was performed for aeronautical, maritime and land mobile operating environments. A two-way interactive or non-interactive data service terminal, broadcast terminals and emergency signalling terminals were investigated.

. Prototype High Gain Vehicle Antenna for Mobile Satellite Use, Antech Antenna Technologies Ltd., September 1984, contract no. DOC-CR-84-074. This report describes the design, analysis and testing of a right-hand circular polarized antenna. The antenna has multiple beams and a microprocessor-based control. The radiation patterns and frequency band are suitable for use with the MSAT system.

Contracts that were let during the initial stages of Phase B but were not fully completed during Phase B include the User Terminal Definition for ACSSB let to ADGA Ltd. and a Voice Quality Study contracted out to Bell Northern Research.

While most of the contracts let during the initial stage of Phase B were being implemented, their results generated parallel research at the CRC.

This research was identified as critical subsystem development toward the successful deployment of the MSAT system. In-house research has included a PELPC/DMSK radio, an ACSSB radio and mobile antenna development. Contracts were let in support of the research to:

- Canadian Marconi Company and COM DEV for high-gain road vehicle antennas; and

- Communications Research Consultants Ltd. for digital processing for ACSSB functions.

Completed contracts include:

- Design, Performance Analysis and Implementation of a (56, 48) Single Error Correcting and Single Burst Detecting Block Code Compatible with the CRC Designed Linear Predictions (LPC) Vocoder, Binary Communications Inc., March 1985, contract no. DOC-CR-85-018.

These additional contracts let near or at the end of Phase B are a direct result of the work described in the Discussion Paper on the Industrial Strategy for the MSAT Ground Segment issued by the MSAT Project Office in March 1985. The results of socio-economic studies completed by the MSAT Program Office were considered in the discussion paper and the results of contract reports were incorporated into a redirection and augmentation of ground segment activities. Developments of the American mobile communication program were also considered. The objectives and strategies for both contracted and in-house research were outlined in the discussion paper. The critical areas in the development of the ground communications equipment were identified and work has begun.

Present objectives include the design and manufacture of mobile radio terminals operating with 5 KHz channel spacing and DAMA control. The types of voice modulation under consideration are ACSSB, because it provides spectrum-efficient voice quality acceptable for telephone networking, and PELPC/DMSK, because it provides spectrum-efficient communications in a digital format. NBFM was discarded as it required excessive bandwidth and power.

The need for a mobile data service was identified in the MSAT Market Study and the PLCP interviews. Present objectives include the design and manufacture of mobile data terminal equipment. The type of data modulation under consideration is DMSK, because it has good sidelobe roll-off, rapid carrier recovery and operates well in multipath fading.

Mobile antenna development was identified as essential to meet the requirements of both low cost and high gain.

Base stations and gateway stations were not deemed to be critical at this point.

The first year of the Engineering Development, Manufacture and Launch Phase, Phase C/D, began in May 1985 with start-up funding.

Response to the MSAT ground segment industry strategy paper has been positive. Specifications and statements of work to engineer, furnish and demonstrate MSAT terminals have been submitted to the Contract Review Board. The terminals include voice terminals using LPC and others using ACSSB for the MRS (half-duplex), the MTS (full-duplex), and the fixed telephone service (full-duplex) data terminals for the Mobile Data Service (MDS) (both half- and full-duplex) and as an option for the voice terminals and for the DACS (one-way) and the DACS (two-way) and data paging terminals (both mobile and fixed service).

APPENDIX 2

DAMA SYSTEM ORGANIZATION

This appendix summarizes the results of a contract study of the MSAT DAMA hierarchical architecture and simulation of various algorithms to determine costs and manpower requirements for complete DAMA design.

The complete study is listed in Section D of the references.

APPENDIX 2 - DAMA SYSTEM ORGANIZATION

Miller Communications Systems Ltd. conducted a system definition study of the MRS DAMA. They recommended a centralized hierarchical architecture to minimize the inter-processor communication costs and reduce the signalling delay, which could adversely affect the call-handling procedures. A district processor would handle all intra-UHF beam calls and inter-beam calls would be referred to the SHF beam processor. Figure 13 illustrates a scenario with two SHF beams and eight UHF beams.

Common-channel signalling was selected to increase the call-handling rate and improve trunk usage efficiency. Figure 14 illustrates the signalling channel formats and packet composition. Slotted ALOHA and reservation ALOHA are used on these channels to avoid overlap and improve call-handling time. Users log on the system and are given timing correction information on their initial exchange with the DAMA; the timing is updated every two hours or on initiating a call.

Simulation of the developed algorithms was carried out and distribution functions of call-handling times were plotted. A numbering plan was developed that permits easy segregation into varying size user communities of interest. Specific hardware was recommended and a software development schedule proposed. Estimated costs and manpower requirements were:

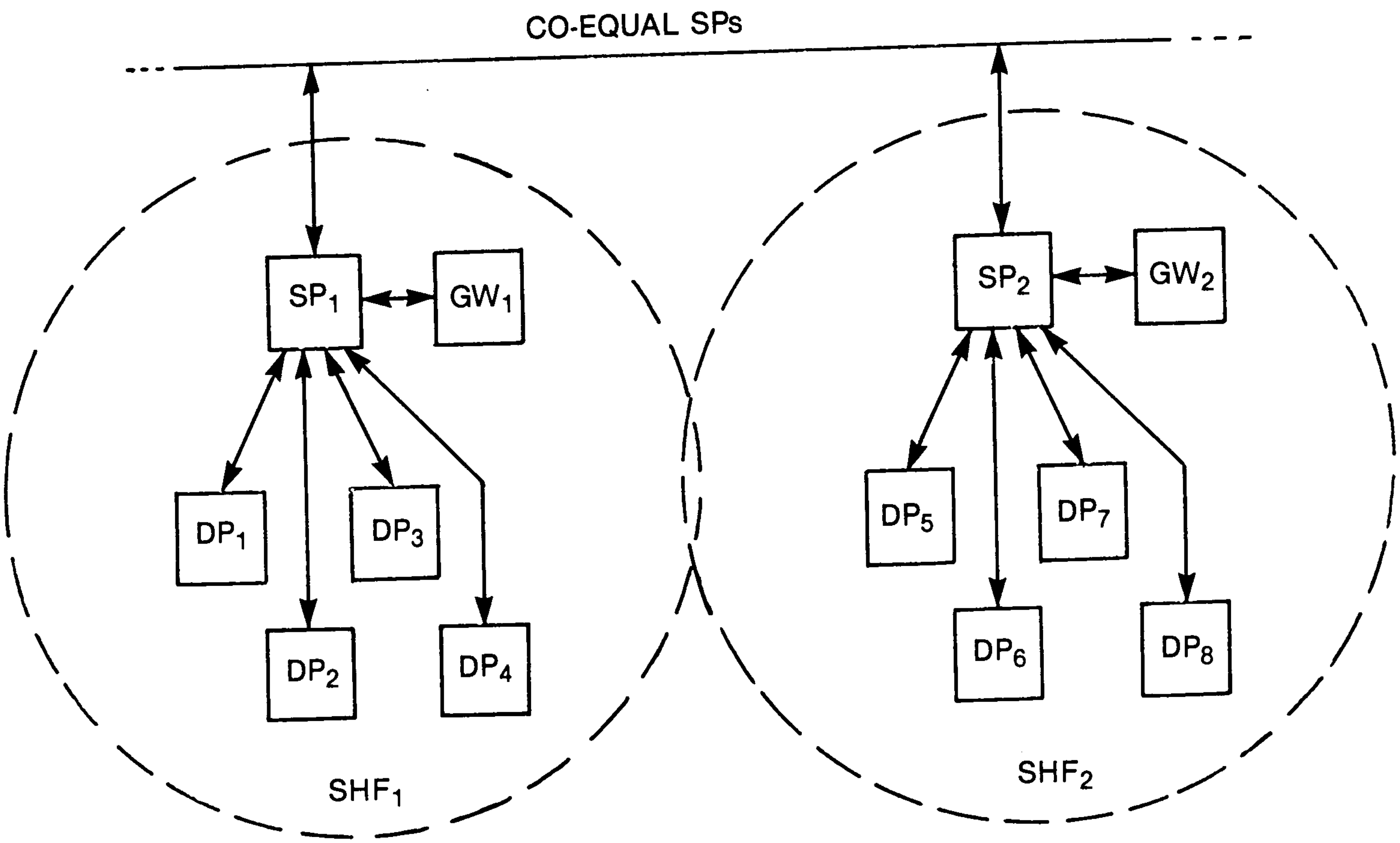
. Software development	72 person-years
. Software maintenance	4 person-years/year
. Equipment cost and installation	$1,717 K
. Equipment maintenance	$10.5 K/month

The final report covers the following subjects:

- system design,
- processor requirements and selection,
- algorithm specification,
- algorithm validation,
- software specifications,
- cost analysis, manpower and scheduling report.

Future activities are dependent to a large extent on the system architecture selected by Telesat. Indications are that a unified MRS and MTS DAMA system is favored and the implications of such a system will be investigated.

Figure 13: Operational MRS DAMA scenario



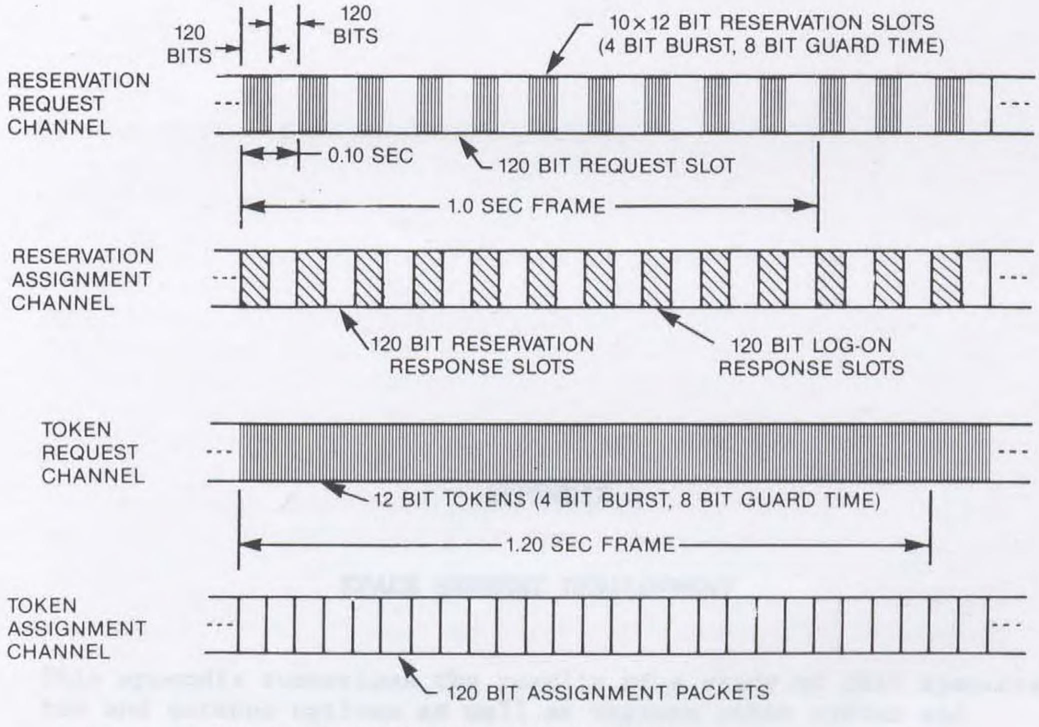


FIG. 14a ORGANIZATION AND MESSAGE

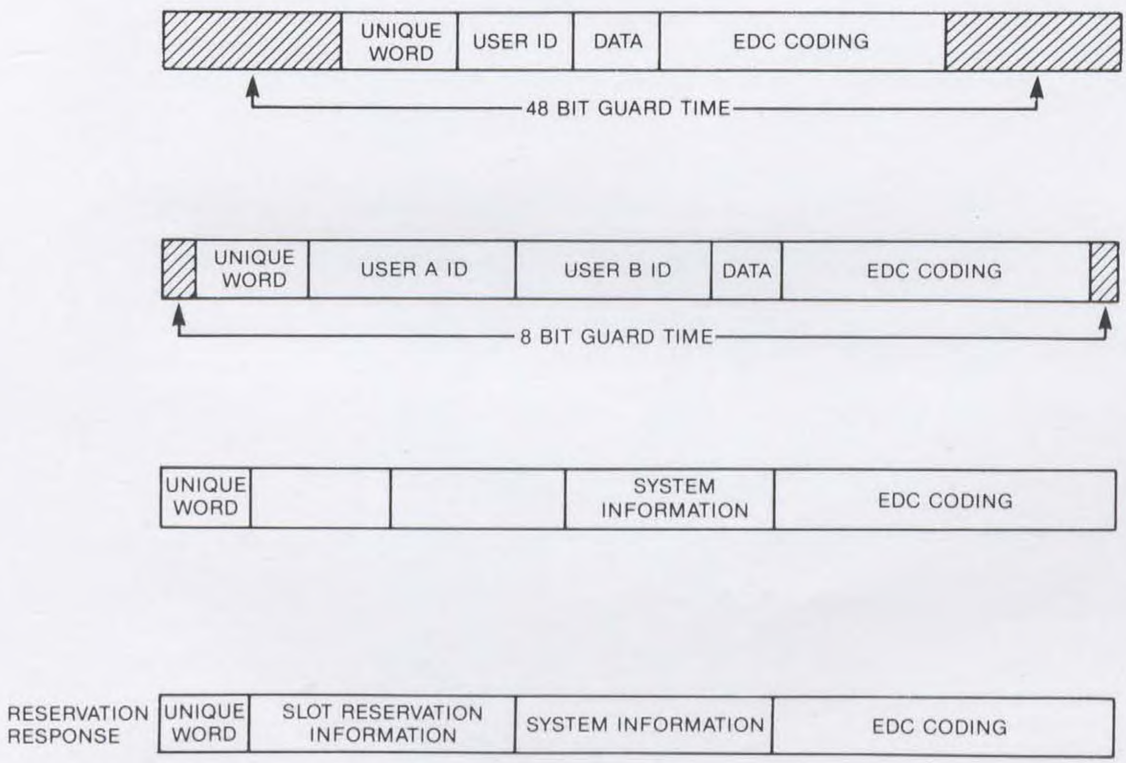


FIG. 14b SIGNALLING CHANNEL FORMATS

APPENDIX 3

SPACE SEGMENT DEVELOPMENT

This appendix summarizes the results of a study of MSAT spacecraft bus and antenna options as well as various other system and payload issues.

The complete study is listed in Section E of the references.

APPENDIX 3 - SPACE SEGMENT DEVELOPMENT

GENERAL

During Phase B, the SPAR work has addressed a variety of spacecraft system concepts and the development of payload hardware. This work was reported in considerable detail by SPAR in the October 1984 Executive Summary of their final contract report covering the period from 1 April 1982 to August 1984.

SYSTEM STUDIES

A Canadian demonstration system concept, using an Olympus bus, was the focus of the early studies. Services in the UHF band, using NBFM, LPC/DMSK and ACSSB along with a military EHF package and 400 MHz communications, placed heavy demands on satellite resources. Dual 30-foot antennas for the UHF were planned to provide four-beam Canadian coverage. An SHF backhaul system and UHF-UHF cross strap concepts were studied.

In response to NASA's interest, two additional American beams were added to the concept and the SHF coverage was expanded. The military package and the 400 MHz service were removed from the system. This configuration was examined in considerable detail, culminating in design reviews of the payload, bus, and spacecraft and in development of plans for the spacecraft integration and testing program in preparation for the detailed cost analysis of the implementation plan.

Owing to the evidence of commercial interest, the demonstration system concepts were not pursued further. In anticipation of a Canadian commercial system concept definition, a range of smaller two- and four-beam configurations were studied using representative PAMD and PAMD2 class buses. As a matter of practicality, the use of NBFM was eliminated from these concepts.

It was concluded that a three-axis satellite bus appeared more technically acceptable than spinners, particularly for the smaller versions.

As other studies progressed, it became evident that a North American system could offer significant economic advantages. Consequently, the SPAR studies of the commercial system were expanded to include two- and four-beam spacecraft systems providing UHF and SHF (backhaul) coverage for the United States and Canada. Dual antennas with reflectors of 16 to 25 feet in diameter were studied.

In total, the application of seven different spacecraft buses (HS376, ECS, INSAT, HS393, EUROSTAR, IVA, and Olympus) and four different types of reflectors (Harris, Lockheed, Corvair and Aerospatiale) has been studied. These options could serve between 18,000 and 85,000 users employing low gain mobile antennas and allowing the full fade margins considered necessary for the demonstration system. Relaxation of these parameters will increase the number of users correspondingly, to the limits imposed by the available spectrum and specific bus capabilities.

Future work related to spacecraft systems depends greatly upon the overall system concept finally chosen and the interface parameters specified, particularly related to coverage, spectrum and the mobile antenna gain. The possible introduction of L-band, in addition to the UHF band, opens up further areas for study. Techniques for minimization of problems from passive intermodulation remain a subject for continuing studies. Since commercial firms will ultimately specify the system, the general objective of the ongoing spacecraft system studies is to remain abreast of the evolving system scenarios and examine a variety of candidate options so that SPAR will be in a position to effectively respond to a Request for Proposal (RFP) for a mobile communications satellite.

PAYLOAD DEVELOPMENT

The payload development work during Phase B kept pace with the evolving spacecraft system concepts while concentrating on areas of highest risk. Following development of candidate payload block diagrams, preliminary designs were carried out for all UHF units and specifications established for the SHF units.

Early versions of the UHF Solid State Power Amplifier, Electronic Power Conditioner and UHF Duplexer were built and performance tested. A life test UHF power amplifier was assembled and a long-term operational thermal cycling test was started on it. A number of other UHF units, including the receivers (at 400 MHz and 823 MHz), upconvertors, feed network and local oscillator chain were partially breadboarded. A combined variable conductance/conductance heat pipe system was assembled and tested. This work served to confirm the design concepts and identify areas needing improvement or optimization.

Other areas of hardware development included the frequency hopping synthesizer for the EHF package, SHF local oscillator chain and an alternate concept for the UHF power amplifier, called high efficiency linear amplification by parametric synthesis (HELAPS), which got underway as a licensing arrangement between Skylink and SPAR near the end of Phase B.

One particular area of technological risk is the deployable spacecraft antenna. Since these are not a Canadian-made item, SPAR worked with a number of foreign firms in developing conceptual designs for a range of sizes from 30 feet down to 16 feet in diameter. To save weight and permit compact stowage during launch, all the designs examined to date are based on mesh-type unfurlable reflectors. Lightweight, yet stiff, accurate-pointing designs appear to be feasible from these studies.

Further work related to payload development depends somewhat on the overall system concept finally chosen. Factors such as the inclusion of L-band and the choice of backhaul frequencies will open up new areas for study. To the extent possible, work will continue on development and optimization of payload building blocks that can be used regardless of which spacecraft payload configuration is adopted to satisfy the commercially driven RFP. In this way, SPAR will be in a position to respond positively and to confidently undertake expeditious payload flight hardware. This preparedness should ensure that payload production can keep pace with the parallel production of already-developed spacecraft buses that are likely to be used for MSAT.

APPENDIX 4

COVERAGE

This appendix summarizes the various CRC studies on issues related to MSAT coverage, such as propagation constraints and angle of elevation.

The complete set of studies is listed under "Results" in this Appendix.

APPENDIX 4 - COVERAGE

MSAT COVERAGE

Since MSAT (being a geostationary satellite) will be in orbit over the equator, it will be seen at different look-up angles from different parts of the country. The look-up angle decreases as one moves away from the equator and finally reduces to zero. Figure 8 in the main report shows the contours at which the look-up angle is zero and 10° respectively.

At very low look-up angles, the interference and signal losses increase, requiring higher-gain antennas to maintain adequate signal availability and quality.

The standards set for availability in the MSAT system are very high; they considerably exceed the usual standards for existing terrestrial mobile systems, which usually operate at an availability of about 95 percent. The MSAT standard has been fixed at 99 percent. It must also be remembered that the standard relates to a mobile in full motion. If a mobile becomes stationary during a conversation, the satellite margins and antenna gain required to meet the availability standards will be considerably lower.

To establish the performance limits of the system and arrive at the best trade-off between satellite margins, antenna gain and signal availability, the DOC is engaged in an extensive program of simulations at both 800 MHz and L-Band.

Tests to date have been carried out using low-gain (4 dB) antennas and fully mobile targets. Subsequent tests will involve higher-gain antennas and stationary targets. The following provides a summary of the results to date.

PROPAGATION AND COHERENCE BANDWIDTH MEASUREMENTS

Background

To establish the margins required for mobile-satellite service at 800 MHz and L-Band at different satellite look-up angles, dates and terrain, a comprehensive set of measurements were made. At 800 MHz, a helicopter was used to simulate the satellite path and L-Band measurements were made using the INMARSAT MARECS A satellite. To verify the channel data capacity, measurements were made of the coherence bandwidth at 800 MHz from a tower to typical rural sites.

Results

The methods used to obtain the propagation and coherence bandwidth data and the results are contained in the following CRC technical notes and memoranda:

Number 723, August 1984, Propagation Measurements for Land-Mobile Satellite Systems at 1542 MHz, by J.S. Butterworth.

Number 724, August 1984, Propagation Measurements for Land Mobile Satellite Services in the 800 MHz Band, by J.S. Butterworth.

Serial Number DRL 84-04, 21 November 1984, Measured Characteristics of 800/900 MHz Radio Channels with High Angle Propagation through Moderately Dense Foliage, by R.J.C. Bultitude.

Serial Number DRL 85-01, 5 February 1985, Measured Characteristics of 800/900 MHz Radio Channels with High Angle Propagation through Deciduous Trees with no Leaves, by R.J.C. Bultitude.

The propagation measurements confirmed that a 13 dB margin is necessary to obtain 99 percent availability in moderate shadowing and a satellite look-up angle of 20° degrees at 800 MHz. To maintain the same availability at L-Band under the same conditions, an increase of 5 dB is necessary to counter the increased blockage loss. The coherence bandwidth measurements indicated that a TDM implementation was possible without impairment, due to the channel response. Figures 15 and 16 present representative graphs of these characteristics; complete data are available in the referenced documents.

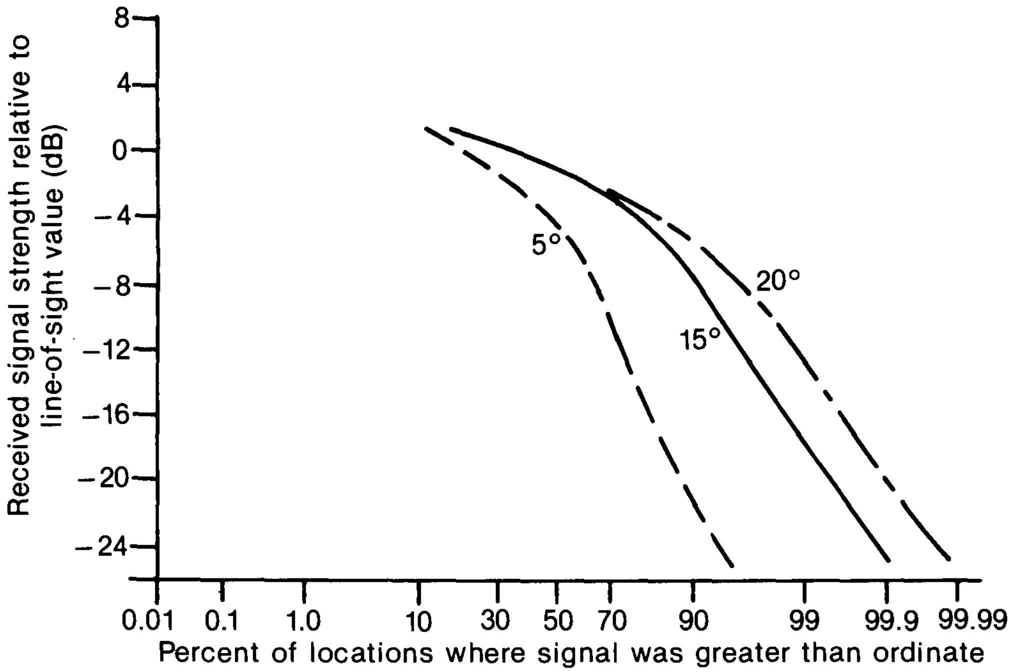


Fig. 15 Distribution functions for June 1983 data at 800 MHz

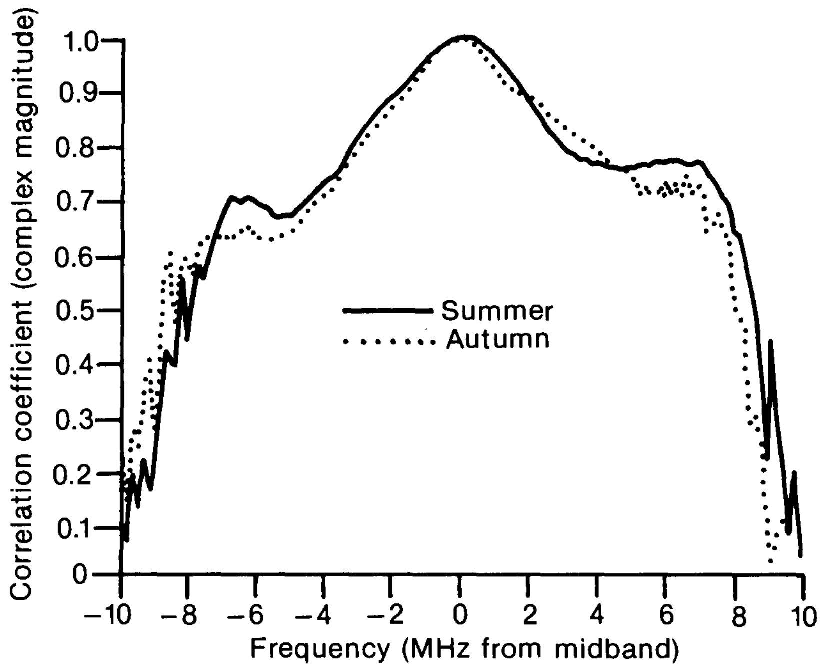


Fig. 16 Coherence bandwidth

APPENDIX 5

EQUIPMENT COSTS

This appendix summarizes the results of equipment cost studies as abstracted and collated from the various socio-economic studies listed in Section A of the references.

APPENDIX 5 - EQUIPMENT COSTS

EQUIPMENT AND SERVICE COSTS

To ensure commercial viability, it was necessary to arrive at affordable user equipment costs and service costs that would make the service attractive to users while allowing the service-providers an adequate return on their investment.

For this reason, considerable effort was expended on determing a realistic set of costs, a process complicated by the fact that projections had to be made five years ahead of service availability.

Experience has shown repeatedly that equipment costs decline drastically in the first few years after service introduction, reflecting technology and volume efficiencies. Only nominal adjustments were made to the present cost estimates to account for future cost reductions and therefore the estimates are considered to be conservative.

The following is the preliminary set of anticipated equipment and service costs that are of importance to the end-user.

Equipment costs	Retail price
1. MRS mobile terminal and antenna*	$3,500
2. MTS mobile terminal and antenna*	$4,500
3. DACS terminal and antenna	$2,700
4. Single circuit UHF base station equipment	$3,300
5. Four circuit SHF base station equipment	$90,000

Airtime costs	Retail price
1. UHF/SHF	$1.40/min.
2. UHF/UHF	$2.20/min.
3. DACS digital messages (2-4 seconds duration)	25c-40c

(continued on page 116)

---

* MRS and MTS could operate in both the voice and data modes. However any digital input-output devices such as modems or visual displays are not included in the prices listed.

Monthly charges	**Retail price**
Fixed charge per mobile terminal	$50/month

The two different rates for airtime have been derived by taking into account the power consumption differences between a call using UHF channels exclusively (UHF/UHF) or a combination of UHF and SHF channels (UHF/SHF). For small users it may be preferable to use the inexpensive UHF/UHF base stations and pay the higher rates for the airtime. Large users may prefer to invest in a more expensive UHF/SHF station and take advantage of the lower airtime rates.

Depending upon the options chosen, a terminal used for 150 min./month would incur charges of the order of $300-$400 a month including the lease charges for the terminal equipment. The cost could be significantly cut by going to digital communications which is expected to substantially reduce airtime usage. For instance, the monthly charges for a digital sensor transmitting six messages per day would range between $120 and $150 a month.

The information provided in this appendix is strictly preliminary and has been included to provide a basic indication of usage costs.

Refinements in both equipment costs and rate variations to account for such things as off-peak usage and discount rates for large users will undoubtedly result in a number of cost-effective user packages.

APPENDIX 6

MARKET, BENEFIT AND VIABILITY STUDIES

This appendix summarizes the results of a number of socio-economic studies that dealt with the market forecast, the benefits to the service and manufacturing industries, the social benefits, and finally the economic viability of MSAT from a commercial point of view.

The complete studies involved are listed in Section A of the references.

APPENDIX 6 - MARKET, BENEFIT AND VIABILITY STUDIES

THE STUDY OF THE MARKET FOR MSAT SERVICES

The market for MSAT services was formally researched by Woods Gordon's Marketing and Economics Group in a study entitled Market Projections and User Cost-Benefit Analysis. This Phase B study had two parts: the development of potential demand forecasts and the determination of user benefits for broad categories of economic benefits tied to the size of the market.

Objectives

The primary objective was to develop projections of potential demand for MSAT mobile terminals in Canada and the level of traffic as a function of price for each of the 15 years of the study. (These demand projections were a follow-up on the projections made by Woods Gordon as a part of the MSAT Phase A studies.) A secondary objective was to identify marketing considerations related to the successful introduction and growth of MSAT in the Canadian marketplace. The study also provided an update of the user cost-benefit assessment performed in Phase A and related this to new market projections.

Main findings of the study

Markets

Woods Gordon prepared an estimate of the growth of all mobile communications in Canada to the year 2009. Usage was projected to increase from 513,000 units in 1983 to 1,255,000 by 2009. Based on this growth estimate and allowing for the special characteristics of MSAT, Woods Gordon, using a product life cycle model, estimated the potential demand for MSAT services to be between 88,000 and 154,000 units by 2002, and between 99,000 and 170,000 units by 2009. The range of estimates corresponds to a range of prices that were used in generating the response from the approximately 300 surveyed organizations.

The total estimate is composed of mobile radio (dispatch or MRS) users, or MTS users, those interconnected with the PSTN. The MTS subscribers could comprise between one-third to one-half of all MSAT subscribers. Another possible categorization is by regional distribution. Woods Gordon expects that slightly more than one-half of all MSAT subscribers will be in the Prairie and Western provinces, with the balance mostly in Ontario and Quebec.

Categorization by industry yielded the following results:

Table 1: MSAT usage by industry - 2009

	% users	% airtime
Transportation industries	16	12
Mineral extraction and exploration	13	18
Service industries	13	26
Forestry	12	n.a.
Government services	10	11
Construction	5	n.a.
Eight other major applications	30	33
Total MSAT usage	100	100

The pattern of MSAT usage on a regional basis is expected to remain relatively stable, while the industry breakdown shown above reflects a gradual shift of expected MSAT usage towards transportation, minerals and service industries.

Other market variables investigated by Woods Gordon included traffic patterns, length of calls, requirement for priority services, and perception of quality of service. These were used in the conjoint analysis, determining the sensitivity of market demand to price. Some 27 combinations of nine price and quality-of-service attributes were used in determination of price elasticity of demand.

The user cost-benefit analysis

The objective of this component of the study was to update the Phase A user cost-benefit study to make it consistent with the assumptions of the Phase B market demand study. Additionally, it incorporated new insights obtained from the user survey and recent cost-benefit studies conducted by others, such as NASA. Quantifiable user benefits occur mainly in two areas: from cost reductions in communications systems and from operational benefits that can accrue from improved communications. Examples of these benefits are:

- reduced operating or equipment costs,
- improved voice quality and extended range,
- improved efficiency,
- additional features, such as data transmission.

The benefits are expected to materialize in a number of major Canadian industries. Among these are forestry and forest-fire fighting, coastal fisheries, emergency medical services, network applications (for example, electricity, gas and oil pipelines, highways), mineral exploration and production, law enforcement, and railways.

Woods Gordon estimated that the average net benefit per mobile would be $4,730 annually (in 1983 dollars). This translates into $306 million over the 15-year period considered in the study.

Conclusions and recommendations

The market study investigated the Canadian market for MSAT services and found that there was a very significant potential for mobile-satellite communications. The results of the market study formed a basis for the subsequent work by other study teams, especially by Telesat. Although the survey was fairly broadly based, it could not possibly address all market segments with intensity; some special markets, such as various data applications which many think to hold significant potential, were researched only peripherally.

Woods Gordon also provided some recommendations regarding the marketing of MSAT services. First, the changes in the mobile communications marketplace should be seen as evolutionary, rather than revolutionary. Therefore, MSAT would be complementary to existing systems rather than displacing them in a majority of cases. Second, it is vital to determine the structure of the service-provider industry early, so that maximum rate of penetration can be achieved from the start. Third, preselling of the service is considered essential, in view of the very competitive mobile communications industry environment. And fourth, competitive pricing of terminals and airtime and access charges is seen as a key to successful MSAT penetration.

THE IMPACT OF MSAT ON THE RCC INDUSTRY

The objectives of this study were to describe and quantify the opportunities and effects of MSAT services on the RCC industry in each province and for Canada as a whole for the years 1987-2002.

Specifically, the study addressed the following areas:

- Market projection for the existing as well as proposed mobile radio systems without MSAT.

  The RCCs in Canada number about 600 individual companies. Most are small, but a handful of large ones are major providers of mobile radio and paging in most areas of Canada. Their total sales (excluding sales of equipment, which amounted to $200 million) were $158 million in 1983 and they employed about 5000 people. Total annual investment was about $42 million in the same year. Most RCCs operate a common system accessed by a number of users for a fixed monthly fee. In addition, RCCs install and repair mobile and fixed radio equipment.

- Description and review of the proposed MSAT operating, billing and technical interface arrangements necessary to integrate MSAT with existing RCC networks.

- Determination of the impact of MSAT in terms of additional market opportunities, revenues, investment, operating expenses and employment.

- Identification, description and analysis of marketing, institutional, regulatory and policy issues.

- Development of recommendations regarding the business opportunities of MSAT for the RCC industry.

Main findings of the study

An economic model using revenue and cost variables based on a set of DOC assumptions was used to forecast the incremental impact of MSAT on the cash flows. A rate of six percent for constant 1984 dollars was used to determine the net present value (NPV) of discounted cash flows, which amounted to a positive $30 million by the year 2002.

The study found that a large capital investment in base stations and terminal equipment would be required: approximately $190 million by the year 2002. This investment, plus the operating expenses, would be recouped by charging a minimum of 25 percent markup on the wholesale prices of airtime, access charges and terminals. The Telesat/DOC baseline market was the main scenario for the study, although others, such as a smaller market (pessimistic) scenario and the inclusion of data and paging services, were also studied. The main results are summarized below:

Table 2: Study results for Canada - Baseline voice market (paging and data services not included)

Forecasted units	
by 1995, max.	19,266
by 2002, max.	41,663
Cumulative revenues	
by 1995	$395M
by 2002	$1,490M
Capital expenditures	
by 1995	$53M
by 2002	$138M
Operating expenses	
by 1995	$316M
by 2002	$1,177M
NPV	
by 1995	$4M
by 2002	$30M

From these results, the study concluded that MSAT would generate significant returns that would benefit the RCC industry.

Recommendations

The RCC industry in Canada is undergoing a transformation in light of the ongoing changes in the technology, regulation, and market demand for personal and data communications. The dramatic pace at which end-user products are becoming available will require high investment and new approaches to networking.

Within this context, the study recommended that in order for MSAT to be successful, attention needs to be directed towards:

- a strong and comprehensive marketing plan on a regional as well as nationwide basis;
- participation in the DOC PLCP;
- establishment of a fair competition policy, especially vis-à-vis telcos and Telesat's service subsidiary;
- compatibility of MSAT services between Canada and the United States, and, where possible, a provision for compatibility with other terrestrial technologies;
- establishment of a favorable regulatory and institutional environment.

The above recommendations were based on an extensive survey of the RCC industry and indicate a real need to continue the consultative and planning process that has already begun.

STUDY TO ASSESS THE IMPACTS AND OPPORTUNITIES BY MSAT TO THE TELECOM CANADA FORUM TELEPHONE COMPANIES

The MSAT telco opportunity assessment study was performed by Telecom Canada on behalf of the 15 telephone companies forming the Telecom Canada Forum. The objectives of the study were as follows:

- to determine the potential market for two generations of services from each of the Forum member's perspective;

- to assess the impact of MSAT on the existing service;
- to analyze the economic viability of the MSAT service;
- to analyze the policy, regulatory and institutional issues associated with the implementation of MSAT;
- to examine the technical issues associated with the integration of MSAT into existing telephone company networks.

Main findings of the study

Today, the telcos supply mobile radio and telephone services to about 125,000 users. According to the study, the introduction of MSAT will have a negligible impact on the existing telco business, mainly because the perceived higher cost of MSAT over the existing services will limit its competitiveness.

The telcos responding to the survey estimated their demand for MSAT services by the year 2001 to be about 17,000 users, primarily in the MTS. The results of the survey and a comparison with Telesat's baseline regional forecast are shown in the following table. It reveals the differences in the perception of regional markets of telcos and Telesat, although the totals are quite similar:

Table 3: MSAT user forecasts

Mobile telephone (MTS)

	Telco estimate	Telesat estimate
AGT & Edmonton Tel	182	3,713
BC Tel	4,277	4,104
Bell Canada		
Ontario	7,191	5,081
Quebec	4,257	2,990
Island Tel	0	60
Manitoba Tel	89	977
Maritime Tel & Tel	113	332
NBTel	375	420
Nfld Tel	62	166
Quebec Tel	332	332
Sasktel	450	1,173
Total	17,328	19,348

While the actual financial results for the individual companies are confidential, all nine responding telcos reported a positive impact of MSAT (measured by NPV and by a rate of return on capital) on their overall business. They expressed concern, however, about the relatively long payback period associated with the investment in the MSAT equipment, although the investment itself is comparatively small.

Among other issues addressed by the study was the question of the appropriate numbering plan for MSAT, and the technical aspects of the MSAT interconnection with the PSTN.

Conclusions and recommendations

As can be expected, the telcos expressed a range of opinions on the various aspects of MSAT. Of particular concern was the market forecast itself, and the role of Telesat in the marketing and sale of MSAT services directly to end-users. Other areas of concern were the regulatory and institutional issues, which, although addressed by various MSAT policy discussion papers, have not yet been finalized by the DOC or the regulatory agencies.

The study indicated that because of the small capital investment required (telcos would purchase the base stations and gateways, but not the terminals) and thus the limited risk involved in providing MSAT service, all responding telcos perceived MSAT as a viable economic undertaking.

The study reported an interest in continued evaluation of the evolving MSAT. The telcos, with their experience in the provision of mobile and fixed telephone services, their direct and indirect involvement in R&D and manufacture of telecommunication equipment, and their very large financial resources, are clearly of vital importance to the success of MSAT.

SOCIAL IMPACTS AND BENEFITS

Social impacts and benefits of MSAT were subject to research and evaluation carried out in a two-part study entitled The Qualitative Description of the Social Impacts of MSAT followed by The Study to Evaluate the Quantitative Social Impacts and Additional User Benefits of MSAT. The time frame addressed was 1989-2002.

Objectives

Social impacts take on a variety of manifestations and are either unquantifiable or only indirectly quantifiable in monetary terms. They may occur at the individual, organizational or societal level over varying lengths of time. They are usually indirect in the sense that they involve parties additional to the direct providers or consumers of MSAT services.

The objectives of this study were:

. determination of the relevance of specific social impact areas to the MSAT Program;

. indication of potential magnitude and likelihood of occurrence of a wide range of impacts;

. assessment of the impact of MSAT on selected policy goals defined by the federal government;

. quantification of selected social benefits and externalities resulting from the implementation and operation of the MSAT system.

Main findings of the study

This pioneering work on social benefits of a new communications technology provided valuable insights into a wide variety of possible non-economic or near-economic impacts of MSAT. Some 70 different impacts were identified in several groups:

. socio-economic,

. organizational/institutional,

. sociological,

. social services,

. policies of federal and provincial governments.

Examples of social impacts and benefits include:

- reduced hazardous work conditions, especially associated with travel and work at remote sites;
- improved effectiveness, efficiency and productivity at various work sites and in the transportation industry;
- substitution of communications for travel and ability to communicate while in transit;
- enhanced environmental protection and monitoring of renewable resources (including forest-fire protection);
- subjective perceived impacts such as relief from isolation, job safety and property protection.

These are secondary and tertiary-level impacts accruing to those working or living in the proposed service areas. All were considered highly likely to occur in the first five to 15 years after the introduction of MSAT service. For the purpose of this study, the emphasis was placed on those social benefits and broader social externalities manifesting some tangible (measurable) aspects, such as saving lives, reducing the compensation payments for health or property damage, and lowering cost because of more effective operations.

The study determined that weighing the externalities in the baseline MSAT scenario and assigning certain "reasonable" economic dollar values to the expected externalities and benefits led to an average of $1,200 of social benefits per mobile annually. This calculation provided externality estimates of close to $40 million annually.

Conclusions

Social benefits and externalities resulting from MSAT are likely to be quite significant. Most types of benefits will start accruing within the first five years of MSAT service. These externalities represent an important addition to the more traditional economic and operational benefits defined in other MSAT studies.

CANADIAN MANUFACTURING

Manufacturing industries, especially those producing mobile radios, antennas, space hardware, advanced microwave electronics, and various software for the control logic of both the space and ground segments, are expected to play a significant role in the supply of the MSAT system components. Woods Gordon researched and analysed the economic impact of MSAT on the Canadian manufacturing industry in their MSAT Manufacturing Impact Study.

Objectives

The main objective of the study was to estimate the industrial and related economic impacts that would be generated if Canadian industry manufactured the MSAT system equipment between 1989 and 2002. This was accomplished by providing the following:

- assessment of the Canadian industry's ability and specific capabilities to develop and produce MSAT equipment for supply in the required time frame;
- assessment of the potential export markets for Canadian-made MSAT equipment;
- estimates of economic, financial and employment impacts for a range of plausible scenarios;
- advice to the DOC on key issues and problems that might interfere with Canada's ability to maximize the potential manufacturing and economic benefits from MSAT.

Main findings of the study

Based on their extensive work, which included a survey of manufacturing companies in mobile radio, space, and other related fields, Woods Gordon identified 31 Canadian companies interested in developing and producing MSAT system equipment. Some firms are current leaders in their respective fields, but many were smaller high-tech firms capable of producing specialized lines of products. For these companies, the combined impact of producing MSAT equipment would add under baseline scenario assumptions:

. 25 percent to their space/MSAT-related sales revenues,

. 17 percent to their space/MSAT-related export sales revenues,

. 26 percent to their space/MSAT-related employment.

MSAT sales would also generate additional profits and taxes.

In dollar terms, Woods Gordon provided this picture of MSAT impacts:

Table 4: Estimated manufacturing impacts 1985-2002 (Base case - in 1984 constant dollars)

Sales revenues	$1,126 million
Operating profits	183 million
Net exports	199 million
GNP contribution	$1,494 million
Employment	33,000 person-years.

In addition to a thorough analysis of manufacturing capabilities and an assessment of domestic sales, Woods Gordon assessed the export market potential in terms of specific equipment sales to various geographical regions. The United States was identified as the best potential market for MSAT and related equipment over the next 10-15 years. Furthermore, new markets could emerge towards the end of the 1990s in Southeast Asia, Australia, Brazil and Mexico.

Conclusions and recommendations

Based on their analysis of the interest and capabilities of Canadian manufacturers, Woods Gordon concluded that domestic firms can make a significant proportion of the MSAT equipment to be sold in this country. Some assistance from the federal government to both the ground segment and space manufacturers might be needed in order to support R&D and defray a portion of preproduction costs.

Although the study made strong assumptions about the ability of Canadian space manufacturers to prime one or more MSAT satellites, these assumptions could well become facts, depending on the final institutional arrangements and procurement agreements between Canada and the United States. In any case, the Canadian manufacturing industry would add significantly to the level of economic activity in Canada due to MSAT and would generate very large benefits for both the private and public sectors.

In order to maximize the industrial and economic benefits, Woods Gordon recommended that the Canadian MSAT be compatible with the American MSAT, that the launch be effected as early as possible to strengthen the export prospects, and that the federal government undertake joint programs with industry to stimulate demand for MSAT in Canada.

A STUDY TO ASSESS THE COMMERCIAL VIABILITY OF MSAT

Telesat Canada, under a contract with the DOC, performed an extensive evaluation of commercial and technical aspects of the proposed MSAT system for Canada in a study entitled MSAT Phase B Commercial Viability Study. Its general objective was to assess the viability of establishing a mobile-satellite service in Canada either as a stand-alone Canadian system or a joint Canadian/American system.

The specific objectives of the study were to:

- assess the Phase B Market Definition and User Benefit Study results to define the role of the future MSAT system;
- define the technical system capable of meeting different market demand levels for satellite mobile radio communications and determine the cost of corresponding satellite systems;
- perform economic and financial investment analyses for candidate systems from the satellite carrier's perspective and assess the risk to Telesat of investment in MSAT;
- identify appropriate marketing approaches, as well as regulatory and policy requirements, and propose a plan for the development of commercial MSAT service in Canada.

While the Telesat study addressed both the technical and economic aspects of MSAT in considerable detail, only the economic and financial findings are summarized below.

Main findings of the study

The user requirements for MSAT, based on the special attributes (such as wide-area coverage, nationwide operation, high reliability and predictable performance) identified by other Phase A and Phase B studies, have been confirmed by this study. The total potential market for MSAT services was estimated by Woods Gordon to be 95,000 units by 1988, growing by 17,000 potential users every year thereafter.

The majority of the demand is expected to originate from transportation, mining and oil and service industries, and from various government users. Ontario, Alberta and British Columbia are expected to account for over 67 percent of all users. Telesat, to develop its economic model, assumed three levels of possible actual market demand, based on findings from other Phase B market studies (the MSAT Market Definition, the Telco Opportunity Assessment, and the RCC Impact Study) and Telesat's own research. The middle level of the market was chosen as a baseline for most of the economic analysis work.

This estimate was based on the following assumptions: the average price of a mobile radio (to the end-user) would be $4,500; the average user would use 150 minutes of airtime a month; the user would be charged $1.50/min. and would also pay a total of $50 in combined monthly charges to Telesat and service-providers.

The voice demand (mobile radio for dispatch, and mobile telephone for interconnected service to PSTN) used in the Telesat study amounted to 35,000 users by the end of the seventh year. This number is the spectrum limit when using a PAMD type spacecraft (for example, RCA 3000) and assuming certain power levels. The baseline scenario assumed that Canada and the United States would jointly procure identical spacecraft and each country would own and operate its own spacecraft and a CCS, including the DAMA.

The corresponding space segment cost was estimated to have a present worth of $133.9M in 1984 dollars. The present worth of revenue generated during the first seven years would be $136.2M, and the NPV of the project, discounted to 1984 at 14 percent, would be $1.1M. These results were based on assumptions of eight percent inflation, 14 percent capital cost, and three percent compounded increase in airtime charges.

While most of the demand for MSAT services is in the form of voice transmission, MSAT is also expected to achieve a substantial penetration of the market for rural and remote data collection, estimated to be 1,200 terminals by 2001. Paging market demand is expected to reach at least 25,000 units by that time. These special markets, although positively identified by Telesat and other market studies, have not been included in the revenue projections.

In addition to the baseline, economic modelling was carried out for higher and lower levels of market demand. While the higher level was considered somewhat speculative, the lower market demand level (the so-called pessimistic scenario) received a good deal of attention in the follow-up Telesat business proposal.

The economic modelling revealed that, in general, the smaller-sized systems showed the best NPVs. The increased revenue potential of larger systems (that is, larger satellites) was not enough to compensate for their higher costs. An antenna gain of eight dB for the mobile terminal was found to be the minimum for serving a large enough number of users to make the system economical. A stand-alone Canadian system did not generate positive results for the market size assumed. All the above findings refer to a one-generation analysis; the MSAT system becomes quite a bit stronger financially in the second generation.

Conclusions

The results of the study indicate that the Canadian satellite operator, Telesat, would opt for a smaller Canada/American joint venture to provide MSAT services. Under this assumption and the baseline market scenario, the NPV of the project is positive, although some financial and technological risks are present.

OVERALL ECONOMIC ANALYSIS OF MSAT

The Phase B program of socio-economic studies culminated with the study of the overall social and economic impacts and benefits due to MSAT. It was performed by Econanalysis Inc. of Toronto, and produced a report entitled The Overall Socio-economic Analysis of the MSAT Project.

Objectives

This major study had three objectives:

- To measure in a systematic and consistent fashion the MSAT project's contribution to the net economic well-being of all Canadians, in order to answer the question of whether the MSAT project would use scarce resources (human and financial) in an economically efficient manner.

  The key measure used was the NPV of MSAT's incremental net economic benefits (gross benefits minus associated costs), discounted by the social discount rate of 10 percent.

- To determine the financial attractiveness of the MSAT project to principal private investors, such as Telesat, potential retailers of the service, and the manufacturers of MSAT equipment.

  The key question from the investor's perspective is whether the expected after-tax returns on investment are sufficient to offset their capital cost. This was measured by NPVs of their respective net cash flows discounted by appropriate private discount rates.

- To determine what government financial assistance, if any, would be justified on economic, financial or social grounds.

Main findings of the study

The methodology for the overall assessment of MSAT was designed to maximize the use of results produced by other Phase B socio-economic studies. These studies produced estimates of MSAT's economic and financial contributions in five key areas: Telesat (as the space segment operator); service providers (RCCs and telcos); manufacturers; the user community; and society at large.

The estimates were fed into the general economic model, which produced the picture of overall financial and socio-economic impacts and benefits. The table below shows the results of the financial analysis under the baseline scenario for two generations, discounted to 1984 by the private discount rates:

Table 5: Financial returns to MSAT key players

NPV of returns to Telesat	$ 32.8 M
NPV of returns to service-providers	$ 58.4 M
NPV of returns to manufacturers	$ 54.6 M
NPV of total returns to private investors	$145.9 M

In addition to the above, the MSAT project would generate other benefits and externalities. These would accrue to the users of MSAT in the form of consumer surplus, that is, the amount that the users would be willing to pay over and above the actual amounts charged by Telesat and the service-providers. Benefits would also be realized by government due to the following externalities: improvements in the foreign exchange balance due to tariffs and net foreign exchange earnings; sales tax earnings; income tax earnings; employment opportunities; tax deductions and externalities foregone due to MSAT. As well, MSAT would generate many indirect social benefits, such as improvements in public security and safety and environmental monitoring and control.

Estimated values for two generations are given below:

Table 6: Overall MSAT socio-economic benefits and impacts

NPV of net cash flows to private investors	$ 145.9 M
NPV of net returns to government	49.6 M
NPV of net other benefits	806.6 M
NPV of indirect social benefits	157.3 M
NPV of total net economic benefits (discounted to 1984)	$1,159.4 M

Table 6 shows the total net contribution of MSAT to the economic well-being of all Canadians, which must be considered when the question of government support is raised.

Theoretically, the maximum amount that the government could spend subsidizing MSAT without producing a negative economic effect on Canadians is the sum of three items: net returns to government, user benefits, and indirect social benefits. This sum, derived from Table 6, is $1,013.5 M under the baseline scenario. In reality, however, only a fraction of this amount may be required as a direct subsidy to various MSAT players, mainly to offset initial start-up cash flow difficulties and to indicate to the private sector the government's commitment to the MSAT Program.

Creation of employment opportunities in manufacturing and communications services industries is one of the stated objectives of the MSAT project. Over the two generations of MSAT, the manufacturing and service activities are expected to generate 14,234 person-years of work in jobs directly linked to the Program, translating into 790 permanent jobs on the average for each of the 18 years under study. About the same number of indirect jobs would be also created in the same time period, for a total of 33,000 person-years.

Conclusions

Econanalysis Inc. found significant economic benefits accruing to manufacturers, service-providers, Telesat, end-users and Canadian society at large from building and operating an MSAT system. The NPVs of various measured component cash flows were found to be highly positive, indicating more than adequate returns on investment to all participants. The study concludes that the MSAT project is a highly desirable one from both the economic and social perspectives.

APPENDIX 7

TELECOMMUNICATIONS POLICY: SPECTRUM MANAGEMENT AND INSTITUTIONAL ARRANGEMENTS

This appendix summarizes the results of the spectrum allocation and co-ordination processes in Phase B together with the in-house DOC comprehensive analysis of the institutional arrangements for MSAT.

APPENDIX 7 - TELECOMMUNICATIONS POLICY: SPECTRUM MANAGEMENT AND INSTITUTIONAL ARRANGEMENTS

SPECTRUM MANAGEMENT AND CO-ORDINATION

General

During Phase B, it was recognized by all prospective participants in MSAT that the allocation of frequencies to operate the MSAT system in Canada was becoming a crucial issue. A great deal of interest had been shown in this area and considerably more effort was needed to ensure the proper discussion and co-ordination of spectrum questions at all levels of various organizations, domestically as well as internationally.

Early in Phase B, the spectrum issues had not yet been sufficiently defined and the actions required were not clear. Spectrum matters were addressed on a regular basis in the MSAT Interdepartmental Planning and Implementation Committee, a body representing various federal departments interested in the MSAT Program and the DOC MSAT Policy Steering Committee. As the issues crystallized, it was recognized that a working group was needed to make use of existing spectrum co-ordination functions in the DOC and to better determine the actions that would lead to approval of the necessary domestic and international frequency allocations. In December 1983, the DOC formed the MSAT Spectrum Co-ordination Sub-committee (SCSC) made up of representatives from various DOC branches and directorates such as Engineering Programs, Radio Spectrum Policy, Network Policy, International Arrangements, International Co-ordination, Spectrum Operations and the MSAT Program office. Telesat was also invited to participate. An action plan was issued that included the required actions, milestones, responsibility areas and interrelationships between these actions.

Of concern were the UHF spectrum (806-890 MHz) needed to communicate directly to the mobiles, small bases and isolated collection platforms; the SHF spectrum (13/11 GHz) needed as feeder links to the large bases, the gateways and the CCS; and finally the L-band spectrum (2 GHz) needed for telemetry, tracking and control (TTAC) of the satellite, the housekeeping duties of the satellite system. Later in the system development it became necessary to consider additional L-band frequencies (1.6/1.5 GHz) for future expansion of the system in view of the enormous demand being placed on the UHF spectrum.

International frequency allocations and co-ordination with the ITU/IFRB

In 1979, the WARC had clearly recognized the need for mobile communications via satellite and had given it status in the International Table of Frequencies for the 806-890 MHz band listed in ITU Radio Regulations. This status is conditional, as indicated by footnote 700 to the Table, which states that the allocation is primary in Region 2 (comprising mainly the Americas). Under the footnote, co-ordination is requested on the use of this spectrum for mobile satellite in countries in Region 2 under Article 14 of the Regulations. Article 14 also calls for co-ordination with the ITU's IFRB under Article 11 in respect of the placing in service of new space stations such as required in MSAT.

Co-ordination under Article 11 first calls for notification to the IFRB in the form of an API giving, to the extent possible at the time, the data in the Radio Regulations Appendix 4 (AP4). This covers the general characteristics and some detailed parameters of the proposed network and invites supplemental data when it becomes available. The IFRB publishes the information, inviting ITU member administrations to respond within four months in regard to the threat of interference with existing networks.

The Article 14 co-ordination, under footnote 700 for example, is somewhat similar and can be done before or simultaneous with the Article 11 co-ordination. It calls for either the above Appendix 4 information about any communications satellites planned to be sent to the IFRB or the much more detailed Appendix 3 (AP3) information when it becomes available. Identification of the administrations to be possibly affected can be included in the submission.

As in the case of Article 11, the IFRB invites comments concerning possible interference within the region concerned and, if there are no objections, approves the changes to the particular spectrum allocations.

Article 11 co-ordination

The required API under Article 11 was submitted to the IFRB in January 1983. It contained information regarding the operation of Canada's MSAT system, but only in the UHF band for mobiles and in the L-band for TTAC frequencies. The API was published in April 1983 and comments were received in June. A corrigendum was added giving further information and published by the IFRB in March 1984.

The requisite AP4 information was to have been sent to the IFRB in due course. By this time, however, the DOC had abandoned the L-band TTAC frequency requirements, since the 2 GHz TTAC would have required a totally new ground station for Telesat and consequently would have been too expensive. It was agreed that Telesat would control the MSAT satellite and use SHF frequencies instead. That left only the UHF band to be co-ordinated under Article 11.

It should be noted that the USSR was the only country to respond to Canada's API under Article 11 and to indicate potential difficulties with the L-band allocation.

Also, in June 1984, an MOU had been signed between the DOC and Telesat, in which Telesat indicated a desire to proceed with the development of a first-generation MSAT system. Since MSAT was no longer a government-led system, the design was to be Telesat's responsibility. Telesat Canada is still today considering various options, including a co-operative system with an American satellite operator as well as a dual-band (UHF/L-band) system. The detailed system parameters for a revision of AP4 are therefore unavailable at this time.

Article 14 co-ordination

In regard to the Article 14 co-ordination under footnote 700, no new API was submitted since it would have contained identical information to the Article 11 submission. Therefore, the second step of providing the AP3 information was adopted at the outset: the co-ordination request was for UHF and SHF TTAC spectrum only. No Article 14 co-ordination is required for any other band since it concerns new satellite implementation.

It should be noted that the L-band spectrum being sought for expansion of future MSAT systems is not yet recognized by the ITU for mobile-satellite systems, only for aeronautical mobile satellite. That will be addressed later in this section.

In regard to the DOC study of L-band use for MSAT, because of the absence of an ITU allocation, the greater mobile power requirement, the higher signal attenuation and the less well developed mobile system technology and higher costs, there is no possibility of L-band being proposed by Canada for the first-generation commercial MSAT service. Nevertheless, L-band represents a sizeable spectrum reserve which could eventually be used in conjunction with the 800 MHz band in accordance with market demand and eventual agreements on international allocation and co-ordination and resolution of objections from the aeronautical community. This will be addressed in the next section.

In December 1983, the co-ordination request in accordance with AP3/4 under Article 14 and footnote 700 for mobile space station frequencies was submitted to the IFRB. Due to administrative delays by the IFRB and the need for additional information, it was not published until March 1985 and reply comments were received from only one country, the United States, in July 1985. The United States could not co-ordinate at that time since their NPRM was in process. The NPRM will determine what bands will be available for the provision of MSS in the United States. If they are different from Canada's bands, there could be potential interference. It was decided to wait until the resolution of the NPRM and the development of a sharing agreement with the United States. This will be further discussed later in the section on the FCC co-ordination. The desirability of a sharing arrangement was predicated on it being mutually beneficial to develop a first-generation MSAT system where engineering costs could be shared and back-up services provided by each country in case of failure.

The Article 14 co-ordination process is therefore dependent upon the successful resolution of a Canadian/American, DOC/FCC agreement on spectrum sharing.

L-band co-ordination for future expansion capability

The last item of interest in the international forum concerns the L-band (1.6/1.5 GHz) requirements for expansion of MSAT future systems. Department of Transport (DOT) and DOC members of the CIC formed a working group to formulate a Canadian position on the expansion of MSS services into the L-band. As a result, the following item was submitted to the ITU Administrative Council for inclusion on the 1987 Mobile-WARC Agenda.

> "To make provisions for the mobile-satellite service in the frequency range 500-2500 MHz in one or more of the bands currently allocated on a primary basis to the mobile, radiodetermination, maritime mobile-satellite or aeronautical mobile-satellite services without adverse impact on other radio services."

Discussions have taken place with the DOT to reassure the aeronautical community that any broadening of the aeronautical mobile-satellite band to mobile-satellite would ensure that essential aeronautical communication needs are met. These discussions are detailed in the next section on domestic allocations. An information paper on MSAT and a Canadian position paper on L-band were presented to the ICAO in September 1985. The Canadian proposal was to share the L-band spectrum and broaden the aeronautical mobile-satellite band to include mobile-satellite. The ICAO rejected the Canadian proposal and recommended continued support of the sole aeronautical mobile satellite allocation in the particular part of the L-band. It further recommended that preparation for Mobile WARC '87 reflect this position. Canada will also have to take account of this adverse position by ICAO in preparing for Mobile WARC '87.

Co-ordination with the U.S. Federal Communications Commission

The MSAT system, like other satellite systems, has the capability of distributing its signal over large geographical areas regardless of national boundaries. The MSAT spectrum clearly has to be co-ordinated with the United States and possibily with Mexico, France (St. Pierre and Miquelon) and

Denmark (Greenland). The United States has its own plans for mobile satellite and because of the possibility of interference with terrestrial mobile systems and the common border with Canada, it was expected that co-ordination with the United States would present special difficulties. Since there were more significant problems of a technical nature, it was felt one appropriate forum to use for negotiation was the already-existing DOC-FCC Technical Liaison Committee. MSAT appeared on the Committee's agenda for the first time in October 1982. Several studies have been completed since then, such as:

- Spectrum Options for Mobile Satellite in Canada and the United States, MSAT Program Office, 30 September 1983, revised 12 January 1984.

- Spectrum Options for Mobile Satellite, DTS-S, 20 December 1983.

- Interference Considerations Related to the MSAT System, DSRS, January 1984.

- Spectrum Sharing Considerations for the Mobile Satellite and Land Mobile Services at 800 MHz, DTS, January 1984.

Meetings were arranged with the U.S. State Department and the NTIA. The discussions were complicated because the FCC only has responsibility for managing the spectrum for non-government organizations (mainly commercial). Discussions with the FCC were made sensitive by the fact that NASA, another United States government agency, had petitioned the FCC for a Rulemaking on Mobile-Satellite Services in November 1982. In November 1983, the DOC had signed a Co-operative Arrangement with NASA in order to pursue the development of MSS and mutually share in the technology.

In January 1984, upon request, the DOC provided reply comments to the FCC on Mobilsat and Skylink applications for licences to provide MSS in the United States. These were the first two applicants to show interest in commercializing mobile satellites in that country.

The frequency issues were raised at the senior management level and became an agenda item at the Niagara III meeting in May 1984, attended by the then DOC Deputy Minister, Robert Rabinovitch, and the Chairman of the FCC, Mark Fowler. Both countries agreed to put forth their best efforts in the development of commercial MSS services and therefore ensure timely resolution of the spectrum issues.

Discussions intensified in the Technical Liaison Committee meetings, with the DOC presenting various possible scenarios, their technical parameters and the difficulties surrounding these scenarios. Commercial viability of the MSAT services also became an important issue that would greatly influence the options presented. The technical basis for a revision of the Canada/United States Frequency Sharing Arrangement was being established to take account of mobile-satellite service. This effort was a contributing factor to the FCC's January 1985 issuance of an NPRM which proposed MSS in the 800 MHz band and requested comments also on the possibility of providing L-band services. It requested replies on types and modulation bandwidth as well as spacecraft technology in terms of antenna size, power, frequency reuse factors and market projections. The FCC received 49 sets of reply comments to the proposal.

Along with the NPRM, the FCC put out a Call for Applications to provide MSS in the United States. The Commission received 12 applications, which suggested substantial American interest in a commercial MSS in the United States. In a number of applications, specific reference was made to the value of a joint venture with Canada with reference to discussions which had already taken place with Telesat.

The FCC must now decide on the bands to be allocated to MSS in the United States; this rulemaking is expected to be made sometime in 1986. Following this process will be the issuance of a licence to one of the 12 applicants, or a consortium thereof. Providing a United States operator is chosen by the FCC that is sympathetic to the joint venture concept, it is assumed that co-operation will then ensue with Telesat on the implementation of a first-generation MSAT system. A Canada/United States Frequency Sharing Arrangement will probably follow. These issues were the subject of another senior management meeting that took place in late 1985.

Domestic allocations

After considerable consultation with various users of mobile communications equipment, the DOC released a final draft MSAT radio spectrum policy discussion paper. The paper was the subject of two Canada Gazette notices, one on the 806-890 MHz and L-bands (May 1984) and the other on the 890-960 MHz band (June 1984).

The discussion paper proposed that the sub-bands 821-825 and 866-870 MHz be allocated to MSS on a primary basis and that the 845-851 and 890-896 MHz sub-bands be assigned to mobile-satellite and mobile services on a co-primary basis in reserve, awaiting the market developments of these systems before evaluating further needs. The 1544-1559 and 1646.5-1660.5 MHz sub-bands were also proposed as potential spectrum for expansion of MSS in the future. The policy was established to accommodate the needs of most users with expansion capabilities for future markets. It also attempted to take into account potential co-operative arrangements with such countries as the United States.

Canadian organizations responded extremely well; by the closing date of August 31, 1984, 23 different entities -- from provincial governments to Canadian industry to potential users and service-providers -- had commented on various aspects of the policy.

Several studies were conducted to analyze the interference and compatibility of mobile satellites with existing domestic systems such as the Canadian UHF Tropospheric Scatter System on the Distant Early Warning Line (DEWL).

The Department of Communications has been reviewing the comments provided by the respondents and is preparing the final spectrum policy document. In view of the changing scenarios in both the Canadian and American industries, this policy has taken longer to finalize than was hoped. The statement on spectrum and changes to the Canadian Table of Frequency Allocations were in the process of being finalized at the end of Phase B.

The Department has been consulting with the DOT on the frequency allocations proposed at L-band. The same issues raised at the international level were raised at the national level and are very closely related. The Department of Transport expressed concerns about safeguarding the provision of essential aeronautical MSS in that band. If an international aeronautical system were to be developed, the DOT would like this system to be operable in Canada as well. It was therefore agreed that if Canada proposed to broaden the aeronautical mobile-satellite band to include terrestrial and maritime MSS, it would guarantee the provision of essential aeronautical MSS. A footnote would be added to the Canadian Table of Frequency Allocations to ensure that those essential services would be provided. Other details on the aeronautical mobile-satellite band (L-band) are contained in Chapter 4.

Spectrum conservation issues

On August 31, 1982, the DOC published a document entitled Discussion Paper: Telecommunications Policy Proposals for Mobile Satellite Service, which dealt with, amongst other things, the impact of technological developments on spectrum conservation.

The Department has proposed that MSAT operate in two 4 MHz slots in the 800 MHz frequency band: the 821-825 MHz and 866-870 MHz bands. In comparison to fixed satellite operations at SHF bands, where a 3° to 4° orbital spacing is generally quite adequate to prevent intersystem interference, current mobile-satellite system technology does not generally permit the simultaneous operation of a number of geostationary satellites in the same frequency band.

This restriction, along with the limited amount of spectrum available at 800 MHz, would limit the number of subscribers that could be serviced via a first-generation mobile-satellite system. There is also the possibility that Canada will have to share the available spectrum with the United States. To offset these constraints, and to achieve the most efficient use of the spectrum, the DOC has proposed a basic 5 kHz channelling plan with 45 MHz duplex separation for mobile-satellite operations.

INSTITUTIONAL ARRANGEMENTS

The evolving telecommunications environment

A number of actions that the DOC and the CRTC have recently taken are intended to decrease regulatory barriers and foster competition and increased user choice in the selection of telecommunications equipment and services. Among them were the following:

- Most of the barriers to the attachment of end-user terminals to the telephone network have been lifted.

  Users may buy or lease terminals of all types (including telephone sets) from any source they wish, provided the terminals comply with certain performance standards initially set by the DOC and later adopted by both the Canadian Standards Association (CSA) and the CRTC.

- The CNCP has been permitted by the CRTC to offer private-line service in Ontario, Quebec and British Columbia in competition with the telephone companies.

- The CRTC decision to permit mobile radio systems to be interconnected to the PSTN under certain conditions was a landmark decision for mobile satellite.

- The CRTC, in a relatively recent decision, now permits Telesat to offer certain satellite services directly to the end-user rather than through an intermediary organization.

  These decisions, coupled with similar (and even) more liberal policies adopted in the United States, point to the need for flexibility in MSAT institutional arrangements now being planned for implementation in 1990. This requirement has been an important factor in formulating the MSAT telecommunications policy proposals.

The consultation process

During the two-year span of Phase B, institutional arrangements for MSAT were subject to discussion in the PLCP working group meetings between the DOC and the federal government users, the CRCCA, Telecom Canada and the provincial governments. The following aspects of the institutional arrangements were examined in detail during Phase B:

- nomination of the satellite carrier and space segment manager,
- rate regulation and licensing of the space segment service,
- nomination of the providers of end-user services,
- rate regulation and licensing of the end-user services,
- competition in the provision of end-user hardware and services.

Many contentious issues arose in discussion of the above and a degree of consensus was reached in advance of the formal DOC policy public consultation activity using the Canada Gazette process. For instance, it was established that the potential threat of MSAT as a bypass for toll telephony did not represent a major issue for the telephone carriers and any possible objections would relate to precedent only. Similarly, for other service aspects, most parties agreed that it would be reasonable to permit some remote fixed services; on the question of which service-providers should be permitted to offer what services, the telephone companies felt that the process of MTS should be limited to telephone carriers whereas the RCCs felt that they should be allowed to offer the service.

Telesat Canada up to now has been a telecommunications carriers' carrier and in this role could sell service only to other carriers and not directly to end-users. Telesat very strongly expressed the opinion that it should be allowed to offer MSAT end-user services. This request was ultimately accepted by most carriers provided there would be sufficient safeguards that Telesat, being the satellite operator, would not derive an unfair competitive advantage over the others.

Provincial governments commented from an end-user perspective: they were generally in agreement with the proposed policies and favored an environment allowing the maximum freedom of choice for the user.

The private-sector end-user suggestions and preferences were sampled primarily through the interfaces generated for the PLCP. They too favored, overwhelmingly, maximum freedom of choice in both type and source of services.

The results of consultation: policy proposals

The comments and suggestions received from all parties were reflected, as much as possible, in the official policy proposals issued on August 31, 1984 in the DOC discussion paper, Telecommunications Policy Proposals for Mobile Satellite Service. In addition to inviting comment on key spectrum issues, it invited comment on the following institutional arrangements proposals.

Satellite and earth-station licensing proposals

The Department proposed that the licensing policies currently applicable to mobile and base stations operating in the conventional terrestrial radio services, and the policies that will apply to satellite earth stations effective April 1986, be extended to mobile and base stations used with MSAT. These policies allow any person to apply for a radio licence to own and operate a radio station. Before a licence is issued, mobile stations operating with the existing terrestrial mobile telephone service must show evidence of a contractual arrangement with the operator of the service. Similar rules will apply to transmit earth stations in the fixed satellite service.

Radio station frequency licensing proposals

The Department, in the past, exercised its responsibility to assign each single frequency within pre-established national and regional frequency allocation plans. For the MSAT system, the Department believed it might be necessary to suballocate frequency channels to certain mobile-satellite services, some of which may develop at a slower pace than others. To ensure the future growth of the new mobile-satellite services, it might be necessary to dedicate a minimum amount of spectrum for each of the proposed end-user services with the remaining nondedicated spectrum available on a first-come-first-served basis. This approach could, however, affect overall spectrum utilization efficiency if the suballocations did not correspond to the realities of the marketplace.

Services and equipment compatibility proposals

A joint venture arrangement was proposed with American authorities, so that equipment and services could be standardized across North America. As the same frequency channelling plan and possibly the same basic mobile equipment could be used for MSRS and Mobile-satellite telephone service (MSTS), the DOC expressed the view that equipment compatibility between MSAT services was also technically feasible.

MSRS proposals

The Department was of the opinion that the current terrestrial mobile radio service infrastructure meets the needs of large and small users, and that a similar infrastructure should be permitted to evolve to meet the needs of MSAT service users. It was, however, envisaged that the service requirements of MSAT users would be slightly different from those of the existing terrestrial mobile radio service users: the MSAT service would mainly be of interest to users in unserved or underserved areas, or those requiring extended service area coverage or long-range mobile communications.

The Department did not intend to limit access to MSAT for any class of users. However, it could well be that the needs of small users could best be served by RCCs, which could arrange for the sharing of base station and other high-cost facilities.

MSTS proposals

Three possible approaches to the provision of MSTS service are given in the discussion paper. In the first scenario, all MSTS customers, whatever their location in Canada, would be served by Telesat. A second approach would be for each major telephone company to establish a gateway station at some convenient point within its operating territory to provide a connection to the PSTN.

A third scenario would be to license one or more other entities to provide MSTS service in competition with Telesat and/or the telephone company, similar to the arrangements in the cellular mobile radio service established as a result of the licensing of CANTEL.

Conditions for operation, billing, settlement of revenues and interconnection arrangements were proposed in the paper.

The Department is aware that any of the three scenarios described above could raise jurisdictional and regulatory issues. It is the DOC's view that the needs of underserved mobile users should take precedence over jurisdictional concerns. A slight modification of the existing institutional approach to the provision of telecommunications, so as to accommodate the needs of mobile users, would be preferable to the development of new and potentially costly institutional structures whose only purpose would be to extend the jurisdictional and regulatory status quo to the provision of new services.

Mobile-satellite remote telephone service (MSRTS) proposals

The mobile-satellite system is primarily designed to provide service to and between mobile terminals, such as radio-equipped vehicles. However, recent departmental studies have identified the existence of a possible market for provision of a basic conventional telephone service to locations that, for technical or economic reasons, are not currently served by a terrestrial fixed telephone infrastructure. Noting that telecommunications access to remote camps, provincial and federal parks, isolated houses, farms in remote areas and unserved northern communities is of prime importance to all levels of government, the Department proposed not to prohibit the use of the MSAT satellite to provide basic conventional domestic telephone services. The use of MSAT for this purpose should, however, be considered an interim measure that would be phased out as other alternatives to the fixed satellite service are brought into use.

Service providers for other mobile-satellite services proposals

Other potential mobile-satellite services are not well defined due to the newness of the product and the technology; in addition, the forecasted launch time (late 1980s) is far enough away to hinder the interpretation and extrapolation of the different market study conclusions. Such services include the nationwide paging service, the data acquisition and control service, and the data transmission service described earlier.

Opportunities for Canadian industry

Mobile-satellite technology was viewed as presenting significant opportunities for Canadian manufacturers of both the space and terrestrial components of an MSAT system. A substantial domestic market was foreseen as necessary to support the establishment of a viable Canadian mobile-satellite system on a long-term basis. Canadian industry's successful deployment of this new technology could also lead to export market opportunities. Accordingly, the DOC indicated its intention to continue its efforts to ensure to the maximum extent practicable that Canadian research, design and industrial personnel, technology and facilities are used to maximize Canadian content in the space and terrestrial components and to optimize economic benefits to Canada.

In reply to the above discussion paper, some 50 responses were received from governments, service-providers, manufacturers and individual users. There was overwhelming support of MSAT as a whole and a number of suggestions were included on individual issues raised in the paper. Only six expressed doubt or disapproval for the MSAT concept: the respondents felt either that MSAT would compete with services provided by them or that MSAT would not provide any significant benefits to them. Of the more than 40 supportive responses, at least half were enthusiastic at the prospect of either marketing or receiving the versatile satellite services to be offered via MSAT.

The Department of Communications is presently assessing all comments and other inputs and will be issuing its final policy paper on MSAT in due course.

REFERENCES

REFERENCES

A. SOCIO-ECONOMIC STUDIES

R1. The Market for MSAT Services: Study to Determine Future Market for Mobile Satellite (MSAT) Services in Canada and the Benefits Accruing to Users. Woods Gordon Management Consultants. June 1984. DSS OSM 82-00014. DOC 36001-2-4-4330.

R2. The Manufacturing Impact Study: System Definition, Industry Capabilities Analysis, Export Market Analysis, Impact Analysis. Woods Gordon Management Consultants. March 1985.

R3. The Qualitative Description of the Social Impacts of MSAT. Wescom Communications Studies and Research Ltd. April 1984. 01SM 3611-2-4454.

R4. Study to Evaluate the Quantitative Social Impacts and Additional User Benefits of MSAT. Wescom Communications Studies and Research Ltd. April 1985. 01SM 36100-4-4009.

R5. Study to Assess The Impact of MSAT on Radio Common Carriers. KVA Communications and Electronics Co. April 1985. OSM 83-0008. DOC 36100-3-0150.

R6. MSAT Telco Opportunity Assessment, (Interim Report). Telecom Canada. December 1984. OSM 83-00011.

R7. MSAT Phase B Commercial Viability Study. Telesat Canada. January 1985.

R8. A Satellite Based Mobile Communication System for Canada: MS Business Proposal. Telesat Canada. February 1985. DSS 01SM 36100-4-4082.

R9. The Overall Socio-Economic Analysis of the MSAT Project Program. Econanalysis Inc. May 1985. DSS 36100-3-0278.

B. POLICY PAPERS (CANADA GAZETTE NOTICES)

R10. Spectrum Reallocation Relating to Mobile Satellite Service. May 1984. DGTP-003-84/DGTR-014-84.

R11. Proposed Changes to the Canadian Table of Frequency Allocations and Proposed Spectrum Utilization Policy for the Fixed, Mobile, Radio Location, Mobile Satellite and Amateur Services in 890-960 MHz. May 1984. DGTP-006-84/TRS-015-84.

R12. Discussion Paper: Telecommunications Policy Proposals for Mobile Satellite Service. August 1984. DGTP-007-84.

C. POST-LAUNCH COMMUNICATIONS PROGRAM

R13. MSAT Users' Guide.

D. GROUND SEGMENT

R14. MSAT Data Services Study. Mobile Data International. April 1983. DOC-CR-SP-83-041.

R15. MSAT SHF Ground Station. SED Systems Inc. June 1984. DOC-CR-84-029.

R16. MSAT Mobile Telephone Service - Definition and Development of UHF NBFM Terminals. Glenayre Electronics Ltd. April 1984. DOC-CR-94-030.

R17. Definition and Development of the UHF Ground Terminals (PELPC/DMSK). SPAR Aerospace Ltd. July 1984. DOC-CR-84-031.

R18. MSAT MRS DAMA System Definition Study. Miller Communications Systems Ltd. July 1984. DOC-CR-84-033.

R19. MSAT UHF Antenna Study. Canadian Astronautics Ltd. November 1983. DOC-CR-84-034.

R20. Study of a Frequency Control System and Prototype Development of Frequency Sources and Synthesizers for the Mobile Satellilte (MSAT) System Mobile Terminals, (Phase II Report). SPAR Aerospace Ltd. October 1983. DOC-CR-84-035.

R21. Definition Study to Determine the Technical Requirements and Develop Cost Estimates for MSAT Data Services. Miller Communications Systems. September 1984. DOC-CR-84-049.

R22. Design, Performance Analysis and Implementation of a (56,48) Single Error Correcting and Single Burst Detecting Block Code Compatible with the CRC Designed Linear Prediction (LPC) Vocoder. Binary Communications Inc. 29 March 1985. DOC-CR-85-XXX.

R23. Definition and Development of the UHF Ground Terminals (ACSSB). ADGA Ltd. May 1985. DOC-CR-85-XXX.

E. SPACE SEGMENT STUDIES

R24. MSAT Spacecraft Design Definition Phase. SPAR Aerospace Ltd. October, 1984. DOC-CR-84-038.