A STUDY ON LONG-TERM SATELLITE COMMUNICATIONS STRATEGY

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Work carried out by: K.E. Hancock
A.H. Vandenham
R.M. Dohoo
Dr. C.R. Haslam
Dr. A.U. Sheikh
Dr. J.M. Barry
D.A. Ford
C.O. Cavell
J.D. Murphy

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Approved by: K.E. Hancock
President

GLOSSARY

ACTS	Advanced Communications Technology Satellite
ACTV	Advanced Compatible Television Systems
AOTS	Advanced Orbital Test System
ATM	Asynchronous Transfer Mode
B-ISDN	Broadband Integrated Services Digital Network
BSS	Broadcast Satellite Service
C Band	6 GHz (Uplink)/4 GHz (Downlink) Fixed Satellite Service (FSS) Frequency Band (Shared with Terrestrial Microwave)
CANCOM	Canadian Satellite Communications Inc.
CBC	Canadian Broadcasting Corporation
CCITT	International Consultive Committee on Telephone & Telegraph
CNCP	Canadian National/Canadian Pacific Telecommunications
CRC	Communications Research Center
CTV	Canadian Television (Network)
DBS	Direct Broadcast Service
DEA	Department of External Affairs
DFL	David Florida Laboratories
DIST	Department of Industry, Science and Technology
DND	Department of National Defence
DOC	Department of Communications
DSP	Digital Signal Processor
EHF	Extremely High Frequency
ESA	European Space Agency
FCC	Federal Communications Commission
FEC	Forward Error Correction
FSS	Fixed Satellite Service
FTA	Free Trade Agreement
GaAs	Gallium Arsenide
GEO	Geostationary Earth Orbit
HD-MAC	High-Definition - Multiplexed Analogue Carriers
HDTV	High Definition Television
HPA	High Power Amplifier
HSAT	VSAT operating at European Primary Rate (2.048 Mbit/s)
INMARSAT	International Maritime Satellite Organization
INTELSAT	International Telecommunications Satellite Organizations
IOL	Inter-Orbit Links
ISC	International Switching Centres
ISDN	Integrated Services Digital Network
ISL	Inter-Satellite Link
Ka Band	30 GHz (Uplink)/20 GHz (Downlink) Fixed and Mobile Satellite Service (FSS;MSS) Frequency Band

Ku Band	14 GHz (Uplink)/12 GHz (Downlink) Fixed Satellite Service (FSS) Frequency Band. Also used for Broadcasting Satellite Service (BSS) in Europe and Japan.
L Band	1530 to 1660 MHz Mobile Satellite Service (MSS) Frequency Band
LAN	Local Area Network
LEO	Low-Earth Orbit
LNA	Low Noise Amplifiers
MF	Multiple Frequencies
MMIC	Millimeter Wave Integrated Circuits
MSAT	Mobile Satellite
MSS	Mobile Satellite Services
MUSE	Multiple Sub-Niquist Sampling Encoding
NASA	National Aeronautical Space Agency
NBC	National Broadcasting Corporation
NEC	Nippon Electronics Company
NRCC	National Research Council of Canada
NSERC	National Science and Engineering Research Council
NTSC	National Television Standards Committee
OBP	On-Board Processing
OBS	On-Board Switching
PDSN	Public Data Services Network
PEMD	Program for Export Market Development
PSK	Phase Shift Keying
PSTN	Public Switched Telephone Network
PTT	Post, Telephone and Telegraph (European National Telephone Company)
RCA	Radio Corporation of America
RDSS	Radio Determination Satellite System
RF	Radio Frequency
RS	Reed Solomon (code)
SAW	Surface Acoustic Wave
SCPC	Single Channel per Carrier
SSPA	Solid State Power Amplifier
TDM	Time Division Multiplexer
TDMA	Time Division Multiple Access
TMI	Telesat Mobile Inc.
TSAT	VSAT operating at North American Primary Rate (1.544 Mbit/s)
TVRO	Television Receive-Only (Earth Station)
UPP	Unsolicited Proposal Program
VLSI	Very Large Scale Integrated
VSAT	Very Small Aperture Terminal

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Scientific authority : Ed Skomorosky
Drina Streibl

NOTE TO READERS:

This study of a long-term satellite communications strategy was commissioned by the Department of Communications and jointly sponsored by the Canadian Space Agency, Telesat Canada and Spar Aerospace Limited. The study is intended to stimulate the discussion of future options and policies and presents the views of the authors and the views of those who were interviewed by the authors. No commitment for future action should be inferred from the contents of this report, and publication and distribution of this report does not constitute approval of the findings or conclusions by the sponsors.

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EXECUTIVE SUMMARY

Over the last five years or so, significant changes have taken place in the satellite communications field, and in the telecommunications and broadcast industries it serves.

These include, among others, the large scale adoption of fibre optic distribution technology by the majority of the developed world's public switched networks for both terrestrial and submarine applications; significant delays in the future of satellite communications caused by the Challenger disaster and a long string of U.S. and European launch failures; and the evolution of three well-defined and strongly competitive Western world telecommunications trading blocks, namely:

- The U.S. and Canada
- The European Community
- Japan and its Pacific rim neighbours

These matters, together with the potential impact on the ability of the Canadian industry to penetrate the consolidated European telecommunications market beyond 1992, and the advent of Canada - U.S. Free Trade, are major issues which require advanced planning.

To ensure that Canada is well served domestically and at the same time maintains and expands its position in the world satellite communications market in the face of changing technology, and a more rigid alignment of international trading groups, the Department of Communications is developing a Long-Term Satellite Communications Strategic Policy.

This study has been commissioned by DOC, together with the Canadian Space Agency, Spar Aerospace Limited and Telesat Canada as co-sponsors, **to provide thoroughly researched inputs to the elements of the strategy and specific recommendations for strategic approaches to meeting the objective of maintaining and expanding Canada's position in the world satellite communications market.**

A further purpose of this study is **to provide a joint focus for the future and to identify to each of the sponsors, in a manner that would fulfil their individual mandates, the technology trends, uses and needs of Canadian and worldwide markets for satellite communications in the period up to the year 2010.**

The study has been carried out in four main phases or tasks as follows:

- Future Technology and Market Assessment and Analysis
- Canadian Capabilities and Market Share Projections
- Government Assistance Mechanisms
- Cost-Benefit Analysis

The prime output of the first phase, *Future Technology and Market Assessment*, was two-fold:

- New communications satellite technologies required in the future

- The total future market, from a strategic sense, for satellite system products and services

In identifying the new technology required, inputs were obtained from a wide variety of sources and analyzed in detail.

In reviewing these outputs and assessing the likely role of terrestrial and satellite based telecommunications networks over the next twenty years a key common thread was identified. This common thread was the fact that all manufacturing and service sources concurred that new development would be market-driven and based upon clearly identified applications which exploited appropriate new technologies to the maximum. There was little or no evidence of a technology-driven telecommunications environment over the next twenty years although new technologies will certainly be exploited to meet both current and new market demands. However the Canadian and International regulatory environments are also expected to exert a major impact on the strength and viability of satellite communications in the future.

Notwithstanding this, it is recognized that it is necessary for applied research to be carried out by government and universities to provide the source knowledge for future technological developments to keep Canada competitive in the world markets. in particular applied research is required on:

- Mobile personal communications via satellites

- EHF propagation studies and research into fading countermeasures

- Advanced high-speed, satellite oriented protocols such as the Asynchronous Transfer Mode

- EHF Components

- Flexible system and payload architectures capable of interfacing with terrestrial networks

- Satellite antenna technologies including inflatable and phased array antennas

- Network management including channel assignment techniques and software defined (and modifiable) networks.

In character with these findings were reasonably consistent opinions as to the most appropriate technologies for each distribution mode. In identifying future telecommunications satellite markets and technologies, it was deemed appropriate to classify the technology findings of the first phase under nine applications headings.

In analyzing these technologies which, during the next two decades, are most likely to be used in satellite networks or in both terrestrial and satellite distribution modes, the following conclusions were reached.

One-Way Video Networks

TV distribution both to terrestrial transmitters or processing points, and direct-to-the-home will remain the dominant application for communications satellites over the next two decades for all three trading blocks. In North America, such distribution is likely to continue using the fixed satellite service (FSS), albeit in part, using some form of advanced television system. At the moment it appears almost inevitable that North America will select an advanced TV system compatible with current NTSC receivers. In the European and Japanese trading blocks, the broadcast satellite service (BSS) is likely to be used primarily for direct-to-home or to cable TV head ends. In both cases it appears quite possible that regional HDTV standards will be selected, HD-MAC in the case of Europe and MUSE in the case of Japan. The distribution of HDTV via these technologies is likely to use primarily high powered DBS, and to a lesser extent FSS satellites.

Public Switched Point-to-Point Voice, Data and ISDN Networks

Although this is an application where on a worldwide basis the main distribution methodology will be terrestrial fibre optics, in all three trading blocks some use of satellite technology is envisioned. In North America there is little indication that this will be other than comparatively minor use of essentially unprocessed point-to-point trunk facilities particularly for service restoration.

However in both Europe and Japan there is currently considerable research into the possibility of integrating point-to-point satellite elements directly into the terrestrial public-switched network by means of on-board switching, beam switching and smart earth station technology. The market here is for back-up routing and for light routes. These satellite-based technologies are likely to be developed into pre-revenue producing payloads during the period under review.

Private Point-to-Point Voice and Data Networks

The technology considerations that apply to common carrier point-to-point voice and data networks apply more strongly to developing private point-to-point voice and data networks. The slow but significant deregulatory thrusts in Canada, Europe and Japan are likely to encourage private networks and the use of satellites as a distribution medium to overcome rights-of-way and other problems. In addition, the on-board switching requirements for private networks are likely to be less sophisticated, and perhaps more easily achieved than those for the common carriers. Consequently, private systems are likely to be the driver, or catalyst in this field.

Public Switched Point-to-Multipoint Two-Way Networks

This application and the technology relating to it is practical only with satellite implementation. Inputs indicate that significant development of cost-effective *hubless* mesh-network high capacity (at least 2 Mbps) VSAT systems in North America and Europe will be an area of significant technology development over the next two decades. In particular satellite-based hub switching and network management systems are areas requiring innovative technological approaches.

Private Point-to-Multipoint Interactive Networks

The comments made above for common carrier Point-to-Multipoint Interactive Networks apply equally to the private sector networks of this type except that star-networks are likely to predominate over mesh networks due to the *head office to branch* requirements of many private networks.

Private Point-to-Multipoint One-Way Data and Audio Distribution Networks

Again, communications satellites are the preferred technology for this application. However the technology used is essentially mature and little or no further development is foreseen during the period under review.

Mobile Networks

Under this heading are included cellular systems, dedicated mobile voice and data networks and one-way paging networks, all of them being considered for the land, maritime and aeronautical services. In the latter part of the period of concern, satellite based mobile personal communications are likely to be the major technological thrust in this area.

Currently the only one of these applications that uses communications satellites to any extent is the Maritime Mobile Service for which INMARSAT has the monopoly. INMARSAT has plans for considerable expansion over the next two decades aimed at smaller and smaller vessels. The technological requirement here is for lower cost shipboard equipment meeting the new INMARSAT standards for smaller vessels.

The aeronautical mobile field has up to now been wholly dominated by terrestrial technology despite gaps in coverage over the major oceans for air traffic control, company and public communications. There is every indication that over the next two decades all of these applications will be fulfilled by communications satellites. Technological advances will be required both in the space segment and in the airborne segment. It is considered likely that the current terrestrial aeronautical systems will continue in parallel with the satellite networks with only minor overlap.

In contrast the land mobile market is likely to be an area of considerable competition. Cellular and private land mobile networks are currently firmly entrenched and expanding. The first domestic mobile satellites, the Canadian/U.S. MSAT system is planned for launch in 1993. While there are specific market niches, specifically in remote and mountainous areas, and for long distance data, for this technology there will be considerable terrestrially-based competition. Nevertheless, considerable technology development is required, particularly for ground segment equipment.

It should be noted that Telesat Mobile Inc. (TMI) is currently carrying out pre-MSAT market development using the INMARSAT space segment.

Data Collection Networks for Space-Based Sensors

Currently this data collection is carried out by tracking earth stations that access military and civilian remote sensing satellites for the comparatively brief period that they are in the field of view of the earth station. Data which had been stored in recording machines on board the remote sensing satellite is transmitted at high speed to the earth station.

Over the next two decades, it is most likely that inter-orbit links will take over this function providing real-time access while eliminating the non-productive recorders from the remote sensing satellite.

New technology required is likely to include optical and millimeter wave transponders, antennas and tracking apparatus.

Data Collection Networks for Ground-Based Sensors

To date, this has been almost wholly a terrestrial network application except for some meteorological (GOES) satellite application. In general terms this is likely to continue, although for a number of remote networks, particularly those serving environmental needs, communications satellites are likely to be more cost-effective, flexible and adaptable. It is unlikely that new technology would be required, only minor modifications to current VSAT networks.

While the study identified considerable detail on potential future markets for specific applications, as the prime objective of this study is to define strategy, this detail has been confined to the main body of the report. From a strategic viewpoint, it was the consensus of the project team that the market for satellite communications over the next twenty years would develop primarily in the following general applications areas, given in order of potential share (by value) of the worldwide satellite communications market:

- Distribution of entertainment television (HDTV and Standard Definition) and audio in point-to-point, point-to-multipoint (FSS) and broadcast modes (BSS, primarily in Europe and Japan)

- Point-to-Multipoint one-way (from hub) and two-way distribution of low, medium and high speed data, analog and digital voice and analog and digital video. This application is likely to be comprised of both shared and unshared networks operated by both common carrier and private entities serving a multitude of markets including, but not necessarily limited to, specialized information services, business video, voice and audio services and the like. This general categorization identifies the current VSAT networks and their future developments including the hubless (switching and processing in satellite) VSAT and the extension of the concept to multi-megabit data rates to accommodate one-way and two-way business video. It also includes hybrid space-terrestrial networks for load-sharing, diversity and restoration.

- Mobile satellite services (MSS) including the proliferation of maritime satellite services; the development and rapid expansion of aeronautical satellite services including those for navigation, trans-oceanic communication, company and public message use; the implementation and development of voice and data land mobile satellite service; and the evolutionary achievement of personal universal mobile communications, capable of worldwide use in all three modes. (Implementation expected in the latter quarter of the period under review).

- Point-to-point, light to heavy trunk telecommunications service interconnecting with the public switched voice and data network as an integral part of that network. Prime applications will be for load sharing and trunk restoration.

- Inter-orbit and inter-satellite links providing service to the remote sensing industry (IOL) and to international point-to-point, heavy route video voice and data traffic (ISL aimed toward the avoidance of double-hops, spectrum conservation and overall system cost reductions.)

Given the time frame considered (the next two decades), it is not considered possible to identify, to any acceptable confidence level, the precise percentages each of these application groups will attract of the satellite communications market as a whole, or indeed to give a very high confidence level to the order of priority given above.

However, a consensus has been reached by the project team that acceptable confidence can be given to the five applications groupings given above, and that future satellites and their payloads should be developed around these five groups to provide the services, and flexibility of services, demanded by the specific market segments as they develop. Thus the need will be for flexible, multi-purpose payloads capable of modification of payload priorities whilst in service.

Given the long gestation period of communications satellites, those planned for launch in the next five years have almost certainly been defined at this time, with most of them in the advanced stages of development. For the following decade, it is likely that in most cases initial planning is underway. Therefore the approach taken to verify the consensus for the communications satellite market over the next 15 years (about the limit for fact-based forecasts) was to identify and review in detail the communications satellite launch plans for the three western world telecommunications trading blocks for the period up to 2005.

This review confirmed to the degree possible the consensus identified above.

In analyzing the overall communications satellite market, the next 15 year period was broken down into the time groups of 1989 to 1993; 1994 to 1999, and the years 2000 to 2005.

The satellites in the first period, 1989 to 1993, are either in the final phases of test, or nearing completion or are already tendered for. Thus the strategic market impact of the satellites is minimal. Thus for the purposes of this study the period 1994 and beyond is the one of most interest.

During the 1994 to 1999 time period it was interesting to note that the number of communications satellites planned to be supplied to Europe is 23 compared with 11 for all of North and South America and 14 for Japan, the Far East and Australia. If the international organizations are taken into account and assigning INMARSAT to the European total and INTELSAT to the U.S. total, the figures are 29 for Europe as compared with 15 for the United States. However due to slippages in the 1989 to 1993 time frame, these figures may change upward for all groups.

It should also be noted that, in line with the consensus, many satellites are multi-service and multi-band and the trend is toward payloads for the newer applications such as broadcast service satellites, mobile service satellites and inter-orbit/inter-satellite links. Also of interest is the continuing trend away from the C Band to the Ku and Ka Bands for fixed satellite services. Perhaps of even greater interest is the fact that Europe, closely followed by Japan, is aggressively pursuing all of these trends (with the exception of the use of Ku Band) with Canada, U.S. (with the exception of the much cancelled and then restored ACTS satellite) and the rest of North America tending to continue with the traditional satellite technologies. It should be noted however, that in the case of Canada, this is based upon the assumption that Anik F would be a straight C/Ku Band replacement for Anik E, an assumption which could well be modified by future Canadian satellite communication strategies.

It is also interesting to note that on a worldwide basis for the same five year period, the forecast requirement is 58 satellites or essentially one a month for the whole five years.

The military satellite communications market is of course one of considerable extent particularly in the United States and in Europe. However all interviewees noted that despite the various agreements between Canada and the U.S., the U.S. military market was one which was virtually impossible to penetrate. There are a few minor exceptions to this, particularly with regard to RF sub-systems and components.

The situation is possibly more difficult in Europe. Notwithstanding this, a number of minor sub-contracts for sub-systems and components for U.K. military satellite communications have been obtained by at least one Canadian company.

The Canadian military market for satellite communications equipment is comparatively small and subject to change. At the moment there is reasonable activity, particularly for Ka Band (20/40 GHz) research and development, systems design and earth station hardware development. Unfortunately it has not been possible to obtain definitive information on DND's satellite communications requirements over the next twenty years.

The second phase of the study *Canadian Capabilities and Market Share Projections,* received inputs not only from Phase One but from a virtually one hundred per cent sampling of the Canadian Space Industry, both manufacturing and service; from many Canadian users; and from all relevant government departments.

Canadian communications satellite capabilities and the relative capability of Canadian industry vis-a-vis foreign competition was evaluated for 30 different market sectors. For each market sector, an evaluation of each company was carried out based upon the eight rating factors below. It should be emphasized that the categories and ratings were developed with respect to the requirements and capabilities needed for the next two decades rather than in relation to the current situations. The eight rating factors were broken down into two groups. The first group was specific to the product, service or technology under consideration and consisted of the following:

- R & D capabilities
- Product or service
- Technology
- Facility

The second set of rating factors was used to evaluate overall company strengths and weaknesses and consisted of the following elements:

- Marketing
- Management
- Financial capability
- Stability

In general, the second set of evaluations remained constant for a given company for all of the market sectors in which it was involved, although there were cases when, for example, the marketing effort with respect to one market sector was stronger than for another.

For each Canadian company supplying each of the 21 market sectors identified, a numeric rating of was assigned using the criteria listed above. These form the *absolute ratings* for the supply side of each market sector. *Relative ratings* were also developed for each Canadian company in relation to worldwide competition. Canadian strengths on a market-sector by market-sector basis were then calculated to quantify Canadian capabilities and the potential market opportunity, taking into account the worldwide competitive environment.

The third phase of the study, *Government Assistance Mechanisms*, received inputs from the previous two phases and from an in-depth matrix of comments from the Canadian Space industry on current government assistance programs that could be accessed by them, including the R & D Tax Credit Program. In addition, industry members were asked to provide their general opinions as to the most appropriate government support methodologies. Further, the whole matter of policy and regulatory impact was discussed in interviews to ascertain the impact of policy and regulation upon the growth and success of the industry.

The responses obtained from the interviews with both industry and government were analyzed under the following seven headings:

- Shared Cost R & D
- Shared Cost Marketing
- Full Price Contracts
- Government Goodwill and Technology Transfer
- Policy
- Tax Credits
- The Regulatory Environment

A common reaction of senior industry personnel was surprise at the number of assistance programs identified by the project team. While most interviewees were familiar with some of the programs, they did not realize their extent or depth.

In a few instances a program was criticized for its own sake, but in the vast majority of cases the implementation of a program was the target of criticism.

The approval process for contracts and shared cost programs is a prime concern of industry, to the point that the investment in time and human resources versus the benefits of obtaining the assistance is in the balance.

The relatively short delivery time on most government development contracts does not allow a contractor time to develop all of the key technology. **In the absence of a**

reservoir of directed research, the result is that some contractors are forced to seek a licence for off-shore technology. In the long term, this is seen as a serious threat to the expansion of the Canadian industrial research and development base.

The government's role as a first buyer for a new product or a new technology was highlighted in a number of interviews. The double-advantage of having credibility with a major buyer - the Canadian government, and an assured buyer for the first saleable item was judged by some to completely overshadow the benefits of all other government assistance efforts. In this context, the first buyer role of Telesat Canada for *show-casing* new Canadian technology is also important on the international scene.

Shared cost research and development assistance is viewed favourably by the majority of industry users. However, public awareness of many of the programs is low, and requires improvement. Companies that have persevered appear to be satisfied in the longer term with shared cost programs.

Shared cost marketing assistance in foreign countries has attracted a large number of users. Views on this activity are more *pro* than *con* but there were a number of criticisms of the paperwork and the severity of the PEMD restrictions.

Direct government development contracts, including the now defunct Unsolicited Proposal Program, are very popular, as they give a company economic leverage and shorten the development chain.

Government goodwill and technology transfer is viewed favourably. The availability of objective, informed R & D personnel from the Communications Research Center and the National Research Council was viewed as important.

Much of the industry felt that Government policy in satellite communications has tended to cast satellite communications as a supplement to, rather than an integral part of, the national telecommunications infrastructure. It was considered that this attitude has not served the public's socio-economic interest well. Clear government policy for the integration of satellite communications into the national infrastructure is critical to ensure the future development of Canada's satellite industry.

R & D Tax Credits are perceived, in the main, to be useful but audit delays and drawn out disputes over eligibility of certain activities hinders more general use.

Considerable feedback was received concerning the current federal telecommunications policy and regulatory environment as it impacts upon the satellite communications industry and users. The general response was negative, with it being felt that the regulatory environment was not serving the needs of either industry or satellite communications users.

The impact of the lack of a Canada-wide interconnect policy on the development of satellite communications was a matter of general concern.

A matter of considerable concern throughout the industry is the perceived Balkanization of industry, and the dispersion of valuable resources, by inappropriate implementation of regional development policies.

To enable satellite communications to be exploited to the full by the telecommunications common carriers, it needs to be perceived from policy, regulatory and technical aspects as merely another distribution method that could be used to improve service of the national switched network. It is felt that future strategic policy planning should consider these points.

The space community addressed two further matters of regulatory and policy concern, both dealing with mobile satellite service.

The first related to spectrum management. Currently the planned MSAT service and its parallel terrestrial cellular mobile service are incompatible from the viewpoint of channel bandwidth and general equipment use. It is seen that compatibility between terrestrial cellular systems and the land mobile service will be greatly to the advantage of not only Canadian service providers and manufacturers but to the user population as a whole. Thus from a strategic regulatory viewpoint, the Department of Communications should take every possible action to encourage the merging of terrestrial cellular and satellite mobile services in both spectrum bandwidth and technology.

The second mobile satellite policy concern is related primarily to off-shore maritime and aeronautical satellite mobile services, but to a lesser extent to land mobile services.

From a strategic viewpoint, Canada should protect its mobile satellite service interests in all three areas; land, maritime and aeronautical. Consideration should be given to ensuring, through Canada's position in INMARSAT, that INMARSAT does not gain the right to provide land mobile service over any of Canada's territories, does not obtain the exclusive right to provide satellite service to shipping in Canadian waters, and preferably Canada should have the right to compete with INMARSAT for maritime traffic to the limit of Canadian satellite coverage areas; and finally to ensure that Canada has the right, and preferably the mandate, to provide aeronautical satellite service to all areas where it has air traffic control responsibilities and can provide satellite coverage.

The outputs of the study have permitted the project team to establish the following criteria to meet the objectives for a long-term satellite communications strategy identified by the Department of Communications:

- Consideration of strategy elements must be driven by demand, recognizing Canada's dual strengths in the payload/major sub-systems market and the niche markets.
- Government must assist industry in developing expanding international markets.
- Strategy must build on current Canadian strengths and capabilities.
- Strategy must provide a framework for world class state-of-the-art developments.
- Any government fiscal support must address identified specific financial needs required to maximize the meeting of the strategic objectives.
- Strategy must provide a flexible framework and support within which industry can meet world demand in the manner most appropriate to the company or companies involved.
- Strategy must ensure that Canada has maximum access to all three international trading groups to address the world market as a whole.
- Strategy must ensure that DOC policy and regulations support the development and expansion of the Canadian satellite communications industry.
- Any strategy must take full account of the overall public good, and ensure appropriate public awareness of Canada's space communications strategy.
- There must be recognition of the linkage between the development of technology (goods) and the use of these technologies (services).

In identifying these criteria, **it was clearly established that satellite communications is a future strategic thrust for the three major trading areas of the world. To maintain and improve its competitive position on satellite communications Canada**

must implement an innovative, forward-thinking and appropriately funded long-term satellite communications strategy.

Analysis of the outputs of the study led the project team to recommend the following eleven key elements or planks of such a strategy:

- **The overall strategy, and its funding, should be long-term, pro-active and flexible rather than relying on short-term reactive responses and funding.**

- **The government should undertake a continuing series of government projects aimed specifically toward satellite communications.**

- **There should be a policy of the government being "first buyer" of new Canadian satellite communications technology directed at the international market, thus enhancing international credibility.**

- **Where appropriate, the government should contract for the "first orbit" of new Canadian technology.**

- **The government should continue to carry out and sponsor directed basic research in specific satellite communications disciplines to provide a research reservoir from which Canadian industry can draw.**

- **The government should work toward modification of the current regulatory environment in order to remove existing disincentives with respect to the full use of satellite technology by domestic telecommunications carriers.**

- **The confirmation, as a policy, of the establishment or maintenance of close linkages with Europe, especially with ESA and Japan, as these two trading blocks have the funds, the will and the public support for continuing development of satellite communications technology. At the same time, the current strong ties with NASA and the U.S. space industry in general should not be neglected.**

- **The government should continue to encourage the maturation of the Canadian satellite communications prime contractor capability.**

- **Canada should continue to use its strengths in international spectrum and other fora to further Canada's satellite communications strategic**

policy.

- **The government should continue and simplify the program for Research and Development Tax Credits.**

- **In implementing a strategy to maintain and strengthen Canada's current world position in satellite communications, the government should concentrate on improving international competitiveness and the development of new world markets for satellite technology, products and services.**

- **In all government programs impacting on satellite communications, the government should, as a policy, avoid splitting or diversifying the industry, and should concentrate on strengthening the industries by building on current skills in areas of appropriate labour availability.**

It cannot be over-emphasized that, in the opinion of the project team, any truly viable long-term satellite communications strategy must contain all of these elements.

It will be noted that the second element is a recommendation that the government should undertake a major project specifically aimed toward satellite communications. This has been done a number of times in the past and has each time provided a significant step forward for Canada's space industry.

In developing a number of alternative scenarios for such programs, the study team has given highest priority to the meeting of the criteria previously identified. Using this approach four scenarios for a government-sponsored payload have been defined, and a preliminary evaluation carried out. In addition, a long-term strategic development program aimed at ensuring a maximum market share for Canada in the future personal communications market is outlined.

The four programs suggested as alternates from which a government-sponsored payload is chosen are as follows:

- **an inter-satellite data relay payload to be carried out as a joint venture with either NASA (who have expressed interest) or ESA (who plan to carry out optical inter-satellite link trials in the appropriate time frame). A prime purpose of such a payload is to further the competitiveness** of international satellite point-to-point trunks by the elimination of *double hops* and the delays associated with them. Such an inter-satellite link would operate either in the millimeter microwave band, for example 60 GHz, or in the optical band. In either case it would take advantage of Canada's strengths in the millimeter RF front-end sub-system niche, or in the optical communications niche. In addition, it would use Canada's proven capability in space qualified servo-mechanisms for acquisition and tracking.

- A Ku Band, hubless VSAT payload capable of at least T1 capability operating into earth stations with a maximum diameter of 1.2 meters. Such a payload would be aimed toward both the private and public sector business data and digitized voice markets with potential capacity for business video. In addition there is indication that there could be considerable Canadian military interest in this service. By eliminating the expensive VSAT hub by carrying out traffic management and switching in the satellite, the double hop requirement (and its attendant delays) for a remote station to communicate with other remote stations would be eliminated. Thus a *virtual mesh* network could be realized.

  The payload would take advantage of, and develop, Canada's strengths in on-board switching and processing and in the development of space segment and earth station antennas and electronics.

- The third payload scenario is for an inter-orbit link to provide (in conjunction with a similar geo-stationary orbit transponder spaced approximately 180° distant in orbital arc) continuous, realtime communications between the second generation Radarsat and a non-tracking earth station. It would thus eliminate the requirement in Radarsat for complex on-board data recording and replay equipment. The payload could also provide continuous realtime communications with a remote sensing satellite from another jurisdiction, such as Japan or Europe, in return for the use of a similar transponder in a satellite operated by the associated organization.

  The payload would be a high-speed data transponder in the 60 GHz Band in geo-stationary orbit, capable of acquiring and tracking a near-polar orbiting satellite in low-earth orbit, and transmitting the data acquired from this satellite to a fixed earth station while the two

satellites are in line-of-sight. It must be capable of the rapid acquisition of a second polar-orbiting satellite after line-of-sight of the original acquisition fails.

This payload would also take advantage of Canada's millimeter-wave front end capability and its tracking and acquisition capability.

- **A Ka Band personal communications satellite service (mobile) experimental payload aimed at overcoming some of the many current inhibitions to the use of this frequency band for such an application. Such a project would take advantage of Canada's prime contractor capabilities, and the capabilities of Canadian industry in millimeter-wave antenna and mobile systems.**

These four scenarios were subjected to a cost benefit analysis and evaluated against other broader policy criteria, which led to the following conclusion:

- The ranking of the projects in decreasing order of preference for inclusion in a long-term satellite communications strategy are:

  1. Personal Communications at Ka Band
  2. Hubless VSAT
  3. Inter-Satellite Links
  4. Remote Sensing Data Relay

Moreover, in undertaking such projects, the following considerations should also be taken into account:

- Directed programs of government assistance are needed for all the projects which are selected, as much as mechanisms for the management of the technology development by government as for risk reduction.

- In the early stages of development, the transfer of government-developed technology and shared cost R & D programs are likely to be most effective. In the later stages, full price contracts followed by shared cost marketing are likely to be most effective.

In addition to the selection of an appropriate payload as a major government-sponsored program in support of the Canadian Space Industry, it is strongly recommended that an on-going long-term, strategic research program aimed at developing Canada's capabilities in future satellite systems be implemented. Such

a program would not be tied to a particular payload, but to providing the directed basic research that will be required in the future by Canada's Space Industry to maintain and enhance its worldwide position in the 21st Century.

The program should have appropriate, but assured, long term funding which would permit the implementation of feasibility studies; followed by directed basic research; followed by applications-oriented research as this becomes appropriate; and by technology transfer to Canadian industry. Co-operative activities among industry, universities, and government laboratories will foster and enhance Canada's position at the forefront of satellite communications and ensure that Canadian companies capture a significant portion of the international market.

The fields of research would have to be specifically defined jointly with Canadian industry and could include:

- on-board switching and processing
- beam-switching, hopping and steering
- antenna technologies
- Ka Band propagation and fade countermeasure research
- the development of appropriate architectures, coding, modulation, protocols and access schemes to concurrently provide maximum efficiency in a satellite environment while being capable of interfacing and interconnection with the public switched network (possibly ATM).

* * *

CONTENTS LIST

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1.0 INTRODUCTION

1.1 Purpose of the Study

Canada, since becoming the third nation in space in the 1950's has, through far-sighted and imaginative planning, maintained and indeed improved its standing among the world leaders in satellite communications. It is currently in the unique and enviable position of accruing a significantly greater revenue from its communications satellite activities than the funds invested by the Canadian government in support of this industry sector.

Over the last five years or so, significant changes have taken place in the satellite communications field, and in the telecommunications and broadcast industries it serves.

These include, among others, the large scale adoption of fibre optic distribution technology by the majority of the developed world's public switched networks for both terrestrial and submarine applications; significant delays in the future of satellite communications caused by the Challenger disaster and a long string of U.S. and European launch failures; and the evolution of three well-defined and strongly competitive Western world telecommunications trading blocks, namely:

- The U.S. and Canada
- The European Community
- Japan and its Pacific rim neighbours

These matters, together with the potential impact on the ability of the Canadian industry to penetrate the consolidated European telecommunications market from 1992 on and the advent of Canada - U.S. Free Trade are major issues which require advanced planning.

To ensure that Canada is well served domestically and at the same time maintains and expands its position in the world satellite communications market in the face of changing technology, and a more rigid alignment of international trading groups, the Department of Communications is developing a Long-Term Satellite Communications Strategic Policy.

This study has been commissioned by DOC, together with the Canadian Space Agency, Spar Aerospace Limited and Telesat Canada as co-sponsors, **to provide thoroughly researched inputs to the elements of the strategy and specific recommendations for strategic approaches to meeting the objective of maintaining and expanding Canada's position in the world satellite communications market.**

A further purpose of this study is **to provide a joint focus for the future and to identify to each of the sponsors, in a manner that would fulfil their individual mandates, the technology trends, uses and needs of Canadian and worldwide markets for satellite communications in the period up to the year 2010.**

1.2 Approach and Methodology

The study has been carried out in four main phases or tasks as follows:

- Future Technology and Market Assessment and Analysis
- Canadian Capabilities and Market Share Projections
- Government Assistance Mechanisms
- Cost-Benefit Analysis

An overview of the methodology in the form of a Flow Chart is given in Figure One. Blocks showing inputs to the various tasks are indicated with double outlines, while outputs both of individual tasks and of the project as a whole are shown in blocks with solid bottoms and right hand edges. Decision points are shown as diamonds, and the individual tasks are delineated by dotted lines.

2.0 FUTURE TECHNOLOGY AND MARKET ASSESSMENT

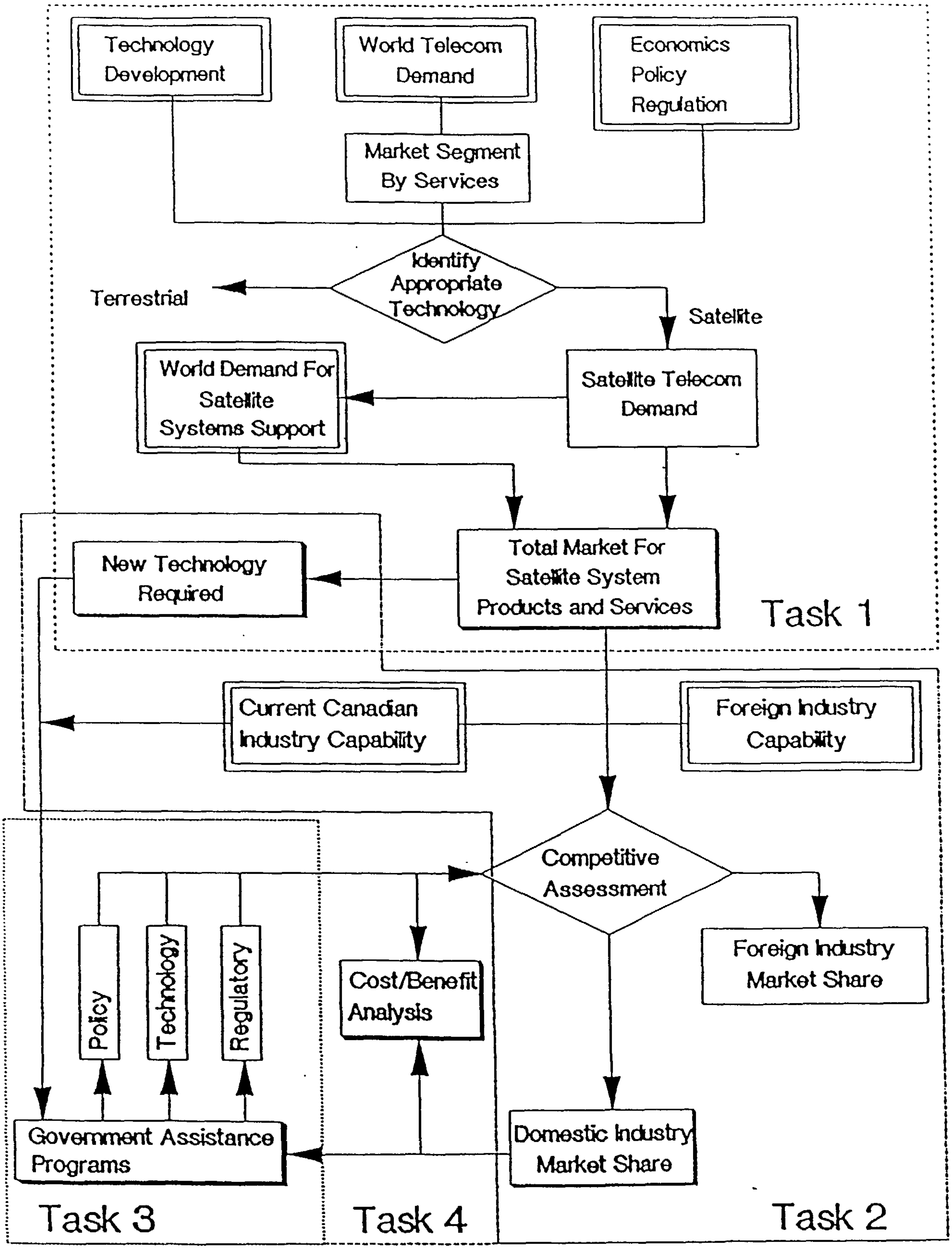
2.1 Introduction

As can be seen from reference to Figure One, "Overview of Methodology", the prime inputs to all tasks of this Phase were threefold:

- Technology Development,
- World Telecom Demand,
- Economics; Policy; Regulation

An initial base of these inputs was obtained from a detailed review of the literature and documentation available from a wide range of sources on a worldwide basis; from the knowledge of the project team; and from comments and inputs from the project review committee. In particular, considerable information on technology trends and worldwide market needs of the future was provided by documentation obtained from the European Space Agency; from individual members of the European community; from U.S. Space

Figure 1: Overview of Methodology



industry sources; from Japanese publications; and from all facets of the Canadian space community, particularly the federal government. A bibliography of these documents, classified by telecommunications application and broken down into the three major input headings is given as Appendix A.

2.2 Projections, Analysis and Summary of Future Technologies and Markets

For this task, a futures scenario was developed covering all aspects likely to impinge upon the market for Canadian communications satellite products and services. This included both space and ground segments, together with services such as launch control and satellite system management. This detailed scenario was the prime output of this task; and provided the input for the modified Delphi approach to the next Task.

2.3 Identification of Trends and Issues

Using the detailed scenario developed in the previous task, a modified Delphi approach was used in this Task to obtain input from Canadian and international manufacturing and service industries to provide the broadest input for the succeeding tasks in this Phase.

In this context, a modified Delphi approach to information gathering meant that key members of the satellite communications manufacturing and service industries were called upon to comment on the detailed scenario developed in the previous task. These scenarios were distributed to a selected list of participants for study and analysis and one to three weeks after receipt were followed up by personal interviews by the Task Team to obtain opinions as to potential variances from the defined scenario. This modified Delphi approach was not only more cost-effective than a full Delphi approach, but had the advantage of obtaining frank and considered opinions. The interviews were carried out concurrently with those required for Phases Two and Three of this study, thus further improving cost-effectiveness.

An initial list of participants was compiled, closely following that given in the proposal, and submitted to the Scientific Authority and Program Review Committee for comment. In addition, very considerable input was received from Lapp-Hancock's European sources both in the form of comments and in the form of ESA and other European reports and documents. (Included in Appendix A.)

All entities on the scenario list were contacted and requested to participate in the modified Delphi process. The response was extremely good, with all organizations agreeing to participate. The scenario, together with an explanatory document, additional questions and information packages requesting information for Phases Two and Three were circulated to all organizations on the list. One company (Glenayre Electronics Limited) withdrew from the interview process after receiving the pre-interview material.

All other organizations were visited by the members of the interview team, and indepth interviews carried out.

In general the participants responded in detail to the scenario and to the marketing and technology questions and very considerable technological and marketing information representing the whole of the Canadian satellite communications industry was obtained. This information was then used not only as an input to the remaining tasks in this Phase but also as primary source of information for the other phases of the study.

It is perhaps appropriate to mention that while many of the interviewees identified mobile satellite communications as a major area of growth over the next two decades, only brief mention was made at the time of the interviews of future satellite-aided personal communications as the natural extension of satellite-based cellular systems.

However during the study considerable documentation was obtained identifying satellite-aided personal communications as a major future technology. In addition, the Department of Communications held a futures-oriented high level policy workshop entitled Search 20. This also identified personal communications as a major telecommunications technology requirement of the future. It was considered appropriate therefore to review this technology in considerable depth, and to add to the information gathering phase of the Study by obtaining inputs from selected experts in the field of personal communications. Prior to giving the results of the overall assessment of satellite and terrestrial technologies it is appropriate therefore to provide an overview of this technology to permit it to be reviewed in context.

2.4 Satellite Based Personal Communications

2.4.1 Introduction

Over the past six years the field of mobile communications has seen exceptional growth which does not seem to be abating. Many new applications have developed including but not limited to mobile fax, mobile data retrieval systems, advanced train control systems, and cellular communications. The need of humans for ubiquitous communications has moved the telecommunications terminal from a fixed location (desktop telephone) in the office to the vehicle and is now moving on to the person for complete mobility. Ultimately, it is envisaged that the mobile portable terminal may be able to offer an assortment of services in voice, data and even video. Considerable progress has been made towards development of this type of personal communications and its interface with the cellular system. Concurrently, the cellular mobile communications system developed from an analog speech system to a digital system, and the interfacing of the mobile terminal with the public switched network (PSTN) public data services network (PDSN), and integrated services digital network (ISDN) have become a reality.

Over the next two decades terrestrial cellular mobile communication systems are not expected to provide global coverage within designated service areas. Major cellular system operators direct their terrestrial services to populated areas because implementation of these systems are uneconomic in sparsely populated areas. For the population living in areas not covered by these networks, satellite communications is the only way to provide reliable and ubiquitous mobile communication service. The proposed mobile satellite service may be regarded as an extension to the terrestrial land mobile personal network. Just as personal and portable communication is regarded as an extension to the second generation digital cellular system, ubiquitous personal services are a natural extension to the services to be provided by the mobile satellites of the future.

During the past several years, the second generation cellular communication systems have been studied extensively and firm design principles have been established. These principles are being applied in planning and development of terrestrial personal communication networks. In Europe, steps have already been taken towards providing such services. For example, tele-point services in the UK, though not fully mature as it does not allow access to the portable, is an important step in the right direction. The extension of personal communications to satellite communication requires the solving of a number of problems, some of which are similar to the ones confronting terrestrial portable systems, while others have a character unique to satellite channels.

2.4.2 Design Considerations

The satellite based personal communication system network design requires considerations of network architecture, signalling, and on-board processor, and transmission techniques similar to those for terrestrial mobile networks, but for which the satellite payload replaces the mobile switching center. The following are some areas where new technology will be required:

- Frequency and propagation considerations;
- Personal terminal architecture;
- Space segment;

2.4.3 Frequency and Propagation Considerations

At present, L Band frequencies are allocated to the mobile satellite system. The frequency allocations for mobile satellite communications are unlikely to be sufficient to provide personal communications for future users who are expected to number in the in many hundreds of thousands. It is predicted therefore that this frequency band will be used exclusively for vehicle based systems. For personal communications a new frequency band has to be explored.

To choose a suitable band, miniaturization and antenna size play important roles. The antenna size can be considerably reduced if the band is moved from L Band to Ka Band. Although propagation loss is likely to be increased considerably, this may not be of overwhelming consequence since phased array antennas are becoming a practical reality. At this frequency the antenna size becomes manageable and highly portable. The other important advantage of this higher band is that miniaturization of circuit components (MMIC) becomes feasible and the mobile terminal is then truly portable. It has also been suggested that MMIC components will be cheaper than those for L Band. Systems operating at 19-21 GHz (downlink) and 29-31 GHz (uplink) have been suggested.

2.4.4 Personal Terminal Architecture

The personal receiver will consist of a high gain antenna, a LNA, a very large scale integrated (VLSI) implementation of the down converter, a baseband signal processor and a control unit/Vocoder. Packaging into the small size required will be a major challenge for second generation devices. It is also envisaged that the personal communicator should handle not only voice but significant data traffic. To conserve power, an adaptive power technique is likely to be required to allow use of higher power when necessary (when the channel is experiencing difficult propagation conditions) to maintain performance.

2.4.5 Satellite Payload

Because of weight, size and battery capacity considerations the portable terminals can only transmit very limited power. Moreover it is most unlikely that the mobile can provide sufficient gain to overcome the high propagation loss. These constraints suggest that the satellite must have considerable power available for transmission and must have high antenna gain.

On board processing is perhaps a prerequisite for personal communications. The processing can either be limited to signal generation and routing or extended to include network management functions.

For routing purposes either microwave or baseband switching can be used. Channel to beam switching will be necessary to provide effective routing capability.

2.4.6 Summary

In reviewing future requirements of satellite aided personal communications, it is concluded that such service will be a natural extension to the current MSAT systems and will provide service to all areas. There is a possibility that this service can be integrated with the digital cellular systems at present being planned.

Whilst there are a number of hurdles which have to be crossed to make the proposed system a reality; access, modulation coding and antenna designs have been identified to be of critical importance. A more detailed description of personal communications requirements and potential technical solutions to outstanding problems is given in Appendix B.

2.5 Competitive Assessment of Satellite and Terrestrial Technologies

The first stage to the development of a market assessment for satellite communications to the year 2010, and the technologies required to address this market, is to identify from a competitive viewpoint those technologies which are likely to be the prime domain of terrestrial networks; those likely to be the prime domain of satellite networks; and those which, given the right environment, could be provided jointly by the two distribution technologies working in concert to provide optimum service to the market.

The following assessment was derived from three main sources as follows:

- Documentation obtained from a wide variety of sources (See Appendix A)
- The responses to the technological scenario developed under Task One of this phase.
- The responses to the questions relating to this phase posed to interviewees representing Canadian space communications industry, the Canadian telecommunications service industry, and the Canadian government.

In reviewing these outputs and assessing the likely role of terrestrial and satellite based telecommunications networks over the next twenty years a key common thread was identified. This common thread was the fact that all manufacturing and service sources concurred that new development would be market-driven and based upon clearly identified applications which exploited appropriate new technologies to the maximum. There was little or no evidence of a technology-driven telecommunications environment over the next twenty years although new technologies will certainly be exploited to meet both current and new market demands. However the Canadian and international regulatory environments are also expected to exert a major impact on the strength and viability of satellite communications in the future.

Notwithstanding this it is recognized that it is necessary for applied research to be carried out by government and universities to provide the source knowledge for future technological developments to keep Canada competitive in the world markets. In particular applied research is required on:

- Mobile personal communications via satellites
- EHF propagation studies and research into fading countermeasures
- Advanced high-speed, satellite oriented protocols such as the Asynchronous Transfer Mode
- Satellite antenna technologies including inflatable and phased array antennas
- Network management including channel assignment techniques and software defined (and modifiable) networks.

In character with these findings were reasonably consistent opinions as to the most appropriate technologies for each distribution mode. In identifying future telecommunications satellite markets and technologies, it was deemed appropriate to classify the technology findings of the first phase under the following nine applications headings:

- One-way video networks (TV distribution for the various current TV systems and for HDTV)
- Public switched point-to-point voice, data and ISDN networks

- Private point-to-point voice and data networks
- Public switched point-to-multipoint two-way networks (VSAT)
- Private point-to-multipoint two-way networks (VSAT) (Voice/Data/Video) including *virtual mesh networks*
- Private point-to-multipoint one-way data and audio distribution networks
- Mobile networks including cellular, and dedicated mobile, voice and data networks and one-way paging networks. These cover land, maritime and aeronautical services
- Data collection networks for space-based sensors
- Data collection networks for ground-based sensors

In analyzing these technologies which, during the next two decades, are most likely to be used in satellite networks or in both terrestrial and satellite distribution modes, the following conclusions were reached.

2.5.1 One-Way Video Networks

All inputs identified one-way distribution of television and shared entertainment programming as the dominant application of domestic and regional satellites, not only in North America, but also in Europe and Japan. This predominance applies both to percentage of available bandwidth used and to percentage of revenue received. Current estimates put these figures at 70% and 65% respectively. There is every indication that this trend will continue throughout the time period under review, as it is more cost-effective for networks to distribute television signals to a multiplicity of terrestrial broadcast stations by satellite than by any other means including terrestrial microwave. The figures for TV and sound entertainment are considered likely to increase to over 75% and 70% respectively despite increases in the use of other applications as overall available capacity increases.

It should be noted that in North America, such distribution currently uses only the fixed-satellite service (FSS) rather than the broadcast satellite service (BSS). In other words the concept of direct-to-home broadcasting using high power DBS satellites has not come to pass in North America despite considerable experimental and planning activity over the last decade. Alternate means are now fully entrenched and it is unlikely that direct broadcast satellites will constitute any significant portion of the communications satellite market in North America over the next two decades.

In contrast, in both Europe and Japan the use of DBS satellites is now established, albeit with problems with the first German DBS satellite. There is every indication that the trend for the significant use of DBS satellites in Europe and Japan will continue over the time scale in question, and that this approach to TV distribution will impact upon the terrestrial broadcast facility market.

The major change expected in television technology over the next two decades is the swing to high-definition television. At the present time there is worldwide consensus only on the fact that a high-definition system is required to replace the current NTSC (North America and Japan), PAL (Europe except France) and SECAM (France and U.S.S.R.) television standards. The aim is to provide television with quality and form factor compatible with 35 mm. film.

While as shown above it is expected that the majority of TV distribution, including HDTV distribution, will be via satellite rather than terrestrial networks, the standard likely to be used is far more difficult to predict. Currently the Electronics Industry Association lists 23 proposals for different advanced television systems. It seems almost inevitable that once more three different standards will be used on a worldwide basis, although the mix would be different. The Japanese appear to be standardizing on the 1125-line format of the MUSE system which requires a bandwidth of 8 MHz. The European community is expected to standardize on the HD-MAC standard requiring a 12 MHz bandwidth formatted with satellite broadcasting in mind.

The situation in North America is far more confused. The U.S. Federal Communications Commission (FCC) announced in an interim discussion of September 1988 that over the air broadcasting should be compatible with NTSC and current 6 MHz channel assignments. It did not state that all distribution of television to the home must meet this criteria. This is a very important distinction since HDTV via satellite, cable, and fibre or VCR could be introduced even before the FCC reaches a decision on an over the air transmission standard. The following quote from the Interim Report of the FCC Advisory Committee on Advanced Television Service (June 16, 1988), reflects the importance of this distinction: "Meanwhile, proponents should be able to develop their systems further so that they can be tested against co-channel and adjacent channel interference and spacing criteria that will emerge from ongoing spectrum analyses efforts. While such activity proceeds, hopefully as rapidly as possible, the Advisory Committee believes that no attempt should be made to retard the introduction of advanced television systems over nonbroadcast media."

It should be noted that the American National Standards Institute and the Society for Motion Picture and Television engineers have already accepted for studio production of HDTV programs a system using 1125-lines interlacing at 60 Hz similar to the Japanese format. North American Philips and the National Broadcasting Corporation propose a system based on 1055-lines and 59.94 Hz interlacing. The David Sarnoff Research Center (formerly RCA Laboratories) in conjunction with NBC propose an advanced compatible TV system (ACTV) using 1050-lines. In its second stage of development ACTV uses two channels. The first channel carries a signal compatible with the current NTSC signal and the second will carry additional information in digital form. The HDTV receivers will receive both channels and combine them. Zenith has also proposed its own spectrum compatible HDTV system which would transmit an additional 6 MHz HDTV signal on a taboo channel to combine with the standard NTSC signal to produce HDTV.

Broadcasters in the FCC are now preparing to evaluate the proposed systems. It is to be hoped that a single standard for HDTV to be used by off-air broadcasters, satellite transmission, cable TV systems and video cassette companies will be forthcoming in North America. It seems however that it is too much to hope that the future change to HDTV will produce a single worldwide TV standard.

2.5.2 Public Switched Point-to-Point Voice, Data and ISDN Networks

All indications are that for technological, economic and regulatory reasons, the majority of public switched point-to-point voice, data and ISDN Networks will remain terrestrially and sub-oceanic based in the North American, European and Japanese/Pacific rim market sectors.

In all three major market sectors the prime thrust over the last decade has been the extensive supplement, and in some cases replacement, of terrestrial cable networks by fibre optic networks. This trend is likely to continue with most telecommunications common carrier point-to-point traffic being carried on such networks. Currently the use of satellite systems by common carriers is limited in most cases to serving remote locations, trans-oceanic services, and some limited trunking for the public network.

While it is expected that this will continue during the study period, it is seen that there will be an expansion of niche applications for satellite-based voice and data services, particularly as back-up during heavy traffic conditions and during periods of catastrophic failure of key terrestrial paths. The rate of growth of these satellite services will increase as the ability of the satellite system to become a dynamic and integral element of the total public network is realized.

To date, in addition to the remote services, the role of satellite technology has been to provide the trunking between the International Switching Centres (ISCs) and, to a lesser extent, the network switching centers with some limited use of satellites for back-up of restoration. These applications are characterized by high traffic volumes and long distances. While the greater use of the satellite system in the access network (as opposed to the local access) has the potential to greatly increase the proportion of traffic carried via satellite, the integration of the satellite system into the core public switched terrestrial network will require both technical and institutional innovations.

However in both Europe and Japan there is currently considerable research into the possibility of integrating point-to-point satellite elements directly into the terrestrial public-switched network by means of on-board switching, beam switching and smart earth station technology. These satellite-based technologies are likely to be developed into pre-revenue producing payloads during the period under review.

2.5.3 Private Point-to-Point Voice and Data Networks

All indications are that on a worldwide basis major corporations are evaluating the cost-effectiveness of implementing private data, and to a lesser extent voice, networks to meet their corporate information distribution needs.

The actual implementation of such networks depends primarily upon the current deregulatory situation in the market place involved and secondly, upon the appropriateness and competitiveness of common carrier offerings for the particular corporate environment. For this market segment there are therefore a number of hurdles to be overcome prior to any consideration as to whether terrestrial or satellite networks are most appropriate.

Present indications are that, over the period of interest, the rapid development of private point-to-point networks in the United States is likely to continue and probably plateau out towards the end of the period.

The slow but significant deregulatory thrusts in Canada, Europe and Japan are likely to encourage private networks and the use of satellites as a distribution medium to overcome rights-of-way and other problems. In addition, the on-board switching requirements for private networks are likely to be less sophisticated, and perhaps more easily achieved than those for the telephone common carriers. Consequently, private systems are likely to be the driver, or catalyst, in this field.

In Canada, there are already significant signs that such satellite networks, in a mesh configuration, could well become an important, albeit small, market segment in the period under review. Given a favourable rate and regulatory environment, it is estimated that this market could develop to carry perhaps 3% to 7% of total digital traffic in the time frame under review.

2.5.4 Public Switched Point-to-Multipoint Two-way Networks

Under this heading the various types of very small aperture terminal (VSAT) networks operated by the telecommunications common carriers are considered. For consideration on a worldwide basis, these can be broken into three headings as follows:

- VSAT systems, typically asymmetrical two-way systems with a hub capability of the order of 56 kbps and a remote capability of typically up to 9.6 kbps.
- TSAT systems, used primarily in North America with a data rate of 1.544 Mbps (ISDN Primary rate of 23B + D or T1).
- HSAT systems, used primarily in Europe with a data rate of 2.048 Mbps (ISDN Primary rate of 30B + D).

It will be appreciated that all such networks are ideal for satellite implementation and are unlikely to be implemented terrestrially due to the sensitivity of terrestrial systems to number of spokes in a star network such as these, and to sensitivity to distance.

This application and the technology relating to it is practical only with satellite implementation. Inputs indicate that significant development of cost-effective *hubless* mesh-network high capacity (at least 1.5 Mbps in North America and 2 Mbps in Europe) VSAT systems in North America and Europe will be an area of significant technology development over the next two decades. In particular satellite-based hub switching and network management systems are areas requiring innovative technological approaches.

In the time frame under consideration, overall VSAT traffic is likely to increase significantly. However the percentage carried by common carriers as compared with that carried privately will be almost wholly dependent on individual regulatory policies.

2.5.5 Private Point-to-Multipoint Two-way Networks

Once more this application sector applies to VSAT, TSAT and HSAT systems but implemented by private entities. For the reasons described in 2.5.4 above, this application is one to which satellite distribution brings overriding advantages and it is unlikely that private point-to-multipoint interactive networks would be implemented terrestrially to any significant degree.

The comments made above for public switched Point-to-Multipoint Interactive Networks apply equally to the private sector networks of this type. During the early stages of the development of this market, star-networks have predominated over mesh networks due to the *head office to branch* requirements of many private networks. As these networks evolve and as some organizations increasingly decentralize their operations, the demands for mesh interconnectivity is also likely to increase.

Mesh interconnectivity requires increasing levels of on-board processing and routing and the complexity required in the satellite system may make public networks a more effective alternative. Once the public networks have developed as outlined in 2.5.4 above, it becomes very likely that equivalent capabilities will become attractive and available for private network operators.

2.5.6 Private Point-to-Multipoint One-Way Data and Audio Distribution Systems

Once more, the point-to-multipoint star network architecture of this application leads to significant advantages for satellite distribution. In addition, the use of cost and spectrum efficient technologies such as the carriage of one-way voice and data on sub-carriers associated with TV satellite distribution systems makes this a particularly cost-effective market segment for satellites.

There are currently a considerable number of point-to-multipoint terrestrial (typically twisted-pair dedicated leased lines) networks in service. All indications are that during the time period under review, the vast majority of these networks, and virtually all new networks of this type will use communications satellite distribution methods. However little or no new technology is required for this FSS application. As the concept of personal communications develops, both North American and European inputs indicate that the use of FSS Satellites to address the one-way paging and data markets will expand over current use probably by ten times over the next two decades. However while reduced channel bandwidths are likely to be used, the basic sub-carrier and "Anikcast" type of technology is likely to remain in use.

2.5.7 Mobile Networks

Under this heading are included cellular systems, dedicated mobile voice and data networks and one-way paging networks, all of them being considered for the land, maritime and aeronautical services. In the latter part of the period of concern, satellite based mobile personal communications are likely to be the major technological thrust in this area.

Currently the only one of these applications that uses communications satellites to any extent is the Maritime Mobile Service for which INMARSAT has the monopoly. INMARSAT has plans for considerable expansion over the next two decades aimed at smaller and smaller vessels. The technological requirement here is for lower cost shipboard equipment meeting the new INMARSAT standards for smaller vessels.

General indications are that the rapid growth of the maritime satellite service will continue, further eroding the maritime radio service markets.
The aeronautical mobile field has up to now been wholly dominated by terrestrial technology despite gaps in coverage over the major oceans for air traffic control, company and public communications. There is every indication that over the next two decades all of these applications will be fulfilled by communications satellites. Technological advances will be required both in the space segment and in the airborne segment. It is considered likely that the current terrestrial aeronautical systems will continue in parallel with the satellite networks with only minor overlap.

In contrast the land mobile market is likely to be an area of considerable competition. Cellular and private land mobile networks are currently firmly entrenched and expanding. The first domestic mobile satellites, the Canadian/U.S. MSAT system is planned for launch in 1993. While there are specific market niches, specifically in remote and mountainous areas, and for long distance data, for this technology there will be considerable terrestrially-based competition for this market. Nevertheless, considerable technology development is required, particularly for ground segment equipment.

It should be noted that Telesat Mobile Inc. (TMI) is currently carrying out pre-MSAT market development using the INMARSAT space segment.

As cellular systems become digitized in the early 1990's, protocols common to cellular and satellite-based systems could be developed, and many opinions are that this integration of the satellite service into the established cellular networks will provide universal coverage. In the absence of common protocols, a modified protocol may be adopted for the satellite network to define clear interfaces between mobile terminals and mobile switching centers on both sides of the radio link. However, duplicate ground equipment, to cope with differing frequencies and antenna requirements, will persist, at not inconsiderable cost to users.

It is not likely that, in the long run, dedicated satellites will provide only one of the three mobile satellite services. Already, INMARSAT is taking part in experiments to provide aeronautical and land mobile service. Domestic providers of mobile service are likely to look at the three environments and, where services can be provided, will seek through regulation, to restrict the competition.

There is already a trend in terrestrial cellular radio for the mobile terminal to become completely portable, and of a size capable of being carried in a pocket or a purse. This trend is expected to continue for the land mobile satellite service and be the precursor to the personal communications system described in Section 2.4 above.

It must be emphasized however that very major technological development is required before the satellite-based personal communication system is a practical entity. Given the potential subscriber base, say equal to that of the current telephone subscriber base, very considerable spectrum allocations will be required, even with maximum frequency re-use. Currently, and in the predictable future, the only satellite service spectrum likely to be available for this service is in the Ka Band. This band suffers from very considerable rain and atmospheric attenuation, in some practical cases over 60 dB, and very considerable research on propagation characteristics and hardware will be required before personal communications, using the Ka Band becomes practicable. However given the potential demand, and the worldwide research being undertaken in this field, there is little doubt that towards the end of the next two decades experimental, and possibly operational satellite-based personal communications systems will become a reality.

Over the last decade there has been a major growth of paging services in all three Western markets. By 2005 the number of paging users in Europe is expected to be three times the number of users of radio telephones and about two-thirds the number of dispatch user terminals. Services are currently local and regional and essentially all terrestrial-based. Indications are that, over the next decade, these will expand to be first intra-continental and later inter-continental, using the "follow-me" concept with satellite communications providing the wide area coverage required. Since this long-distance traffic is likely to be light, it will most likely be "piggy-backed" on existing public and private satellite networks with the paging units linked to local nodes on land, at sea and in the air.

2.5.8 Data Collection Networks for Space-Based Sensors

Communications satellites have, for the last 25 years, represented the prime area of commercial exploitation of space. The non-military use of remote sensing satellites is now beginning to be significant. Starting with the U.S. LANDSAT satellites, and followed by the French SPOT satellites, a considerable number of remote sensing satellites are planned for the next decade by the U.S., Canada, ESA, Japan, the Soviet Union, China and India.

These satellites, in near polar orbit, gather vast amounts of data. Currently this data collection is carried out by tracking earth stations that access military and civilian remote sensing satellites for the comparatively brief period that they are in the field of view of the earth station. Data which had been stored in recording machines on board the remote sensing satellite is transmitted at high speed to the earth station.

Over the next two decades, it is most likely that inter-orbit links will take over this function providing real-time access while eliminating the non-productive recorders from the remote sensing satellite.

New technology required is likely to include optical and millimeter wave transponders, antennas and tracking apparatus.

2.5.9 Data Collection Networks for Ground-Based Sensors

With the growing concern for the environment, and on the monitoring and prediction of natural disasters such as earthquakes, volcanoes, floods and the like, data collection for ground-based networks extending over considerable geographic distances have been proliferating. All indications are that this trend will continue over the next two decades, requiring reliable, low cost, low speed telecommunication networks. By its very nature, this market segment is financially a comparatively insignificant portion of the whole telecommunications market, but one of growing importance. For many decades, there have been efficient terrestrial facilities to meet these needs in all but remote areas. For some remote areas limited use has been made of the GOES meteorological satellites. These facilities will continue to meet the vast majority of these needs.

However many of the newer environmental and resource-based applications require such networks in remote areas where the public-switched telecommunications network is either unavailable or too costly and where the use of GOES is impractical.

With the development of inexpensive, low data rate, remote terminals in VSAT and

MSAT systems, many experts are considering the use of satellite multipoint-to-point networks for data collection from such remote ground-based sensors. The technology required for such networks is likely to be derived from VSAT and MSAT technology and will likely share the same frequency bands and possibly the same hubs. It should be emphasized however that this market segment for satellites is likely to remain a "niche" market, essentially as a sub-set of the VSAT and MSAT markets.

2.6 Markets for Satellite Applications

From a strategic viewpoint, it was the consensus of the project team that the market for satellite communications over the next twenty years would develop primarily in the following general applications areas, given in order of potential share (by value) of the worldwide satellite communications market:

- Distribution of entertainment television (HDTV and Standard Definition) and audio in point-to-point, point-to-multipoint (FSS) and broadcast modes (BSS, primarily in Europe and Japan)

- Point-to-Multipoint one-way (from hub) and two-way distribution of low, medium and high speed data, analog and digital voice and analog and digital video. This application is likely to be comprised of both shared and unshared networks operated by both common carrier and private entities serving a multitude of markets including, but not necessarily limited to, distribution of specialized information services, business video, voice and audio services and the like. This general categorization identifies the current VSAT networks and their future developments including the hubless (switching and processing in satellite) VSAT and the extension of the concept to multi-megabit data rates to accommodate one-way and two-way business video. It also includes hybrid space-terrestrial networks for load-sharing, diversity and restoration.

- Mobile satellite services (MSS) including the proliferation of maritime satellite services; the development and rapid expansion of aeronautical satellite services including those for navigation, trans-oceanic communication, company and public message use; the implementation and development of voice and data land mobile satellite service; and the evolutionary achievement of personal universal mobile communications, capable of worldwide use in all three modes. (Implementation expected in the latter quarter of the period under review).

- Point-to-point, light to heavy trunk telecommunications service interconnecting with the public switched voice and data network as an integral part of that network. Prime applications will be light routes, load sharing and trunk restoration.

- Inter-orbit and inter-satellite links providing service to the remote sensing industry (IOL) and to international point-to-point, heavy route video voice and data traffic (ISL aimed toward the avoidance of double-hops, spectrum conservation and overall system cost reductions.)

It is perhaps appropriate at this point to review the likelihood of probable user markets for each of these applications over the next twenty years, from both a domestic and international viewpoint. This analysis has been derived from a wide number of sources, some of them conflicting, thus representing *a best estimate* based upon these inputs, comments from the review committee and the combined knowledge of the project team.

The first application identified above, that of entertainment television and audio, is currently the major user of satellite communications in Canada, and indeed worldwide. In Canada, all major broadcasters now use satellite for the distribution of their programming with a total of some 30 different organizations. However the major users are the C.B.C., and CANCOM with nine and eight full transponders in use respectively. The other major users are the Global and C.T.V. Networks and the Pay TV and supplementary channels.

In Canada, it is seen that this market has essentially *plateaued out* with evolutionary increases in transponder use expected as a small additional number of Pay TV, supplementary channels and network channels are licensed. The biggest user change is likely to be additional channels and duplication of channels when HDTV is introduced. Almost certainly this new technology will require additional bandwidth thus further increasing its slice of the market. However basic satellite technology will not change as full transponders are capable of carrying this service. There is a dichotomy of opinion as to the most likely frequency bands to be used for this service in Canada. On the one hand, it is pointed out that there is likely to be sufficient capacity still available in the Ku Band while the opponents of this view feel that the additional services and bandwidths required will precipitate a move to the Ka Band.

The next two decades are likely to see a major increase in users of point-to-multipoint one and two-way satellite distribution systems. Many predictions indicate business TV, including video conferencing and one-way promotional videos to retail outlets as being the areas of major expansion, with annual increases in satellite use of 15 to 25% (based on numbers of remote locations) over most of the period under review. In the United

States this trend is already established with the automotive industry becoming a very major user, closely followed by retail organizations.

Under this general applications heading is also included both private and public data networks, considered to be another area of considerable expansion over the next 20 years. The use of private VSAT networks for inventory control of large national organizations has already commenced and is expected to continue at an exponential rate with the cost being minimized by the use of shared hubs organized by *brokers* such as Telesat Canada, CANCOM and Rogers/CNCP. These Canadian trends are likely to be duplicated on a worldwide basis.

The market for mobile satellite services is also expected to boom in the next 20 years, but will be the scene of major competitive battles.

On the land mobile side these competitive battles will be two-fold. The first will be between MSAT and the terrestrial cellular companies for the most lucrative portions of the land mobile market. Contrary to previous market studies, the current trend appears to show that the revenue base is likely to be supported by organizations such as real estate agents, insurance agents and salesmen rather than the trucking industry as was previously forecast. It should be made clear however that the transportation industry is predicted to be a major user of land mobile services, but is finding ways of reducing message links by standard data messages and other means, and thus significantly reducing the revenue from this sector. These trends are likely to continue with any delay in the launching of MSAT allowing the terrestrial cellular systems to make further in-roads in areas of maximum traffic.

The other competitive area in Canada, dependent on the regulatory situation, could be from INMARSAT whose mandate has now been changed to permit it to offer land mobile service. At the time of writing neither the Department of Communications nor Telesat Mobile Inc., was able to clarify this situation.

While there is little doubt that the marine mobile market, both from business and recreational users, will boom over the next 20 years, the question once more is whether much of this will be satellite or terrestrially-based. Current terrestrial cellular networks have the potential of covering most of the Great Lakes, the major waterways and the in-shore coastal waters. INMARSAT has major plans to address the coastal water market with their comparatively inexpensive data offerings currently going into service. These could impact negatively on the MSAT market, and to a lesser extent, on the Canadian terrestrial cellular market, unless there are regulatory steps taken.

A similar situation is likely to occur in the aeronautical mobile market. Again, users are likely to proliferate, falling into three major areas:

- Air Traffic Control
- Airline Business Use
- Public Voice Message

In Canadian air space, for national flights it is unlikely that the current terrestrial air traffic control system will be modified. However international flights are likely to use MSAT within coverage, and the INMARSAT or U.S. mobile satellites outside of Canadian coverage. A point which is likely to have a significant impact upon aeronautical use of MSAT is Canadian regulations pertaining to the use of MSAT by foreign aircraft. The FCC has stated that the U.S. mobile satellite must be used by all aircraft, foreign and domestic, whereas it is understood that Canada's present position is that it would not enforce the use of MSAT by foreign aircraft. This would include all three applications. It is foreseen that public voice message use of the aeronautical band is likely to be significant and, within coverage, is a market eyed by the terrestrial cellular systems. Once more both the timing of MSAT and the regulatory position taken by the Canadian government can significantly impact upon the number of users of MSAT.

The point-to-point trunk telecommunications services between major population centers has been virtually fully addressed over the last decade by fibre optic trunks both terrestrial and sub-oceanic. Notwithstanding this, these distribution systems are quite vulnerable to catastrophic disruption by everything from earthquakes to back-hoes. Thus most telecommunications common carriers, worldwide, are looking at low-cost back-up systems. This is a potential major use of satellite communication systems, particularly if on-board switching and appropriate protocols and architectures permit transparent integration into the public-switched network. Additional telecommunication common carrier use for such point-to-point links will be for light routes and load sharing on trunk routes. Quantitative estimates for this user group vary very significantly, and are dependent upon national regulations, deregulation policy and individual common carrier philosophy and ownership.

One of the problems of using satellite communications for voice and certain types of data traffic is the significant delay which, for all practical purposes, limits satellite communications to single hops. There is thus considerable research being carried out by the U.S., Europe and Japan on the use of inter-satellite links where direct communication takes place between geostationary orbit satellites. In most cases this significantly decreases the end-to-end delay for very long links. As this potential market is primarily for long haul international routes, and as INTELSAT, the service provider for such satellite routes, has its satellites primarily in mid-oceanic orbits, it is likely that a market could arise for domestic or regional satellite service providers to interface with the INTELSAT satellites via inter-satellite links.

It is extremely difficult at this stage in the development of this technology to estimate the size of this market. However in comparison with the satellite capacity required by the other user groups this market is likely to be comparatively small but a steady niche market, probably worth addressing.

A not dissimilar situation arises with inter-orbit links. The three major trading groups plan to orbit some 34 low-earth orbit remote-sensing satellites over the next two decades. (See Figures 2 to 7) Each of these satellites currently records its data and dumps this to tracking earth stations when these are in sight. Inter-orbit links between the low-earth orbiting satellites and two or three geostationary satellites at suitable longitudinal spacing would provide realtime recovery of the data and permit far more cost-effective remote sensing satellites by the elimination of the expensive on-board recording and replay equipment.

This market, once obtained, would be continuous full-time lease of a dedicated transponder for the lifetime of the low-earth orbit satellites involved. It thus represents an attractive market.

Given the time frame considered (the next two decades), it is not considered possible to identify, to any acceptable confidence level, the precise percentages each of the five application groups identified above will attract of the satellite communications market as a whole, or indeed to give a high confidence level to the order of priority given above.

However, a consensus has been reached by the project team that acceptable confidence can be given to the five applications groupings given above, and that future satellites and their payloads should be developed around these five groups to provide the services, and flexibility of services, demanded by the specific market segments as they develop. Thus the need will be for flexible, multi-purpose payloads capable of modification of payload priorities whilst in service.

Given the long gestation period of communications satellites, those planned for launch in the next five years have almost certainly been defined at this time, with most of them in the advanced stages of development. For the following decade, it is likely that in most cases initial planning is underway. Therefore the approach taken to verify the consensus for the communications satellite market over the next 15 years (about the limit for fact-based forecasts) was to identify and review in detail the communications satellite launch plans for the three western world telecommunications trading blocks for the period up to 2005. The prime source for the information given below, was "Commercial Satellites: A World Market Forecast; Satel Conseil, 1989" analyzed, reconstructed and modified by new information obtained by the Project Team. It should be noted that for the sake of completeness, non-communications satellites, both in geostationary and low earth orbit, have been included using the philosophy that all satellites require a communications element. However the remainder of the report concentrates on communications satellites *per se*.

The approach taken in making the forecasts given in Figures 2 to 7 was to restrict the forecast to those satellites with a very high probability of launch. Thus for the earliest two time columns in the Figures, the satellites are virtually all under construction or contracts let for such construction. Most of the satellites in the last two time period columns represent follow-on satellites for systems already in operation, thus themselves have a high probability of being required. Some satellites which have been discussed in depth in the literature, but do not meet these criteria, are notably absent. In addition, some payloads (for example, ESA's AOTS 2 and ARINC's AVSAT) are planned to be incorporated in other satellites and thus do not appear as separate entities.

This review confirmed to the degree possible the consensus identified above.

In analyzing the overall communications satellite market, the next 15 year period was broken down into the time groups of 1989 to 1993; 1994 to 1999, and the years 2000 to 2005.

The satellites in the first period, 1989 to 1993, are either in the final phases of test, or nearing completion or are already tendered for. Thus the strategic market impact of the satellites is minimal. For the purposes of this study the period 1994 and beyond is the one of most interest.

During the 1994 to 1999 time period it was interesting to note that the number of communications satellites planned to be supplied to Europe is 23 compared with 11 for all of North and South America and 14 for Japan, the Far East and Australia. If the international organizations are taken into account and assigning INMARSAT to the European total and INTELSAT to the U.S. total, the figures are 29 for Europe as

FIGURE 2

Forecast of Commercial Satellites to be Orbited for C A N A D A : 1989 to 2005

SYSTEM	QUANTITY 1989-90	1991-93	1994-99	2000-2005	REMARKS
Anik E	2				Geo: C/Ku Bands;FSS Currently in assembly, integration and test
M-SAT(1)		1			Geo: MSS RFP due 1989
Radarsat-1			1		Leo: Radar remote sensing approved
Anik F				2	Geo: C/Ku Band, FSS Initial planning not yet approved
Radarsat-2				1	Leo: Radar remote sensing, Initial planning. Not yet approved.
M-SAT(2)				1	Geo: MSS. Very initial planning only. Not yet approved.
COMSAT TOTALS	2	1	0	3	

FIGURE 3

Forecast of Commercial and Experimental Satellites to be Orbited for U S A : 1989 to 2005

SYSTEM	QUANTITY 1989-90	1991-93	1994-99	2000-2005	REMARKS
ALASCOM/ AURORA		1		1	Geo: C-Band FSS
CONTEL-ASC		2		2	Geo: C/Ku BandsFSS
AT&T/TELSTAR		2	1	3	Geo: C/Ku Bands FSS
HUGHES COM INC.					
- Galaxy	1	5		3	Geo: C-Band FSS
- Galaxy A/B		2		2	Geo: Ku Band FSS
- Galaxy C+K			1	2	Geo: C/Ku BandsFSS
- SBS	1	1	1	1	Geo: Ku Band FSS
GTE Spacenet		2	1	2	Geo: C/Ku BandsFSS
G Star		1	2	3	Geo: Ku Band FSS
GE Americom					
Satcom C		3		2	Geo: C Band FSS
Satcom I		1			Geo: C Band FSS
Satcom C/Ku		1		3	Geo: C/Ku Bands FSS
Satcom K		2	2		Geo: Ku Bands FSS
IBM-Comsat-MCI (SBS+Comstar)		2			Geo: Ku Band FSS
AMSC		1			Geo: MSS,RFP due 1989
NASA ACTS		1			Geo: Ka,Optical FSS
Geostar		3			Geo: RDSS
Goes			5		Geo: MET
Landsat		1	1		Leo: Earth OBS
NOAA/TIROS	3		5	5	Leo: Earth OBS/MET
COMSAT					
TOTALS	2	25	7	21	

FIGURE 4

Forecast of Commercial Satellites to be Orbited for The rest of North and South America : 1989 to 2005

SYSTEM	QUANTITY 1989-90	1991-93	1994-99	2000-2005	REMARKS
Brazil Sat II		1	1	2	Geo: C Band FSS
Morelos II			2	2	Geo: C/Ku Bands FSS
Panamsat IB		1	1	1	Geo: C/Ku Bands FSS
COMSAT TOTALS		2	4	5	
COMSAT TOTALS N & S AMERICA	7	28	11	27	

FIGURE 5
Forecast of Commercial Satellites to be Orbited for International Organizations : 1989 to 2005

SYSTEM	QUANTITY 1989-90	1991-93	1995-99	2000-2005	REMARKS
INMARSAT					Geo: MSS
INMARSAT 2		2			1.6/1.5 & 6/4GHz
INMARSAT 3			6		
INMARSAT 4				6	
INTELSAT					
INTEL VII FSS		3			Geo: C/Ku Bands
INTEL VII A			4		Geo: C/Ku Bands FSS
INTEL VI replacement				5	Geo: C/Ku Bands FSS
INTEL VII FSS replacement				3	Geo: C/Ku Bands
COMSAT TOTALS	0	5	10	14	

FIGURE 6

Forecast of Commercial and Experimental Satellites to be Orbited for Europe and Middle East : 1989 to 2005

SYSTEM	QUANTITY 1989-90	1991-93	1994-99	2000-2005	REMARKS
Eutelsat					Geo: Ku Band
Eutel 2A		2			FSS & BSS
Eutel 3			3	2	Geo: Ku & L Bands, FSS BSS MSS
Telecom (France)					Geo: C,X,(MIL) & Ku, FSS,BSS
Telecom 2		2	1		
Syracuse 3				2	Geo: X Band (MIL)
Telecom 3				2	Geo: C, Ku Bands, FSS
TDF (France)	1		2	2	Geo: Ku Band, BSS
DFS Kopernicus (West Germany)				3	Geo: Ku/Ka Bands FSS, BSS
TV Sat (West Ger)		1	2	2	Geo: Ku Band, BSS
Telex-Nordsat (Scandinavia)	1		2	2	Geo: Ku Band, BSS & FSS
Itelsat (Italy)		1	2		Geo: Ku/Ka Bands, FSS
Sarit (Italy)			2	2	Geo: Ku/Bands, Note low probability

BSB (U.K.)	1		2		Geo: Ku Band BSS
SES/ASTRA (Luxembourg)		1	1	3	Geo: Ku Band, FSS
Spanish Sat System (Spain)		2		2	Geo: X(MIL) & Ku Bands, FSS & BSS
ESA					
Olympus 1 FSS	1				Geo: Ku & Ka Bands and BSS
Sat 2		1			Geo:IOL/ISL, S,Ka and mm wave bands
AOTS 1			2		Elliptical:MSS L Band
DRS			2	2	Geo: Optical/mm
ERS		1	1		Leo: Earth OBS
Spot(France)	1	1	1	1	Leo: Earth OBS
LOCSTAR		1	1		Leo: RDSS
Metrosat	1	1	2		Leo: MET
ARABSAT (France)			2	2	Geo: C/Ku Bands
COMSAT TOTALS	4	10	23	26	

FIGURE 7

Forecast of Commercial Satellites to be Orbited for Japan, Far East and Australia : 1989 to 2005

SYSTEM	QUANTITY				REMARKS
	1989-90	1991-93	1994-99	2000-2005	
JCSAT/SCC (Japan)					
JCSAT	2		2		Geo: Ku Band,FSS
SCC	2		2		Geo: Ku/KaBands, PSS
B.S. (Japan)	1	1	2		Geo: Ku Bands, BSS
NASDA (Japan)					
ETS		1		1	Geo: Ku/Ka Bands, FSS
GMS	1		1	2	Geo: MET
MOS/JERS	1	1	1	2	Leo: Maring ORS/ Earth RES
ASIASAT (Private Regional)	1	1	1	1	Geo: C Band, FSS
AUSSAT (Australia)		2	1	2	Geo: Ku/Ka/L Bands FSS
CHINASAT (P.R.C.)		1	1		Geo: C Band, FSS
INSAT (India)	1	1	2	1	Geo: C/S Bands PSS and MET
PALAPA (Indonesia)	1		2	2	Geo: C/Ku Bands FSS
COMSAT TOTALS	**8**	**7**	**14**	**7**	

compared with 15 for the United States. However due to slippages in the 1989 to 1993 time frame, these figures may change upward for all groups.

It is also useful to analyze, on the basis of the three trading blocks plus the international organizations, the telecommunications satellites required by service band and frequency for the two time periods of prime interest. These are given in Figure 8.

* * *

FIGURE 8

BREAKDOWN OF INTERNATIONAL MARKETS INTO SATELLITES PER SERVICE TYPE

1994 to 1999

SERVICE	FSS			BSS	MSS	IOL-ISL
BAND	C	Ku	Ka	Ku	L/Ku	60 GHz or Optical
N & S America	7	9				
Europe etc.	4	10	2	9	5	2
Japan etc.	4	6	3	2	1	
Internat. Organs.	4	4			6	
COMSAT TOTALS	19	29	5	11	12	2

2000 to 2005

SERVICE	FSS			BSS	MSS	IOL-ISL
BAND	C	Ku	Ka	Ku	L/Ku	60 GHz or Optical
N & S America	24	21				
Europe etc.	4	16	3	13	2	2
Japan etc.	4	5	3		2	
Internat. Orgs.	6	6			6	
COMSAT TOTALS	38	48	6	13	10	2

It should also be noted that, in line with the consensus, many satellites are multi-service and multi-band and the trend is toward payloads for the newer applications such as broadcast service satellites, mobile service satellites and inter-orbit/inter-satellite links. Also of interest is the continuing trend away from the C Band to the Ku and Ka Bands for fixed satellite services. Perhaps of even greater interest is the fact that Europe, closely followed by Japan, is aggressively pursuing all of these trends (with the exception of the use of Ku Band) with Canada, U.S. (with the exception of the much cancelled and then restored ACTS satellite) and the rest of North America tending to continue with the traditional satellite technologies. It should be noted however, that in the case of Canada, this is based upon the assumption that Anik F would be a straight C/Ku Band replacement for Anik E, an assumption which could well be modified by future Canadian satellite communication strategies.

It is also interesting to note that on a worldwide basis for the same five year period, the forecast requirement is 58 satellites or essentially one a month for the whole five years.

The military satellite communications market is of course one of considerable extent particularly in the United States and in Europe. However all interviewees noted that despite the various agreements between Canada and the U.S. the U.S. military market was one which was virtually impossible to penetrate. There are a few minor exceptions to this, particularly with regard to RF sub-systems and components.

The situation is possibly more difficult in Europe. Notwithstanding this, a number of minor sub-contracts for sub-systems and components for U.K. military satellite communications have been obtained by at least one Canadian company.

The Canadian military market for satellite communications equipment is comparatively small and subject to change. At the moment there is reasonable activity, particularly for Ka Band (20/40 GHz) research and development, systems design and earth station hardware development. Unfortunately it has not been possible to obtain definitive information on DND's satellite communications requirements over the next twenty years. The second phase of the study *Canadian Capabilities and Market Share Projections,* received inputs not only from Phase One but from a virtually one hundred per cent sampling of the Canadian Space Industry, both manufacturing and service; from many Canadian users; and from all relevant government departments.

3.0 COMPETITIVE ANALYSIS

3.1 Introduction

This chapter begins with a description of the approach used by the project team in conducting the competitive analysis. The rating scheme is described in detail, following which are listed the sources of information on which the ratings were based. The major part of this chapter is devoted to the results of the analysis and conclusions.

The following caveat with respect to the objective of the analysis should be noted. Since the study itself is primarily oriented to the development of alternative long-term strategies for government to adopt, and for the formulation of government programs in support of the industry, the emphasis in this analysis is two-fold:

- an assessment of the existing capabilities and strengths of Canadian industry with respect to future opportunities in various market sectors; and

- an assessment of the significance for Canada of the market opportunity in each of the market sectors.

It is the belief of the project team that government support should be used, in general, to foster existing strengths to meet current and predictable future demands. In areas where new technologies, products or services are foreseen, but where there is no current strong Canadian capability, government support is recommended only where the future technologies are seen to be of major importance and where there is latent Canadian capability.

This chapter describes and presents the analytical results of a process which was conducted at a very detailed product, service and market level. However, because many of the products involve only one or a small number of firms, and since the analysis in many cases was based on confidential information obtained during personal interviews with executives of the companies, the results of the industrial analyses are reported at an aggregated level. The consulting team had access to and used the detailed results of the analysis in the remainder of the study.

3.2 Approach

The technological forecast that was conducted in the first part of the study and presented earlier in this report indicated future trends in terms of satellite technologies, products and services. The objective of the competitive analysis described in this section was to determine those products, services and technologies with considerable market potential and for which Canadian industry had a strong competitive position or could, with assistance from government, develop a strong competitive position.

Canadian capabilities and the relative capabilities of Canadian industry vis-à-vis foreign competition were evaluated for each of the following 30 market sectors:

- Systems Design and Operation
    - Communications System Design
    - Satellite Specification and Procurement
    - Launch Procurement
    - Orbit Injection Services
    - Flight Dynamic Systems, including Orbit Control
    - Satellite Payload Specification and Procurement
    - Earth Station Specification and Procurement
    - Network Management
    - Training
- Spacecraft
    - Duplexers and RF Multiplexers
    - On-board Switching, including Phased Array Antennas
    - On-board Processing at Baseband
    - Prime Contractor Responsibility
    - Environmental Testing of Spacecraft
    - Optical Systems
    - Optical Devices
    - RF Antennas
    - Bus - Battery Management
    - Front End LNAs
    - RF Up/Down Converters
    - Solid State Power Amplifiers (SSPAs)
    - Link Management (Adaptive Flux Control) Systems
    - Acquisition and Tracking Servomechanisms
- Earth Stations
    - Design and Integration of FSS Earth Stations
    - FSS Earth Stations except HPAs, LNAs and Antennas
    - LNAs

- HPAs
- FSS Antennas
- Mobile Terminals
- In-orbit Control

For every market sector, an evaluation of each company was carried out, based on the eight rating factors as described in the following section. It should be emphasized that the categories and ratings were developed on a prospective basis. That is, requirements and capabilities with respect to the next decade were evaluated.

For each market sector, an overall rating for the market potential was also assessed, as described in the following section.

3.3 The Rating Schemes

In this section are described the rating schemes used to develop the detailed assessments of absolute and relative strengths and weaknesses of Canadian industry in each market sector, and the assessment of the market potential for Canadian industry in each market sector.

3.3.1 Supply Side Ratings of Canadian Firms

For each market sector, the abilities of Canadian companies and their foreign competitors were evaluated in terms of two sets of rating factors. The first set was specific to the product, service or technology under consideration, and consisted of the following:

- R&D Abilities
- Product/Service
- Technology
- Facilities

For ease of reference in the balance of this report, the ratings in this group are termed "above the line".

The second set of rating factors was used to evaluate overall company strengths and weaknesses, and included the following elements:

- Marketing
- Management
- Financial Capability
- Stability

In general, the second set of evaluations remained constant for a given company, although there were cases when, for example, the marketing effort with respect to one market sector was stronger than for another. For ease of reference in the balance of this report, these ratings are termed "below the line".

For each of the above and below the line rating factors, an evaluation scale of one to five was developed. The criteria for assigning the numeric evaluations for each of the rating factors were as follows:

3.3.1.1 R & D Abilities

This rating factor was developed to reflect the abilities, commitment and experience of the company with respect to R&D in the particular category under consideration. At the lowest level (1) would be a company whose R&D was non-existent or imported. An intermediate rating (3) would describe a company with significant R&D in this category of product/service, but such R&D is highly dependent on the availability of government funding. At the highest level (5) would be a company with a continuous, well established, world calibre R&D program.

3.3.1.2 Product/Service

This factor reflects both the quality and diversity of the product line within a given product/service category. At the lowest level would be a company with a single product with one application. The highest level would describe a company having a diverse and innovative product line within the category.

3.3.1.3 Technology

Technology in this context refers to both the developed technology and the knowledge related to that technology. The lowest level would describe a company having a mature technology only, with little access to state-of-the-art technologies in the product/service area under consideration. The highest level would apply to a company with world class, state-of-the-art, innovative technology in this area.

3.3.1.4 Facilities

Facilities refers to both the adequacy and flexibility of the production and testing facilities as well as their efficiency. The lowest rating would be applied to a company with inflexible, limited, and relatively inefficient production facilities, while the highest rating would describe a company with efficient, state-of-the-art, world class production facilities.

3.3.1.5 Marketing

Marketing, in the context of this evaluation, means export marketing, and is composed of two parts: Export experience and access to export markets. The lowest rating would describe a company which has concentrated on domestic marketing and has no export marketing organization marketing. To be at the top end of the scale, a company would require a world-wide marketing thrust including demonstrated export experience and access to foreign markets.

3.3.1.6 Management

The highly subjective measure of management ability consisted of two separate measures. In the first part, general management abilities were evaluated, with a one-man operation at the lowest end of the scale, and with a large international company at the highest end. However, the aspect of vulnerability was also considered as part of the overall management evaluation.

3.3.1.7 Financial Strength

Financial strength was evaluated in terms of available information. In the case of private companies, detailed financial information was not available and the consulting team relied instead on general impressions with respect to the profitability of operations. The lowest level, and there were none at that level, would describe a company whose financial position could be described as "precarious". Most companies tended to be at the stable and profitable level (3) or highly profitable level (4). The highest level describes a division of large company with access to very considerable capital resources.

3.3.1.8 Stability and Maturity of the Firm

For this factor, the lowest level would describe an immature, new company, with no track record. An intermediate score would describe a company whose future was "likely". The highest level would describe a company which is virtually certain to exist for whole study period.

3.3.1.9 Absolute and Relative Ratings of Canadian Firms

For each Canadian company supplying each of the 29 market sectors, a numeric rating was assigned using the criteria listed above. These formed the *absolute ratings* for the supply side of each market sector.

Relative ratings were also developed for each Canadian company supplying each of the 29 market sectors. These relative ratings were assessed as "+", "=" or "-", depending on whether, in the opinion of the consulting team, the company and product/service being evaluated:

- Regularly outperforms the competition with competitive products and prices (+);
- Is in the mainstream, and always a competitor, with credibility equivalent to the competition (=); or
- Rarely gets ahead, with insufficient depth to be original, and not a serious threat to the mainstream players (-).

Exhibit 1 is a hypothetical but typical matrix which might result from the evaluation of a recently-founded, small, independent company with a single product or service. This hypothetical example illustrates a product or service area in which the company has demonstrated superior R&D capabilities, a strong product/service, a well-developed technology supporting the product/service and fully adequate, but not state-of-the-art, production facilities. This hypothetical company is strong, in absolute terms, "above the line". Such a company might exhibit strong management capabilities, but lower marketing capabilities, and exhibit weakness in terms of financial strength and maturity or stability. In absolute terms, the ratings "below the line" are much lower. Compared with the composite evaluation of the world-wide competition, this hypothetical company is better in terms of R&D, equivalent in terms of product/service, technology and management, but ranks below the competition in terms of facilities, marketing, financial strength and maturity/stability. Its relative strengths are "above the line", but its relative weaknesses are "below the line".

3.3.2 Demand Side Ratings of Market Sectors

In a way similar to that described above for the absolute ratings on the supply side, assessments of the significance of the "market potential" or the attractiveness of each of the 29 market sectors were developed.

In this case, because the information on which the assessments were based is more qualitative in nature, a single composite rating on a scale of 1 to 5 was developed. The factors considered in the assessment were:

- Size of the market ($)
- Certainty of the market opportunity
- Technical risk associated with the technology
- Expected profitability relative to investment

A rating of "1" would be assigned to a market sector with high technological risk, having few applications for the technology within a small, uncertain market, and a return on investment potential well below the norm. At the other extreme, a rating of "5" would be assigned to a market sector with a low technological risk and having many applications within a large, certain market, and attractive return on investment opportunities.

3.4 Sources of Information

The consulting team had access to and used a number of sources of information in conducting this analysis. The major source of information with respect to the capabilities of Canadian industry was the personal interviews which were conducted in the initial stages of the project. In addition, the team used other published and unpublished information from the files of the project team members.

With respect to the capabilities of foreign competition, information was available to the team from a major parallel study which Lapp-Hancock Associates Limited is carrying out for the European Space Agency, as well as other published and unpublished information from the files of the project team members.

Information on the market opportunities for the demand side assessment was obtained from the interviews, from literature searches, from the European Space Agency study, and from other information from the files of the project team members.

3.5 Results of the Analysis

This section contains a detailed discussion of the results and findings of the competitive analysis.

3.5.1 Systems Design and Operation

The market sectors within the Systems Design and Operation category are:

- Communications System Design
- Satellite Specification and Procurement
- Launch Procurement
- Orbit Injection Services
- Flight Dynamic Systems, including Orbit Control
- Satellite Payload Specification and Procurement
- Earth Station Specification and Procurement
- Network Management
- Training

For the market sectors in this category, only two "above the line" ratings were applied: Products/Services and Technology. The reason for this is that, unlike the product market sectors which are analyzed in the following sections, R&D and Facilities do not have the same significance in these service market sectors.

Of the ten market sectors in this category, many Canadian firms are involved in only two: Communications System Design and Earth Station Specification and Procurement. These firms are the equal of firms elsewhere in the world. In the two categories, Products/Services and Technology, Canadian firms rate a 5 and an =: their technology (knowledge) is world-class and state-of-the-art. They have many foreign competitors. Canadian firms vary in size from small to large; if a small firm disappears from the market, others appear to enter it.

In all other market sectors in this group, there is only one Canadian firm, and its assessment is the same for all:

	Absolute	Relative
R&D Abilities	n/a	n/a
Products	5	=
Technology	4 to 5	= or +
Facilities	5	=
--		
Marketing Abilities	5	=
Management	4	=
Financial Strength	4	+
Maturity	4	+

3.5.2 Spacecraft

The market sectors within the Spacecraft category are:

- Duplexers and RF Multiplexers
- On-board Switching, including Phased Array Antennas
- On-board Processing at Baseband
- Design, Assembly and Integration of Spacecraft
- Environmental Testing of Spacecraft
- Optical Systems
- Optical Devices
- RF Antennas
- Bus - Battery Management
- Front End LNAs
- RF Up/Down Converters
- Solid State Power Amplifiers (SSPAs)
- Link Management (Adaptive Flux Control) Systems
- Acquisition and Tracking Servomechanisms

Each of these market sectors is assessed in turn.

3.5.2.1 Duplexers and RF Multiplexers

There are three Canadian firms in this market sector, one of whom has 70 percent of the western and international market (excluding Japan). This major player has been assessed a 4.5 "above the line" for industrial capability, but its major weakness is "below the line" due to the concentration of management, which makes it extremely vulnerable.

The demand side of this sector rates a 5 in the short term, but only a 4 in the medium term due to changes in technology which will be required. These changes induce a small element of risk and uncertainty in the market. Overall, the market potential assessment is 4.5.

3.5.2.2 <u>On-board Switching, including Phased-Array Antennas</u>

There are two Canadian companies in this sector, one of whom has state-of-the-art Technology and Facilities. Above the line, it rates top marks in the Technology and Facilities areas, but its product strength would benefit from increased diversification, and its R&D abilities could be improved. It rates a 4.5 "above the line" for industrial capability. Below the line, the major weakness is due to the vulnerability of management.

The market potential rating in this sector is only 3.5 due to the strong competition in this area which limits the potential market and restricts potential profitability.

3.5.2.3 <u>On-board Processing at Baseband</u>

The two Canadian firms in this market sector are both weak "above the line" with apparent deficiencies in the R&D and Facilities areas, and strong deficiencies in the product area. Overall, the industrial capability in this area is only a rating of 3.

From the market potential side, there is strong international competition from companies like NEC, Matra, and Alcatel. While the total market is large, with many as yet unspecified applications, the extremely strong competition increases risk, leading to a potential market rating of 2.

3.5.2.4 Design, Assembly and Integration of Spacecraft

Three Canadian firms are active in this sector, one of whom is competitive internationally. Its ratings are:

	Absolute	Relative
R&D Abilities	3	-
Products	4	=
Technology	4	=
Facilities	5	=
--		
Marketing Abilities	4	=
Management	4	-
Financial Strength	3	-
Maturity	4	-

It should be mentioned that the above ratings include the facilities of the David Florida Laboratory. Overall, an "above the line" rating of 4 is assigned to this market sector.

On the demand side, a somewhat lower rating of 2.5 is assessed. This is based on an assessment of relatively low risk, and many applications, but extremely strong competition. It should also be noted that this is seen as a key market sector: other Canadian firms can sell their products to a designer, assembler and integrator of spacecraft. This means that this market sector is critical to the success of Canadian firms.

3.5.2.5 Environmental Testing of Spacecraft

Only one organization in Canada, the David Florida Laboratory, offers complete environmental testing services, although a number of firms do certain kinds of testing. DFL rates 5s and +s in all "above the line" categories except R&D Abilities: funding and personnel are required to improve its facilities. The resulting overall above the line rating is a 4.5.

From the potential market side, only a 3.5 rating is assessed because of the world-wide competition.

3.5.2.6 Optical Systems

One Canadian firm is engaged in this market sector. Its strengths are on the technology side, with less favourable assessments in the other three areas. Overall, an assessment of 3 above the line was determined. Niche marketing is a strength "below the line", but as with many small firms, the major weakness is the vulnerability of its capable but small management team.

The market assessment in this market sector is only 2, reflecting in large part the high risk associated with the technology in this area, and the strong competition, particularly in the major U.S. market.

3.5.2.7 Optical Devices

One Canadian firm is a dominant force in certain kinds of devices. It ranks high both above and below the line, with mostly +s in the relative rating column. An overall industrial capability assessment of 5 above the line has been made.

On the market side, a rating of 4 has been assessed, reflecting the strong Canadian competitive position in this developing market.

3.5.2.8 RF Antennas

The two Canadian firms which are active in the area have the following ratings:

	Absolute	Relative
R&D Abilities	3 to 4	-
Products	2 to 3	-
Technology	3 to 4	-
Facilities	3 to 4	-

Marketing Abilities	4	-
Management	4	-
Financial Strength	3 to 4	-
Maturity	4	-

An overall rating of 4 above the line reflects the project team's assessment of Canadian capabilities in this area.

With respect to the potential market evaluation, the strong competition from Hughes in the U.S. was the major reason why the project team agreed on a market assessment of 3.

3.5.2.9 Bus -- Battery Management

The one firm which is active in this area does not yet have a product which is space qualified. Above the line, it rates 3s and -s. Overall, Canadian capabilities in this area are rated as 3.

The market is narrow, and the foreign competition is strong. Since Hughes and some other American Firms have their own battery management systems, it is unlikely that there is much room for another supplier. On this basis, this market sector warranted a rating of only 1 on the market side.

3.5.2.10 Front-End LNAs

Two Canadian firms are active in this market sector, one of whom is a true competitor in the world market. Absolute ratings above the line were all 4s and 5s, and the relative ratings were =s in the case of the more experienced firm. Overall, Canadian capabilities in this market sector were assessed a rating of 4.5

With respect to the evaluation of the potential market, a relatively strong 4 was assigned based on the size of the market, relatively low risk, and the strong competitive position of Canadian industry.

3.5.2.11 RF Up/Down Converters

One Canadian firm is active in this market sector. It rated 4s and minuses in all categories, except for Financial Strength, where it was considered a 3. It was noted that the minuses were not deep ones: the firm is almost the equal of any in the world. Overall, Canadian capabilities in this market sector were rated 4.

Since the technology is conventional, the technological risk is low, but there is a significant amount of competition. Overall, the potential market rating was 3.5.

3.5.2.12 Solid State Power Amplifiers

One Canadian firm is engaged in this market sector. Its ratings are:

	Absolute	Relative
R&D Abilities	3	-
Products	4	-
Technology	4	-
Facilities	4	-
--		
Marketing Abilities	3	-
Management	4	-
Financial Strength	3	-
Maturity	4	-

Overall, Canadian capability rates a 3.5.

This is a huge, highly profitable market sector, with many applications. However, there is also very strong competition, particularly from the major Japanese firms working in this area. For Canada, this market opportunity rates only a 2.5.

3.5.2.13 Link Management (Adaptive Flux Control) Systems

Two Canadian firms, and CRC, are active in this sector. CRC is by far the strongest in Canada: its ratings above the line are:

	Absolute	Relative
R&D Abilities	4	-
Products	4	-
Technology	5	=
Facilities	5	-

It was considered that CRC puts Canada well up in Technology and Facilities; it is a little weak in R&D Abilities and Products because it has few personnel and a limited budget in this area. Overall, Canadian capabilities above the line rate a strong 4.5.

The market opportunity for Canada is also strong, receiving a rating of 4 reflecting the growing market, particularly at higher frequencies, and the strong competitive position of Canadian industry, assuming the technology is transferred to industry.

3.5.2.14 Acquisition and Tracking Servomechanisms

This market sector can also be called Antenna Pointing. It is related primarily to inter-satellite and inter-orbit links (ISLs and IOLs). The servomechanisms required for IOLs are an order of magnitude more complicated than those required for ISLs. A limited amount of work has been done in this area in Canada in conjunction with Anik E. Overall, a rating of 4 was assessed above the line.

In terms of market potential, a 2 was assessed this market sector based on the expected limited market and the high risk associated with it.

3.5.3 Earth Stations

The market sectors in the Earth Station category are:

- Design and Integration of FSS Earth Stations
- FSS Earth Stations except HPAs, LNAs and Antennas
- LNAs
- HPAs
- FSS Antennas
- Mobile Terminals
- In-orbit Control

It may be noted that TVROs have been omitted from the list of market sectors. They have been omitted because it is a well established consumer market, using mature technology, in which Canadian firms make few international sales now. It is unlikely that Canadian firms will penetrate world markets during the study period.

3.5.3.1 Design and Integration of FSS Earth Stations

The consulting team identified six Canadian firms who are engaged in this market sector. Three of the firms rated:

	Absolute	Relative
Products	4	=
Technology	4	=
Facilities	5	=

Since sub-system R&D is considered separately below, R&D ability was considered not applicable to this sector.

Overall, Canadian capabilities rate a 4 in this market sector.

In terms of the potential market opportunity, even though the market is large, the six Canadian firms face strong international competition. Overall, the market opportunity was assessed as 3.5

3.5.3.2 FSS Earth Stations except HPAs, LNAs and Antennas

This is another area where there are many Canadian firms; again, the consulting team identified six. The best ratings above the line were:

	Absolute	Relative
R&D Abilities	4	-
Products	4	-
Technology	4	-
Facilities	4	-

This is seen as a larger market than most. In view of the size of the market, tempered by the strong international competition, an overall market opportunity rating of 3.5 was assessed.

3.5.3.3 LNAs

One Canadian firm is active in this market sector. Its ratings are:

	Absolute	Relative
R&D Abilities	2	-
Products	2	-
Technology	3	-
Facilities	4	-
Marketing Abilities	1	-
Management	4	-
Financial Strength	3	-
Maturity	4	-

The overall Canadian capability rating in this market sector is only 2.5.

In view of the weak Canadian competitive position and the strong international competition in this market sector, a market rating of only 2 was assigned.

3.5.3.4 HPAs

Three Canadian firms were recognized as being active in this market sector, but in three different parts of it: modules, tubes, and RF R&D.

Canada's position in HPA modules is weak, receiving an overall rating above the line of only 2. In tubes for HPAs, Canada has state-of-the-art technology and products now, but the R&D effort and facilities are weak. This firm has limited marketing, because the market has come to it: this may not be the case in the future. Above the line, Canadian capabilities in HPA tubes are rated 4.

With respect to the market opportunity side, the tube market received a rating of 3, reflecting a degree of uncertainty or risk with respect to the continued use of tube-type HPAs for low to moderate power outputs. With respect to modules, the weak position of Canadian industry was the main reason for the very low rating of 1.

3.5.3.5 FSS Antennas

In this market sector, one Canadian firm is a world leader: it rates solid 5s and +s in all Product Categories, and 4s and =s below the line. They are not active in developing phased arrays. However, it is foreseen that phased arrays will not be used, in any number, for FSS antennas during the study period. Overall, Canadian capabilities in this area are rated as 5.

The market opportunity is also a good one for Canada as it is expected to maintain its current strong competitive position and retain its current share of the world market. A rating of 4.5 was assessed.

3.5.3.6 Mobile Terminals

Various Canadian firms, and CRC, are well placed in this market sector. The ratings are:

	Absolute	Relative
R&D Abilities	5	+
Products	4	+
Technology	5	+
Facilities	5	+

Marketing Abilities	4	=
Management	4	=
Financial Strength	3	-
Maturity	3	-

Overall, Canadian capabilities above the line rate a 4.5, reflecting the excellent deployment of DOC funding in the past.

This market sector includes everything from the antenna, to baseband, and back. The principal product in this sector is for use with MSAT. It is foreseen that, while cellular radio has captured much of the land mobile market, MSAT terminals may serve most of the marine and aeronautical markets, and those portions of the land mobile market which cannot be economically served by cellular. An overall market rating of 4.5 was assessed, reflecting both the size of the potential market opportunity and the strong competitive position of Canadian firms in this area.

3.5.3.7 <u>In-Orbit Control</u>

One Canadian firm offers hardware for in-orbit control. Its ratings are:

	Absolute	Relative
R&D Abilities	2	-
Products	2	-
Technology	2	-
Facilities	3	-
--		
Marketing Abilities	3	-
Management	2	-
Financial Strength	1	-
Maturity	2	-

Overall, Canadian capabilities rate 2.5 above the line.

There is significant competition in this fairly narrow market segment. The potential market opportunity is assessed at 2.5.

3.6 Conclusions Regarding the Competitive Analysis

The conclusions regarding the competitive analysis can be summarized in the table on the following page:

	Potential Capability	Potential Market
Systems Design and Operation		
Communications System Design	5	4.5
Procurement, Launch, etc.	4.5	4.5
Spacecraft		
Duplexers and RF Multiplexers	4.5	4.5
On-board Switching, including Phased Array Antennas	4.5	3.5
On-board Processing at Baseband	3	2
Prime Contractor Capability	4	2.5
Environmental Testing of Spacecraft	4.5	3.5
Optical Systems	3	2
Optical Devices	5	4
RF Antennas	4	3
Bus - Battery Management	3	1
Front End LNAs	4.5	4
RF Up/Down Converters	4	3.5
Solid State Power Amplifiers (SSPAs)	3.5	2.5
Link Management (Adaptive Flux Control) Systems	4.5	4
Acquisition and Tracking Servomechanisms	4	2
Earth Stations		
Design and Integration of FSS Earth Stations	4	3.5
FSS Earth Stations except HPAs, LNAs and Antennas	4	3.5
LNAs	2.5	2
HPAs - Tubes	4	3
- Modules	2	1
FSS Antennas	5	4.5
Mobile Terminals	4.5	4.5
In-orbit Control	2.5	2.5

The appropriate weighting which should be accorded each of "industrial capabilities" and "market opportunities" in developing strategies for high technology areas like communications satellites is a matter of widely varying opinion. The market sectors examined in this study demonstrated aspects of both technology-push and demand-pull. It is therefore appropriate to include both factors in the overall assessment of opportunities.

If the capability and market factors are multiplied, the following overall ratings apply to the market sectors under review, ranked in order of decreasing score within each major group:

	Overall
Systems Design and Operation	
Communications System Design	23
Procurement, Launch, etc.	20
Spacecraft	
Duplexers and RF Multiplexers	20
Optical Devices	20
Front End LNAs	18
Link Management (Adaptive Flux Control) Systems	18
Environmental Testing of Spacecraft	16
On-Board Switching, including Phased Array Antennas	16
RF Up/Down Converters	14
RF Antennas	12
Prime Contractor Capability	10
Solid State Power Amplifiers (SSPAs)	9
Acquisition and Tracking Servomechanisms	8
Optical Systems	6
On-Board Processing at Baseband	6
Bus - Battery Management	3
Earth Stations	
FSS Antennas	23
Mobile Terminals	20
Design and Integration of FSS Earth Stations	14
FSS Earth Stations except HPAs, LNAs & Antennas	14
HPAs - Tubes	9
In-Orbit Control	6
LNAs	5
HPAs - Modules	2

4.0 GOVERNMENT ASSISTANCE PROGRAMS

4.1 INTRODUCTION

The conclusions of the competitive analysis of the foregoing chapter constitute the best judgement of what will happen over the time frame of the study if the present industry capability and momentum go forward in the current government policy, regulatory, and industry-assistance environment.

It might be argued that it is gratifying to see a large number of sectors with scores high enough give confidence that Canadian industry will survive in the international forum. It might be argued further that the current government environment is effective, and should continue without major changes, assuming that improvements, as opposed to changes, are of course, always desirable and are likely to occur.

The study team is persuaded, however, on the basis of the industry interviews and the trends in satellite communications technology presented in Chapter 1, that the industry position, from a consideration of the previous twenty years to the end of the study period, is in decline, in spite of the fact that several sectors are expected to flourish. During the analysis of task 2 the discussion of the market opportunity of the various sectors revealed, more often than not, that the outlook for the future was less promising than the present situation because of increasing competence on the part of the international industry, increasing numbers of companies in the field, increasingly aggressive marketing on the part of foreign administrations and the emergence of highly competitive trading blocks.

Carefully chosen, specific government initiatives can reverse this trend thereby enhancing the market opportunity for Canadian satellite communications products and services, to match the growing competence of the Canadian labour force in these areas. "Government initiatives" in this context goes beyond the concept of government assistance to the satellite communications industry. It addresses also the broader strategic objectives of DOC vis-a-vis the role of satellite communications in the Canadian socio-economic infrastructure.

It is the purpose of this chapter to present the current industry-assistance mechanisms as seen through the eyes of the industry interviewee, to analyze the results, and to extract those findings which can be used to help develop a more strategic approach for the future.

To begin, the interviewee opinions are presented and discussed.

A number of short-term tactical (as opposed to strategic) aspects of current government assistance mechanisms suggest themselves as a result of the interviews. These aspects are presented as a short list of short-term tactical objectives.

The remainder of the chapter is a discussion and recommendation on a number of strategic policy and regulatory issues raised by industry and government representatives during the interviews.

4.2 INTERVIEW RESULTS

4.2.1 Methodology

Industry views of current government assistance programs were obtained simultaneously with the interviews for Tasks 1 and 2 of the study.

In preparation for these industry and government interviews, basic information on current federal assistance programs was obtained from government departments and agencies. In all, six principle sources of assistance were identified and selected as representative of the current situation:

- Department of Communications (DOC)
- Department of Industry, Science and Technology (DIST)
- Department of External Affairs (DEA)
- Department of National Defence (DND)
- National Research Council of Canada (NRCC)
- National Science and Engineering Research Council (NSERC)

The DOC industry support office at CRC was most helpful in identifying contacts for these programs; in many instances the DOC Office had basic information on hand as part of its industry-briefing package. Key personnel in DIST, DEA, NRCC, and NSERC were contacted to confirm details and to discuss the objectives of the study and request their views. The information obtained from all of the programs was summarized under three headings - grants and shared costs, one hundred per cent contract, and goodwill - in the three page Table shown in Appendix C.

It should be noted that the summary of government assistance programs is not intended to be an authoritative guide. It is intended rather to illustrate, qualitatively, the breadth and variety of federal government activity.

Copies of the Table were taken to all interviews as an introduction to the discussion of government assistance. During the interviews comments were also requested on government policy, the regulatory environment, research tax credits and the overall Canadian industrial climate as it is established by government activity in general. Interviewees were asked to compare the Canadian industrial climate to the climate in other industrialized countries if they were familiar with it.

Key comments obtained from the interviews with both industry and government are summarized in Table 3.1 under seven headings:

- Shared Cost R & D
- Shared Cost Marketing
- Full Price Contracts
- Government Goodwill and Technology Transfer
- Policy
- Tax Credits
- The Regulatory Environment

* * *

INTERVIEWEE OPINIONS OF CURRENT GOVERNMENT ASSISTANCE, POLICY AND REGULATORY ENVIRONMENT

#	SECTOR	SIZE	AGE	SHARED-COST R&D	SHARED-COST MKTG	FULL-PRICE CONTRACTS	GOVERNMENT GOODWILL & TECHNOLOGY TRANSFER	POLICY	TAX CREDITS	REGULATORY ENVIRONMENT	OTHER
1	mfg	l	m	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	sat comms going nowhere in Cda
2	mfg r&d	m	m	not effective; no incentive to take risks; maybe ok for small companies	n.a.	UPP useful. DOC ICF useful. Intellectual property a problem. Govt funding gives needed leverage to begin & keep going until mkt is secured	critiquing of r&d by experts at CRC and DOCHQ valuable	n.a.	n.a.	n.a.	govt cant commit to multi-year funding approval delays are crippling
3	ser-vice	s	y	n.a.	n.a.	positive experience with DOC contracts to modify eqt	satellite time & exp'l hdwe from DOC is good	n.a.	n.a.	Cda should extend spectrum regs beyond 200-mi limit	n.a.
4	mfg	l	m	ok for general r&d; should be 100% for targetted r&d, e.g. military, as in USA.	PEMD is good, used to the limit	UPP requires dept'l sponsor; risk of dept going to open tender with your ideas	n.a.	stop regionalization; its counter-productive to FTA goals and inefficient; Cda is low on mgt skills; leave hi-tech in Ont & Que	useful pleas audit sooner, possible liabilities are a worry	n.a.	n.a.
5	mfg sw		m	IRAP a key source DIPP not appropriate for sw	n.a.	UP sometimes, govt hdwe & sw procurements are good	n.a.	n.a.	n.a.	n.a.	n.a.
6	user	l	m	n.a.	n.a.	n.a.	continue SHARP; application is waiting	n.a.	n.a.	n.a.	n.a.
7	user	l	m	n.a.	n.a.	n.a.	n.a.	govt role re financial, regulatory, & policy is critical for future dev of sat comms	n.a.	deplores lack of uniform regs policy across Cda, especially inability to interconnect to switched net in all provinces	n.a.
8	ser-vice	l	m	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
9	ser-vice	l	m	incentives are better; Ontario's matching at U of Ott is useful	ind'y should do itself; must learn how	n.a.	n.a.	assistance to service sector well below that to mfg; service not given credit for job creation	better than sponsoring tech'l dev't	DOC can conduct spectrum management to assist Canadian service ind'y	when supporting tech dev't follow it all the way to a successful business; ensure business skills are in place
10	ser-vice	l	new	incentives are better	n.a.	govt as first customer is good; gives major impetus; also avoids FTA	r&d at CRC is appropriate but govt should follow up as 1st customer	n.a.	n.a.	n.a.	govt as customer is excellent; all else has minimal
11	govt	-	-		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	no comments on govt assistance
12	govt	-	-	n.a.	n.a.	n.a.	n.a.	emphasize personal sat services where fibre is absent	n.a.	n.a.	no comments on assistance
13	ser-vice	l	m	n.a.	n.a.	n.a.	n.a.	dont institutionalize a technology, e.g.sat comms, it hinders integration into a system in the proper niche	n.a.	sat standards not compatible with terrestrial network	too much emphasis on components & eqt. 10-year, $20M govt/ind'y program on a systems approach is needed to keep Cda ahead

INTERVIEWEE OPINIONS OF CURRENT GOVERNMENT ASSISTANCE, POLICY AND REGULATORY ENVIRONMENT

#	SECTOR	SIZE	AGE	SHARED-COST R&D	SHARED-COST MKTG	FULL-PRICE CONTRACTS	GOVERNMENT GOODWILL & TECHNOLOGY TRANSFER	POLICY	TAX CREDITS	REGULATORY ENVIRONMENT	OTHER
14	service	l	m	n.a.	n.a.	n.a.	n.a.	dont subsidize sat services at the expense of tax-paying competitors; sat comms must pay its own way or change to a public service for special social needs, but not a competitor to terrestrial net.	n.a.	n.a.	n.a.
15	govt	-	-	n.a.	n.a.	n.a.	govt must support ind'y to penetrate EC'92 by joint ventures thru ESA, as in the Lapp-Hancock/ESCO project	ANIK-E completes govt effort to establish SPAR as a prime, it is hoped;	n.a.	interconnect obstacles noted	n.a.
16	govt	-	-	ind'y 50% share does not assure quality; proposals need financial audit as in Doyle's NSERC paper on tech transfer, June, 1985		supporting $30M in r&d contracts		MSAT and cellular must be compatible	n.a.	not convinced that regulatory environment keeps long distance rates high	spin-off from Mil'y EHF program is to mkts outside Cda
17	mfg	m	m	10-year IRAP user, good for small/medium co's; DIPP essential to keep competitive, major catalyst; NSERC is good; dont know TOP, looks good	PEMD requires too much paperwork; never used; overhaul it or scrap it	UPP is excellent; needs more funding; MILCOM is excellent; why not fly payloads on SAT-B	very good; signing MOU with CRC	implementation of MSAT favored SPAR; Cdn space objectives in satcomms, milcomms & remote sensing must be jointly defined and focussed	very good, r&d incentive; keep restraints down, plse	n.a.	current funding on space inadequate; India outspends Cda
18	mfg	m	m	IRAP used; good for focussed tech dev.;DIPP is good; dont know of TOP or MSOP: more publicity please.	PEMD used; cost sharing aspect means efficiency for the co.	UPP not used	unknown, but will enquire	n.a.	useful, no problems; small business limit of $2M should be $10M	n.a.	n.a.
19	service	l	m	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	mfg	m	m	IRAP 200-person limit bad; maybe ok to START a co. DIPP approval cycle a definite disadvantage; not use recently	limited use of PEMD in high-risk mkts in China & Africa; will use for mil'y mkt in future	not a major UPP user, requires much govt support	n.a.	n.a.	n.a.	n.a.	n.a.
21	govt	-	-	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Cdn microwave testing 10 yrs behind; work needed on sat antenna deployment
22	sw	s	m '83	n.a.	PEMD used; QUE is better, acts like a partner, more relaxed than PEMD;CIDA used successfully; DEA trade shows worthless; co. must be the driver, not the govt	one major good experience, govt kept rights but allowed exploitation; tight govt specs produce a product with too narrow a mkt; UPP approval too political, dont know what you're up against	positive collaboration with NRC, hopes for more	n.a.	good, now that difficult negotiations with Revenue Cda are over	n.a.	feds more finnicky than provinces in supporting ind'y; provs more progressive: use outside experts to assess proposals

INTERVIEWEE OPINIONS OF CURRENT GOVERNMENT ASSISTANCE, POLICY AND REGULATORY ENVIRONMENT

#	SECTOR	SIZE	AGE	SHARED-COST R&D	SHARED-COST MKTG	FULL-PRICE CONTRACTS	GOVERNMENT GOODWILL & TECHNOLOGY TRANSFER	POLICY	TAX CREDITS	REGULATORY ENVIRONMENT	OTHER
23	mfg	m	m	ok but approval too slow; need mfg contracts to follow up dev't	PEMD used but very restrictive	IP big issue, co. component gets lost; DSS demand for return of non-consumables queried, who uses them?; DSS boilerplate punishes ind'y, dev't at fixed price doesn't make sense, co. must contribute own input so not really fully funded; UPP moves faster than shared cost; different UPP sponsors cause different handling of the same basic mechanism	n.a.	n.a.	good idea, botched, not worth the complexity	n.a.	DSS rules on r&d procurement not logical: can't warrant r&d when no provision in the price for it
24	sw	l	m	n.a.	PEMD used but too many strings, prefer to pay own way	n.a.	test facilities at CRC are useful; relations with CRC always good	n.a.	n.a.	common carriers wont reduce L-D rates so sat nets will grow; govt wont make CC's reduce L-D rates; non-regulated monopolies will drop prices to attract volume	general policy is to 'steer clear of govt'
25	sw & mfg	s	new	bad experience with MSDP, too many contradictions; IRAP not appropriate for dev't; TOEP used but seems to favor big co's; dev't support for small co. is difficult	trade fairs good for govt image but ineffective for co.; trade counselors do more for big co.	large UP ended up 8/5 govt/co. split; govt specs too tight, system wont sell, but subsystems would be useful	tried twice to relate to CRC, no success	Telesat should not be operator and provider of value-added services; should split as for mobile sat	n.a.	n.a.	govt programs not sufficient for small business: e.g.-Dipix needed help to sustain r&d while investing in a product; 'prove you dont need the money and you can have it!'; 10 local co's getting Japanese assistance, so tech'y exported to Japan
26	mfg	s	m	IRAP: 'no aggravations'; not big user of 50-cent dollars	PEMD used, rules not always clear on the forms; trade counselors generalists-regrettable necessity; hope to use export credit	little UPP experience; utility of govt contract reflects who wrote the spec; as follw-on to prior studies they effectively bring the govt into a govt dev't team(e.g.CRC or DREO)	tech transfer never attempted; dev't contracts supported certain staffing level for systewm dev't and products	why can't Cda access the ESA tech dev't program?	used, with minor problems with Revenue Cda	n.a.	need assistance to recruit especially in UK
27	mfg	s	m '84	IRAP more professionally run than DIPP, both used; 'friends at court' help in DIPP; IRAP for small grants, DIPP for bigger grants	Trade counselor service is excellent, Americans are jealous	dev't contracts somewhat useful; contracted-out r&d gives outstanding economic leverage, shortens dev't chain in ind'y,avoids increases to govt lab staff; recipients of govt r 7d contracts not always motivated to exploit results, govt should purchase the product	n.a.	need coherent govt purchasing policy that supports r&d in ind'y	useful; dont change it	n.a.	govt financial assistance is good but co's must remain firmly in control of their mktg plans

INTERVIEWEE OPINIONS OF CURRENT GOVERNMENT ASSISTANCE, POLICY AND REGULATORY ENVIRONMENT

#	SECTOR	SIZE	AGE	SHARED-COST R&D	SHARED-COST MKTG	FULL-PRICE CONTRACTS	GOVERNMENT GOODWILL & TECHNOLOGY TRANSFER	POLICY	TAX CREDITS	REGULATORY ENVIRONMENT	OTHER
28	mfg	l	m	special shared-cost MOU/MOA; MOA is with DOC; both utilize normal assistance programs; big DIPP user; endorses NSERC-funded space-related research at Cdn univ's; use NRC part-payment summer students	PEMD used, is good	100% contracts common; pressure to put this inder the MOA with DOC; MSAT contracts are under the MOA	n.a.	n.a.	have used tax credits; some are passed to customers	n.a.	Active in centre of excellelence, CIAR, TRIO; Active in federal Networking of centres of excellence program;
29	mfg	m	m	DRIE support important	dont use gov't reps	dev't contracts were key to entry into sat comms; need funds to develop new generations of products	tech transfer in the past, none current	gov,t membership in INMARSAT necessary to bid; contracting-out r&d reduced overall "r" since most contracts are "d", but gov't r&d both down; industrial off-sets good, so is CIDA	n.a.	Cdn regulatory climate destroyed Skyswitch	no gov't interest to fund work aligned to co's business plans; competitors in other countries have: -large domestic mkt in US -heavy gov't support(PTT's + military) in France -MITI omni-present in Japan for good strategic planning
30	mfg	m	m	lionited use of IDRP grant; DIR & ECRDC were better;need commercial version of DIR; DIR & DIP very flexible;	have own reps	dev't contracts very important; UPP is good but requires time the co. doesn't have; now covered by DRED & DREV	DFL calibration services used in past, not offered now since available in ind'y; gov,t person helpful in getting $380K ESA contract	offset agreements are good; gov't must suport systems after the components are developped, as in US defence ind'y; gov't needs targets	investment tax credits used	n.a.	Cda needs fully-funded program of research in ind,y; research in Cdn univ's reaching critically low level; shortage of qualified people, must hire immigrants; centres of excellence are bad:-syphon funds from programs for direct ind'y assistance
31	mfg	l	m	tried & gave up, not worth the effort	EDC financing works	same as for shared-cost:- tried and gave up	no appropriate technology in govt labs	n.a.	ITC helps; trend is to higher % of professional staff, so more ITC expected	n.a.	suppliers must license foreign technology to met gov't delivery times, this is WRONG STRATEGY! hurts Cdn ind'y in long-term int'l mkts
32	R&D	s	y '86	n.a.	n.a.	n.a.	seeking licence on CRC digital technology	Cda spends too little on R&D vis-a-vis other countries	bad ITC experience, Revenue Canada doesn't understand r&d	n.a.	approval times too long; Cda needs equivalent to US defence program; US co's in best position to compete globally, have big domestic mkt
33	mfg	l	m	old DRIE MOU waste of time	tech attaches in embassies are great, especially Korea, India, & US	contracts are ok	n.a.	n.a.	n.a.	n.a.	lead time too short to develop technology, must license off-shore, especially for defence
34	ser-viice	l	m	no experience	does its own and helps others in foreign countries	n.a.	supports work at CRC	gov't should identify global potential areas and promote them to ind'y; FTA will put pressure on assistance programs	n.a.	n.a.	n.a.

INTERVIEWEE OPINIONS OF CURRENT GOVERNMENT ASSISTANCE, POLICY AND REGULATORY ENVIRONMENT

#	SECTOR	SIZE	AGE	SHARED-COST R&D	SHARED-COST MKTG	FULL-PRICE CONTRACTS	GOVERNMENT GOODWILL & TECHNOLOGY TRANSFER	POLICY	TAX CREDITS	REGULATORY ENVIRONMENT	OTHER
35	mfg	m	m	good idea but approval too long; 50% is fiction, co. share is much more; old DIR was good	cant use, products too specialized; need electronics experts in embassies	dev't contracts ok but impose additional overheads on the co.; approval delays hurt	CRC GaAs service is excellent; more of this kind needed; other groups not as helpful; licencing is good	gov't must learn to exert leverage with for e.g. ESA; dont demand up-front payment foe licence, wait for some profit, make licence exclusive; SPAR-as-a-prime is not working, change is required; SPAR is doing the gov't job	ITC good but stringing out benefits over years dilutes effect for small co.; why not allow co. to retain employee deductions at source, for new jobs, as an incentive, for a certain time	n.a.	gov't participation in int'l organizations is critical, int'l rules are rough; money under the table is sometimes necessary; large domestic mkt not a key for hi-tech, need niche, mktg, technical, skills plus excellence to export; Cda must learn this.

4.2.2 General Comments

A general reaction of senior industry personnel was surprise at the number of assistance programs. While most interviewees were familiar with many of the programs, they did not realize how numerous they were until they saw them listed.

In a few instances a program was criticized for its own sake, but in the vast majority of cases programs and their objectives were praised, the implementation of a program being the target of criticism. An example of the former view is found in the criticisms of the PEMD program in DEA. One interviewee felt that companies must learn to do their own marketing, without government assistance. Two others believe international trade fairs are not a suitable vehicle for marketing industry know-how though they make Canada look good.

The lengthy approval process for contracts and shared cost programs is a prime concern of industry. The investment in time and human resources and the benefits of obtaining the assistance are often in the balance. Industry believes that government must do better to make these programs fully effective. Until that is done, important windows of opportunity will be missed.

The relatively short delivery time on development contracts does not allow a contractor time to develop all of the key technology. The result is that contractors are forced to seek a licence for off-shore technology. In the long term, this is seen as a serious threat to the expansion of the Canadian industrial research and development base.

The government's role as a first buyer for a new product or a new technology was highlighted in several interviews. The double-advantage of having:

(a) credibility with a major buyer - the Canadian government, and

(b) an assured buyer for the first saleable item was judged by one interviewee to overshadow the combined benefits of all other government assistance efforts.

4.2.3 Comments on Specific Types of Assistance

- Shared cost research and development assistance is viewed favourably by the majority of industry users. Better publicity is needed. Companies that have persevered appear to be satisfied in the longer term with shared cost programs.

- Shared cost marketing assistance in foreign countries has attracted a large number of users. Views on this activity are more "pro" than "con" but there are a number of criticisms of the paperwork and the severity of the PEMD restrictions and their pedantic implementation.

- Full price contracts, including the now defunct Unsolicited Proposal Program (UPP) of Supply and Services Canada, are very popular. 100% paid contracts for development are singled out for special praise. Fully paid development contracts, as opposed to shared-cost projects, can be critical to the successful initiation and completion of longer-term R&D projects because of the financial risk involved. In addition these contracts give a company economic leverage, shorten the development chain, and help maintain viable levels of key development staff.

- One interviewee made a strong appeal to the government to avoid balkanizing the communications industry through an inappropriate use of regional development programs. It was argued that inappropriate regionalization of the industry leads to inefficiencies and low international competitiveness and is counter-productive to the goals of the Canada - U.S. Free Trade Agreement (FTA). Other interviewees also noted the possible conflict between policies for FTA and policies for regional assistance.

- Government Goodwill and technology transfer is viewed favourably. Of 27 industry interviewees, 17 commented on this activity, 14 of them positively. The availability of objective, informed R & D personnel at the Communications Research Center and at the National Research Council is important. The GaAs CAD and foundry service at CRC is held up as a model because it is readily accessed with a minimum of paperwork; proprietary concerns are handled professionally.

- Government policy in satellite communications has tended to cast satellite communications as a supplement to rather than as an integral part of the national telecommunications infrastructure. This attitude has not served the public's socio-economic interest well. Clear government policy for satellite communications is critical for its future development.

- Tax Credits are perceived, in the main, to be useful but audit delays and drawn out disputes over eligibility of certain activities hinders more general use.

- The telecommunications regulatory environment is not serving the needs of the satellite communications industry or public users.

4.3 SHORT-TERM TACTICAL OBJECTIVES

Some of the criticisms voiced by the industry are long-standing complaints that have their origin in the complicated approval process carried out to ensure contracts and grants and other forms of assistance meet the criteria attached to a specific program. An analysis of government management practice is beyond the scope of the present study but the project team urges the government to examine closely some of the management practices, especially the use of committee approval, as opposed to line management authority, to approve projects. The experience of industry indicates that line managers in some departments and agencies use their authority decisively to expedite approval. This expeditious approach assures that the work set out in a proposal will be started while the concept is still timely or novel.

The short-term tactical objectives listed below do not require high level policy decisions, they are day-to-day management issues, but they are nevertheless a key link in a successful government strategy.

1. The government must assure that the time taken to approve government assistance awards to Canadian industry is consistent with the timeliness of the proposed activity and the investment in resources on the part of the company in securing the support.

2. The government should take positive steps to inform the satellite communications industry of available government assistance mechanisms and promote their use. A clearing-house type of information centre with expert staff that actively seeks out and gets to know the players in the industry, and then acts as a broker and expediter between a company and a source of assistance, keeping the momentum in an initiative on the part of the company, is required.

3. The government should recognize the need for adequate time to develop new technology or establish a Canadian capability when acquiring and setting schedules for new products and services under procurement contracts.

4. The government should clarify conditions and criteria for assistance programs **before the fact** to avoid misunderstanding and the unnecessary expenditure of company resources on application for assistance that is inappropriate.

5. The government should expedite the audit of company submissions in aid of tax credits.

4.4 STRATEGIC REGULATORY ISSUES IMPACTING ON SATELLITE COMMUNICATIONS

4.4.1 Strategic Concerns of Mobile Satellites from an International Viewpoint

It is considered that the mobile satellite service will be a major area of expansion over the next two decades. Canada's MSAT will be the world's first operational land mobile service. However it has the potential capability of serving both aeronautical mobile satellite service and maritime satellite service.

Currently INMARSAT, an international organization made up of the League of Maritime countries, has the monopoly to provide maritime satellite mobile service throughout the world. Approximately two years ago, this mandate was extended to cover the provision of service to aeronautical mobile satellite service. Currently, INMARSAT has tabled a resolution to permit it to provide land mobile service as well.

From a strategic viewpoint, Canada should protect its mobile satellite service interests in all three areas; land, maritime and aeronautical. Consideration should be given to ensuring, through Canada's position in INMARSAT, that INMARSAT does not have the right to provide land mobile service over any of Canada's territories, does not have the exclusive right to provide satellite service to shipping in Canadian waters, and preferably Canada should have the right to compete with INMARSAT for maritime traffic to the limit of the MSAT service areas; and finally that Canada should have the right, and preferably the mandate, to provide aeronautical satellite service to all areas where it has air traffic control responsibilities.

It is felt that over the next two decades there will be considerable competition for the rights to provide such mobile satellite services and Canada should position itself at the moment to make full use of its leading position in mobile satellite service given to it by its MSAT activities.

By such strategic regulatory and policy actions, Canada can position itself so that its manufacturing and service industry is provided with the maximum opportunity in the future to access these markets.

4.4.2 Impact of a Lack of a Canada-wide Interconnect Policy on the Development of Satellite Communications

It is considered that the lack of uniformity of interconnection policies have inhibited the development of satellite communications in Canada by negating in part its key advantage of distance insensitivity. Over the last decade or so, considerable liberalization of interconnection regulations between customer-owned networks and the public switched network has taken place in those areas where the government has exercised its jurisdiction, primarily in Ontario, Quebec, British Columbia, Yukon, NWT and parts of Newfoundland.

Until recently, the provinces have exercised jurisdiction over telecommunications in the other seven provinces, and in those parts of Ontario and Quebec served by independent telephone companies. However, on August 14, 1989, the Supreme Court of Canada handed down its decision in the CNCP-AGT case. This decision found that AGT was under federal jurisdiction. While AGT, SaskTel and Manitoba Telephone System are technically exempt from the provisions of the *Railway Act* under the Crown immunity rules, simple amendments to that Act or the *Interpretation Act* would make them subject to the *Railway Act*. The decision of the Supreme Court clears the way for the federal government to establish uniform interconnection rules throughout Canada.

4.4.3 Recognition of Satellite Communications as an Integral Part of Communications as a Whole

To date, satellite communications, particularly in relation to the use of satellite communications by the telecommunications common carriers, has developed as a separate entity rather than an integral part of the national network. This has come about for a number of reasons, including the initial regulatory and policy approaches taken in the Telesat Canada Act.

One impact of this has been to essentially exclude consideration of satellite communications as an integral part of the national telecommunications network. One factor is that the federally incorporated common carriers, and indeed the majority of the provincial telecommunications common carriers, are regulated on the basis of return on equity. The lease of space segment capacity by Telesat Canada to the common carriers is an operational expense rather than a capital investment for the common carriers. As such, there is no equity element on which the common carriers are permitted to earn a rate of return, and in fact the use of space segment eliminates the need for terrestrial investments, thereby having a further negative impact on potential profit for the common carriers. This has provided a major inhibitory factor in the consideration of the use of satellites by the common carriers. Other factors are the development of technical specifications that are not necessarily compatible and homogenous with terrestrial network standards.

To enable satellite communications to be exploited to the full by the telecommunications common carriers, it needs to be perceived from policy, regulatory and technical aspects as merely another distribution method that could be used to improve service of the national switched network. Future strategic policy planning should consider these points.

It is worthy of note that such liberalization and consideration of satellite communications as an integral part of telecommunications public switched networks is being worked towards in the other major trading areas of Europe and Japan, in recognition of the fact that cost-effective communications is a critical element of socio-economic progress in the future.

4.4.4 Regulatory and Policy Concerns in the Development of Land Mobile Satellite Service

Currently, the planned MSAT service and its parallel terrestrial cellular mobile service are incompatible from the viewpoint of channel bandwidth and general equipment use. Thus a service user requiring mobile service in urban areas as well as remote areas will require two separate and expensive pieces of equipment. Technological trends are exerting pressures to reduce this incompatibility with the cellular systems working towards digital service over the next five years, and the possibility that lack of spectrum will provide significant pressure towards the user of 5 KHz channels (as used by MSAT) rather than the current 25 KHz channels. It is seen that compatibility between terrestrial cellular systems and the land mobile satellite service will be greatly to the advantage of not only Canadian service providers and manufacturers but to the user population as a whole. Thus from a strategic regulatory viewpoint, the Department of Communications should take every possible action to encourage the merging of terrestrial cellular and satellite mobile services in both spectrum bandwidth usage and technology.

The foregoing discussion of short-term tactical objectives and strategic regulatory issues serves as an introduction to the broader issue of overall government policy for satellite communications and the satellite communications industry, the subject of the next chapter. It will be noted that the subject of government assistance is discussed further in the next chapter, in the context of government policy. This approach is taken in view of the fact that government policy frequently serves a combination of strategic objectives, in this case the public socio-economic requirement for satellite services in the future, and the needs of the Canadian industry for the appropriate government assistance to meet this requirement.

5.0 RECOMMENDED STRATEGY AND SELECTION OF PROJECTS

5.1 Introduction

This chapter begins by developing the basis for a long term satellite communications strategy. A broad range of potential projects which could form an integral part of that strategy are defined as well as other supporting government initiatives in the policy and regulatory area.

The potential projects are analyzed in terms of the strengths and weaknesses of Canadian industry as determined in Chapter 3. Next, evaluation criteria are developed which, along with the cost/benefit analysis, is used to conduct the in-depth analysis of these projects. The chapter ends with conclusions as to the most cost-effective programs to help implement the long range satellite communications strategy.

5.2 Elements of the Strategy

Based on the outputs of the earlier work in this study, the project team developed the following desirable elements, or planks, which should be the basis for a long term satellite communications strategy:

- The overall strategy, and its funding, should be long-term, pro-active and flexible rather than relying on short-term reactive responses and funding.
- The government should undertake a major government program aimed specifically toward satellite communications. This program may include a series of space demonstration projects.
- There should be a policy of the government being "first buyer" of new Canadian satellite communications technology directed at the international market, thus enhancing international credibility.
- Where appropriate, the government should contract for the "first orbit" of new Canadian technology. Any major project must meet Canadian needs.

- The government should continue to carry out and sponsor directed basic research in specific satellite communications disciplines to provide a research reservoir from which Canadian industry can draw.

- The government should work toward modification of the current regulatory environment in order to remove existing disincentives with respect to the full use of satellite technology by domestic telecommunications carriers.

- The confirmation, as a policy, of the establishment or maintenance of close linkages with Europe, especially with ESA and Japan, as these two trading blocks have the funds, the will and the public support for continuing development of satellite communications technology. At the same time, the current strong ties with NASA and the U.S. space industry in general should not be neglected.

- The government should continue to encourage the maturation of the Canadian satellite communications prime contractor capability.

- Canada should continue to use its strengths in international spectrum and other fora to further Canada's satellite communications strategic policy.

- The government should continue and simplify the program for Research and Development Tax Credits.

- In implementing a strategy to maintain and strengthen Canada's current world position in satellite communications, the government should concentrate on improving international competitiveness and the development of new world markets for satellite technology, products and services.

- In all government programs impacting on satellite communications, the government should, as a policy, avoid splitting or diversifying the industry, and should concentrate on strengthening the industries by building on current skills in areas of appropriate labour availability.

5.3 Other Policy and Regulatory Initiatives which could form Part of the Strategy

Huge increases in capacity, very significant reductions in unit costs, active competition among both national and out-of-country service suppliers and the potential volatility of regulation all will affect the magnitude of the benefits to be derived from any specific R&D activity. However, it is clear that a number of policy and regulatory initiatives will enhance the benefits to the satellite communications industry. Included in these initiatives are:

- Improvements in telecommunications systems compatibility and interworking, including technical and operational standards for overall systems integration for broadband, data, voice, mobile, and new services.

- Regulatory considerations which do not mitigate against the use of the most technically and economically suitable technology for each specific application because of ownership of the facilities.

- Organizational structures to foster the most economic selection and use of each telecommunications technology for each specific application or parts thereof.

- Inter-satellite transmission and on-board channel switching capability to allow for transmission beyond the range of one satellite without multiplying transmission delays. This will have to be developed and marketed soon to enable Canadian satellites to perform an intercontinental "hubbing" role, or the opportunity will be seized by other countries.

5.3.1 Telecommunications System Compatibility and Interworking

Within the time-frame of this study, satellite telecommunications by themselves will not be able to provide the total telecommunications packages required by the majority of users on a cost-effective basis, but there are some segments in which satellite telecommunications can excel. Hence most, if not all, of Telesat's customers will also be customers of one or more terrestrial telecommunications suppliers.

The common carriers have spent much time and many millions of dollars in developing and implementing common technical, operating and protocol standards to facilitate interworking and integration of services and facilities provided by various suppliers, thus simplifying telecommunications usage from the customers' viewpoints, and allowing customers to use a variety of suppliers both nationally and internationally. Unfortunately, satellite telecommunications have not been meshed with the much more ubiquitous terrestrial services to anywhere near the same extent. For example, as things now stand, a mobile customer will have to choose between systems, or subscribe to both, and suffer from lack of easy network interworking.

Given the rapidly expanding and low cost telecommunications available via terrestrial facilities within the built-up areas, subscription to these services is very attractive. If satellite services are not easily integrated into a customer's telecommunications network, he will tend to resist them. Even large customers seldom employ widely skilled telecommunications managers needed for difficult and costly interworking techniques, and customers look for simplicity of operation to get their jobs done.

The terrestrial common carriers use some satellite capacity for service to remote areas, particularly the North. They could use more capacity for route diversity and restoration in their mainstream operations. Lack of easy networking is one of the problems currently limiting increased usage.

Thus, for the benefit of customers and Canadian telecommunications in general, R&D of a systems nature is an important requirement. This need not impose prohibitive restrictions on satellite systems initiatives, as evidenced by the great variety of technologies employed by the terrestrial carriers without sacrificing the customers' ease of operation.

Unfortunately, the tendency to treat satellite telecommunications as an entity unto itself is inhibiting commercial use of this technology. Extensive systems R&D (as opposed to component R&D) is needed to correct this situation.

Because of the various competing commercial organizations involved, leadership and partial funding by the government appears to be the most likely catalyst to get things moving, but there should be heavy participation and joint funding by all of the commercial organizations involved in Canadian telecommunications. Progress of satellite telecommunications to its full potential, or maybe even its economic survival, is the benefit, with the multi-million dollar costs being shared by government and commercial institutions (Bell Canada estimates that "systems" R&D needed to develop the full potential of satellite telecommunications could require $20 million per year for the next ten years).

5.3.2 Regulatory Conditions

Regulatory conditions in Canada reward the ownership of facilities by telecommunications common carriers. Hence there is a continual desire for a commercial enterprise to expand its owned network rather than leasing from others. As the major Canadian carriers have become big enough to build their own diverse structures in the limited portions of Canada where telecommunications demand is economically significant, the leasing of satellite facilities is given real consideration only for service to remote locations, such as the far North. This limited use is inhibited even further by the government's pressure to keep the rates charged in these remote locations low, probably well below the costs of providing the services.

The cost of changing these regulatory constraints would be small, probably representing the costs of already employed government personnel and some consulting assistance. The benefits would be the removal of one of the constraints that limit satellite usage by the other common carriers.

5.3.3 Organization Structure

It appears wrong to attempt to institutionalize a technology. This leads to efforts by commercial organizations to get as much business as possible on their own facilities, regardless of which technology is most appropriate for any given application. Because the larger, well established common carriers in North America have widespread terrestrial networks throughout the developed regions, they tend to use rentals of satellite facilities only for services to remote areas, which represent a very small part of their total market. Some rationalization of the ownership of satellite facilities could encourage increased participation in the systems R&D needed to further incorporate satellite facilities into the general networks, and help develop satellite telecommunications technology to its full potential.

The cost is leadership, diplomacy and flexibility by the government in rationalizing the organizational structure(s) at the expense of entrenched positions. At stake is the inter-company rivalry which is limiting satellite development versus the part that Canada should play as a world leader.

5.4 Identification and Selection of Potential Projects

One of the major planks of the proposed strategy is the use of major programs or projects to support a specific direction for the Canadian space industry. In selecting projects to include in a government strategy, the role of government programs must be considered first. It is assumed, of course, that the intent of the government programs is to build on existing strengths and to eliminate existing weaknesses. This assumption was implicit in the inclusion of the competitive analysis in the study.

There are still two major alternatives to the development of programs. One alternative is to fund programs which assist the products, services and technologies for which existing capabilities are the highest, with funding allocated to the highest ranking projects until the funding is exhausted. The other alternative is to fund programs which are composed of products, services and technologies which can complement each other in terms of development and marketing, resulting in the potential for synergy, or which together support a more general strategy. The approach taken in this study has been the latter one.

A list of generic projects was developed on the basis of the future technology and market assessment work in the first phase of the project. This list included the following projects:

- Mobile
- Paging
- Personal Communications at Ka Band
- Hubless VSAT (ISDN and B-ISDN)
- DBS
- HDTV
- Remote Sensing Data Relay
- IOL/ISL

Each of these generic projects is composed of a combination of products, services and technologies. The strengths and weaknesses of Canadian industry with respect to these products, services and technologies were determined in the second major phase of the project. Table 5.1, overleaf, shows the products, services, and technologies for which *major* technological advances are required by each of the generic projects, and the overall ratings of Canadian industry for each one. It should be noted that evolutionary technological developments will also be required in other areas.

5.4.1 Development of a Short List of Projects

On the basis of the information in Table 5.1 and other conditions and considerations as discussed below, the long list of generic projects was reduced. The information in Table 5.1 was used to identify those projects which made use of combinations of Canadian products, services and technologies for which the current capabilities indicate that future strengths exist. The projects selected for in-depth analysis also satisfy the following broad conditions:

- Significant demand is expected for each of the products/ser-vices/technologies and applications which will result from the project.

- The project would involve many Canadian firms, who would look to DOC, as the focus, both for funding and for development of international markets.

- The developments resulting from the project would be truly world-class.

- Canada would be likely to find a market in each of the trading groups and beyond.

In addition, the following considerations were taken into account in examining individual projects:

- Canada already has a major program in Mobile Communications. The project team sees this as a technological success. Satellite-based paging is eliminated because there is little requirement for technological advances: a new generation of mobile terminals would need to be developed, and the system design is new, but in all other areas only normal evolutionary development is required.

- A program in broadband ISDN hubless VSATs would be much more risky than ISDN hubless VSATs: it is yet to be shown that there is a market for broadband ISDN at all.

- It does not make sense for Canada to invest heavily in high power, narrow beam DBS, because such a DBS is not suited to a country with a huge area to cover. The lower power, wide coverage direct-to-home service provided by Anik C and Anik D type service is more suitable for Canadian and North American coverage areas.

- Development of HDTV would be enormously expensive. Further, the U.S. will set the standard for North America, and will do its own development. There is no point in Canada duplicating U.S. efforts.

- Inter Orbit Links (IOL) is an integral part of Remote Sensing Data Relay. For these purposes, ISL is a less demanding version of IOL.

TABLE 5.1
SATCOMS APPLICATIONS PROBABLY REQUIRING MAJOR TECHNOLOGICAL ADVANCES

	Overall Rating	Mobile	Paging	Personal Comms	Hubless VSAT ISDN	Hubless VSAT B-ISDN	DBS	HDTV	Rem Sens Data Rly	IOL ISL	Remarks
<u>System Design and Operation</u>											
Communications System Design	23	•	•	•		•			•	•	
Procurement, Launch, etc.	20										
<u>Spacecraft</u>											
Duplexers and RF Multiplexers	20					•			•	opt	
Optical Devices	20								•	•	
Front-End LNAs	18									•	
Link Management Systems (Adaptive Flux Control Systems)	18			•	•	•	•	•			if EHF
Environmental Testing of Spacecraft											
On-board Switching, including Phased Array Antennas	16	•		•							
RF Up/Down Converters	14										
RF Antennas (passive)	12	•		•					•	•	
Design, Assembly and Integration of Spacecraft	10								•	•	
Solid State Power Amplifiers	9								•	•	optical only
Acquisition & Tracking Servomechanisms	8								•	•	
Optical Systems	6									•	
On-board Processing at Baseband	6	•		•	•	•				•	
Bus — Battery Management	3										
<u>Earth Stations</u>											
FSS Antennas	23						•				
Mobile Terminals	20	•	•	•			•				
Design and Integration of FSS Earth Stations	14						•				
FSS Earth Stations except HPAs, LNAs and Antennas	14										
HPA Tubes	9										
In-Orbit Control	6										
LNAs	5										
HPA Modules	2			•							

Normal evolutionary development will be required, and will happen, in most sectors not marked with a •
opt = optical only
Paging: assumes a piggybacked payload

On the basis of this analysis, the remaining projects which are subjected to further in-depth evaluation in the study are:

5.4.1.1 Personal Communications at Ka Band

This payload scenario is a Ka Band personal communications satellite service (mobile) experimental payload aimed at overcoming some of the many current inhibitions to the use of this frequency band such as application. Such a project would take advantage of Canada's prime contractor, millimetre-wave antenna and mobile systems capability.

5.4.1.2 Hubless ISDN VSAT "Virtual Mesh" Network

This is a Ku Band, hubless VSAT payload capable of at least T1 capability operating into earth stations with a maximum diameter of 1.2 meters. Such a payload would be aimed toward both the private and public sector business data and digitized voice markets with potential capacity for business video. In addition, there is indication that there could be considerable Canadian military interest in this service. By eliminating the expensive VSAT hub by carrying out traffic management and switching in the satellite, the double hop requirement (and its attendant delays) for a remote station to communicate with other remote stations would be eliminated. Thus a *virtual mesh* network could be realized.

The payload would take advantage of, and develop, Canada's strengths in on-board switching and processing and in the development of space segment and earth station antennas and electronics.

5.4.1.3 Data Relay between Satellites in Polar Orbits and two Geostationary Satellites

This payload scenario is for an inter-orbit link to provide (in conjunction with a similar geo-stationary orbit transponder spaced approximately 180° distant in orbital arc) continuous, realtime communications between the second generation Radarsat and a non-tracking earth station. It would thus eliminate the requirement in Radarsat for complex on-board data recording and replay equipment. The payload could also provide continuous realtime communications with a remote sensing satellite from another jurisdiction, such as Japan or Europe, in return for the use of a similar transponder in a satellite operated by the associated organization.

The payload would be a high-speed data transponder in the 60 GHz Band in geo-stationary orbit, capable of acquiring and tracking a near-polar orbiting satellite in low-earth orbit, and transmitting the data acquired from this satellite to a fixed earth station while the two satellites are in line-of-sight. It must be capable of the rapid acquisition of a second polar-orbiting satellite after line-of-sight of the original acquisition fails. This payload would also take advantage of Canada's millimetre-wave front end capability and its tracking and acquisition capability.

5.4.1.4 Inter-satellite links (ISL) between satellites in geostationary orbit

This is an inter-satellite data relay payload to be carried out as a joint venture with either NASA (who have expressed interest) or ESA (who plan to carry out optical inter-satellite link trials in the appropriate time frame). A prime purpose of such a payload is to further the competitiveness of international satellite point-to-point trunks by the elimination of *double hops* and the delays associated with them. Such an inter-satellite link would operate either in the millimetre microwave band, for example 60 GHz, or in the optical band. In either case it would take advantage of Canada's strengths in the millimetre RF front-end sub-system niche, or in the optical communications niche. In addition, it would use Canada's proven capability in space qualified servo-mechanisms for acquisition and tracking.

5.5 Evaluation Criteria

In order to conduct an in-depth evaluation of the suitability of these projects or inclusion as government programs in support of a long range satellite communications strategy, a set of payload evaluation criteria was developed. These criteria were designed to complement the cost/benefit analysis.

The criteria for the payload application are that it:

- should be capable of meeting a defined, but preferably new, market in a competitive manner in a Free Trade environment,
- should draw upon the strengths of the Canadian space manufacturing industry to develop appropriate technologies, preferably in areas where they have considerable international strength,
- should have an application in Canada, while having significant potential for future overseas sales,

- should contribute identifiable socio-economic benefits and have future commercial viability,

- should be capable of potentially providing a reasonable business return to Telesat Canada after the completion of sponsored experiments,

- should, if at all possible, contribute to other sectors of the Canadian space program in addition to satellite communications,

- should have a reasonably high profile, and at the same time have a high probability of success to attract cabinet and national support,

- should further Canada's interests in at least one of the major satellite communications trading blocks. If at all possible this should be in the Japanese and Pacific rim market, to establish a foothold in this very competitive trading block which has currently been denied to Canada,

- should be innovative and forward thinking, and as a program draw upon the skills resident in the Canadian Space Agency, DOC Headquarters, CRC and DFL,

- should be able to take advantage of the coordination mandate of the Canadian Space Agency,

- should be such as to attract the interest and support of other interested but potentially competitive, government departments such as DIST, External Affairs, Energy Mines and Resources, the Department of the Environment, other user departments and the provinces.

5.6 Evaluation of the Projects and Development of Programs

5.6.1 Introduction

In this section, the assessment of overall strengths and weaknesses of Canadian industry with respect to each of the shortlisted projects and the cost benefit analysis are described.

TABLE 5.2

STRENGTHS AND WEAKNESSES OF CANADIAN FIRMS IN MARKET SECTORS NEEDING ADVANCES IN POTENTIAL PROJECTS

	Personal Comms	Hubless VSAT ISDN	Rem Sens Data Rly	IOL ISL	Remarks	R&D Abil	Prod /Svc	Techno logy	Facil ities	Mktg Abil	Mgmt Abil	Mgmt Vuln	Fincl Strng	Stabil Mature
System Design and Operation														
Communications System Design	•		•	•		n/a	5 =	5 =	5 =					
Spacecraft														
Duplexers and RF Multiplexers			•	opt		4 +	5 +	5 +	5 =	4 +	4 +	1 -	priv	4 -
Optical Devices			•	•		5 +	5 +	5 +	5 +	5 +	4 =	4 -	5 +	5 +
Front-End LNAs			•	•		4 =	4 =	4 =	5 =	5 =	4 =	1 -	priv	4 -
Link Management Systems (Adaptive Flux Control Systems)	•	•			if EHF	4 -	5 =	5 +	5 =					
On-board Switching, including Phased Array Antennas	•					4 -	4 -	5 =	5 =	4 -	4 -	1 -	priv	4 -
RF Antennas (passive)	•		•	•		4 -	3 -	4 -	4 -	4 -	4 -	4 -	3 -	4 -
Design, Assembly and Integration of Spacecraft			•	•		3 -	4 =	4 =	5 =	4 =	4 -	4 -	3 -	4 -
Solid State Power Amplifiers			•	•	optical	3 -	4 -	4 -	4 -	4 -	4 -	4 -	3 -	4 -
Optical Systems				•		3 -	3 -	4 =	3 -	4 =	4 =	1 -	priv	4 =
On-board Processing at Baseband	•	•		•		3 -	2 -	4 -	3 -	4 -	4 -	1 -	priv	4 -
Acquisition & Tracking Servomechanisms			•	•		4 =	4 =	4 =	4 =	4 -	4 -	4 -	3 -	4 -
Earth Stations														
Mobile Terminals	•					5 +	4 +	5 +	5 +					
						5 +	4 +	5 +	5 +	4 =	4 =	3 -	3 -	3 -
HPA Modules	•					2 -	1 -	3 -	3 -	1 -	4 -	2 -	3 -	4 -

Ratings are those of the leading firm in each product/service/technology.

5.6.2 Strengths and Weaknesses

Of the four projects, three, including the Hubless VSAT, Data Relay and Inter-satellite Links, are, relatively speaking, the next logical major development; the fourth, Personal Communications at Ka band, is still at the basic research stage, meaning that both research and development in university, government and industrial laboratories will be required.

Table 5.2, previous page, shows the sectors in which major technological advances would be required, and for each sector, how the leading Canadian firm rates technologically and corporately. The ratings, absolute and relative to other firms in the world, are from the competitive analysis described in Chapter 3.

On the basis of the analysis described in Chapter 3, the following comments can be made about the four projects.

5.6.2.1 Personal Communications at Ka Band

Many bridges need to be crossed before personal communications at Ka band can be offered commercially. This could be an excellent project which would build on Canadian capabilities and would help Canada to continue to be in the forefront of satellite communications. To bridge the gap between the state of the art in this technology and commercial viability, the initial research phase would need proper funding. As commercial viability becomes more apparent, the technology could be transferred to Canadian industry. This approach has worked well in the past and existing government laboratories have the required strengths on which to build. The size of the market for these services is yet to be defined and this could be further defined. Government and industry laboratories would require both funding and additional personnel to carry out this large project.

5.6.2.2 Hubless Narrow-band VSAT

The Hubless VSAT would require technological development in two areas: Link Management Systems (assuming use of EHF frequencies) and On-board Processing at Baseband. CRC has the basic know-how in Link Management Systems, which could be transferred to Canadian industry. At least one Canadian firm has made a beginning in On-Board Processing at Baseband, but is significantly behind foreign competitors such as NEC, Matra and Alcatel. This is a sector which, while weak now, could be strengthened through government support.

5.6.2.3 Remote Sensing Data Relay

Sectors requiring technological breakthroughs, in which Canada is already strong, are Communications System Design, Duplexers and RF Multiplexers, Optical Devices, Front-End LNAs, and Acquisition and Tracking Servomechanisms. This project would build on existing strengths.

Canadian industry is relatively weak in the other sectors requiring breakthroughs: RF Antennas, Design, Assembly and Integration of Spacecraft, Optical Systems, and On-board Processing at Baseband. Canada's abilities in these sectors could be strengthened through an appropriate government program.

5.6.2.4 Inter-satellite Links

The sectors involved in ISL are much the same as for Remote Sensing Data Relay. Two additional sectors are involved: Optical Systems and On-board Processing at Baseband. Canada is weak in both of these sectors at present, but could be strengthened.

A Canadian firm has been successful in supplying optical systems for the transatlantic fibre optic link. With government support, its know-how could be transferred to satellite communications.

5.6.3 Cost/Benefit Analysis

The government programs examined in Chapter 4 which have applicability in the context of this study include:

- Tax Credits
- Technology Transfer
- Shared Cost R&D
- Full Price Contracts
- Shared Cost Marketing

These are in essence tools which the government has at its disposal and which it can use as part of its strategy. The objective of the government is to use these tools in the most effective way possible. That is, to use them so that not only is the overall benefit to cost ratio greater than one (meaning that the benefits exceed the costs), but also so that the ratio is as large as possible. This can be thought of as a form of *leverage*.

Similar to financial leverage, the leverage of government programs is the extent of the R&D, capital and labour expenditures by industry which result from seed money provided through the government program.

In this section, the nature of the programs or tools is described. Next, the projects on the short list are subjected to a cost/benefit analysis. In keeping with the strategic nature of this study, the cost/benefit analysis and sensitivity analysis deal with issues and concepts with respect to future potential costs and benefits. Based on the analysis of Canadian capabilities, an analysis of regional impacts is carried out.

5.6.3.1 Nature of the Government Programs

Tax credit programs are a broad form of industrial support program. They are statutory programs, not discretionary programs. This means that rather than seeking approval in advance for a grant under the program, the tax credit is made available on a retroactive basis to any research or development or capital expenditure which meets the criteria of the program. As a result, tax credit programs tend to be rather unfocused in terms of specific industrial policy objectives. They tend to provide broad support for private sector spending initiatives, but do not eliminate specific technical risks except that they generally provide for a more rapid recovery of the costs incurred. The extent of the leverage obtained through tax credit programs can be significant, but since tax credit programs are not focused on specific industrial policy initiatives, the results are highly variable.

Technology transfer programs are at the opposite end of the spectrum, in that they are the result of direct government expenditure initiatives, and are focused on specific developments or products. Government bears all the technical risk of the research and development, and industry takes over to commercialize the development and to achieve the economic benefits. Such programs are highly discretionary in that government must initiate the research, fund the development and seek out industrial partners to whom the technology is to be transferred. In terms of leverage, the ratio of benefits to costs is not high, since government expenditures can be considerable. At the same time, since the initial R&D is the riskiest part of the undertaking, there may be no option if government is convinced that the development should proceed.

Shared cost R&D programs are a compromise between the first two, since both government and industry must agree on the objectives and directions for the project. Such programs are discretionary since government must enter into a contract with its industrial partner. The technical risk is shared between the two. At the same time, the leverage is greater since the level of expenditure by government is lower.

Full price contract programs usually follow the product development phase, with the government being the first buyer of the commercial product. The government is assuming part of the business risk in that it is likely funding a part of the engineering and design costs, and helping the firm or consortium to iron out manufacturing difficulties. Such programs also assist the credibility of industry. Again, such programs are discretionary and permit government to specify specific directions for products and technologies. The leverage of such programs is relatively high in those cases where the government purchase is used to demonstrate the capability of the company or consortium, and this leads to further sales.

Shared cost marketing programs are the final phase of support. They generally support the development of export markets for proven products. They share the commercial or business risk associated with specific marketing programs, and tend to have a large leverage in terms of the benefit to cost ratio. Such programs feed on and enhance the success of other government programs, especially directed programs. The results are also fairly immediate.

5.6.3.2 Costs and Benefits Associated with the Four Projects

In estimating the costs and benefits associated with the various projects under consideration, the major indicator of costs is the weaknesses identified in the analysis of Canadian industry capabilities described in Chapter 3. These assessment were based on judgments with respect to current strengths and weaknesses as an indicator of future potential capability. Similarly, the indicator of benefits is the evaluation of the future potential market.

5.6.3.2.1 Personal Communications at Ka Band

This project is at an early stage of conceptual development as shown by the low product/service ratings for HPA Modules, On-Board Processing at Baseband and RF Antennas. The research phase would need proper funding, and preliminary government laboratory research has established the basic capabilities for this work.

This project would help Canada continue to be in the forefront of satellite communications, particularly as the Ka band opens up. This project will require both funding and additional personnel. The direct benefits will be that Canada will be well positioned at an early stage of the development of personal communications technologies, with additional spin-off benefits in the area of Ka band technologies. The potential markets for the individual products, services and technologies are not large, but their integration into personal communications would be expected to enhance the size of the potential market.

5.6.3.2.2 Hubless Narrow-band VSAT

On-Board Processing at Baseband is a technology which, while weak now on the product and R&D side, can be strengthened through government support of the existing technological capability. This project could be carried out through shared development programs and full price contracts for first products in order to assist in bringing the actual products to market.

On-Board Processing at Baseband will be an important technology, in that it is expected to have rather wide application. Flexibility of satellite configuration is the main direct benefit. If it accompanies a personal communications development as well as forming part of a hubless VSAT technology, the potential market will be significantly greater than that for the technology in conventional satellite applications.

5.6.3.2.3 Remote Sensing Data Relay

Canada has a strong potential capability in many of the underlying technologies, including Communications System Design, Duplexers and RF Multiplexers, Optical Devices, Front-End LNAs, and Acquisition and Tracking Servomechanisms. This project would build on existing strengths in these areas. Shared cost development programs would bring these areas along with reasonable efficiency and with little risk.

Canadian industry is relatively weak in the other underlying technologies, including RF Antennas, Design, Assembly and Integration of Spacecraft, Optical Systems, and On-board Processing at Baseband. Basic development work is required in some of these areas. If developed in concert with the Hubless VSAT, the On-Board Processing developments could serve both projects.

However, the market for remote sensing hardware and software is essentially a government market, and is fairly small. It is unlikely that major increases in demand will result. Moreover, there is a possibility that scientists and other users of remote sensing data will oppose changes in the technology of data delivery since they are extremely concerned about the integrity of the data. Spin-off benefits are not likely to be significant, since the potential markets expected for the individual developments are not promising.

5.6.3.2.4 Inter-satellite Links

The sectors involved in ISL are much the same as for Remote Sensing Data Relay. Two additional sectors are involved: Optical Systems and On-board Processing at Baseband. Canada is weak in both of these sectors at present, but can be strengthened through increased R&D. The risk is higher in cases like these where basic R&D is required. On the other hand, existing Canadian know-how in optical systems could be transferred to satellite communications with a relatively high degree of confidence.

The technical difficulty associated with the tracking for ISLs is much less than is the case with IOLs. Therefore the technical risk is lower. At the same time, the range of potential applications is much greater than for the remote sensing data relay, since such a development could render satellite an appropriate technology for a number of voice and data applications by eliminating the double hop.

Again, the main concern is the size of the potential market for the technology in the inter-satellite application and other spin-off applications. Unless the availability of inter-satellite links increased the demand for voice and data by satellite, which is not likely to be the case given the investment by terrestrial carriers to carry transit traffic, then the benefits associated with the development will not be significant. The potential markets for the individual technologies are not expected to be large.

5.6.3.3 Sensitivity Analysis

The assessments of costs and benefits of the projects are based on estimates of future capability and future demand, using current capability and demand in related sectors as the basis of the forecasts. Such extrapolations are, of course, highly judgmental in nature.

The assessment of future capabilities is considered to be fairly reliable where significant capability exists now, since the developments are then more likely to be evolutionary instead of revolutionary. However, for those areas in which Canadian capability is not high, there is more room for error, and the risk or uncertainty with respect to both costs and benefits increases.

On-Board Processing at Baseband is a technology for which the Canadian capability is not expected to be high. It is required for both the Personal Communications and Hubless VSAT payloads. Some care should therefore be exercised in interpreting the likely costs and the level of assistance which would be required to develop the technology.

The general tendency with respect to market expectations is to be overly optimistic, which would normally indicate that there is a downside risk to the estimates of the potential market. However, this was definitely not the case with respect to cellular radio, for which the demand has greatly exceeded what were at the time considered to be very optimistic forecasts. Expectations with respect to future demand for personal communications services may be similarly conservative.

Demand for the rather specialized remote sensing data relay and inter-satellite link applications may be optimistic, although it is not expected to be high in any case. However, as stated above, the demand for personal communications and the technologies involved may be pessimistic. To an extent, the same may be true for the hubless VSAT technology. VSAT services are by far the fastest growing segment of the satellite communications industry at this time.

It should also be noted that there is a range of program support which leads to the optimum results. There is not a one-to-one correlation between the amount of funding and the benefits. It is not possible to be more specific in terms of the appropriate level of funding for these projects.

5.6.3.5 Regional Impact Analysis

Table 5.3, overleaf, provides an indication of the regional impact of each of the projects under consideration. Since it is impossible to estimate expenditures on capital and labour which will be required, this analysis is based on the current geographic location of the companies involved with each product/service/technology.

The most uniform spread of regional impacts is in the personal communications project, with all five regions of the country participating. The remote sensing data relay project and the inter-satellite link projects will involve primarily central Canada (Ontario and Québec). The hubless VSAT project would involve primarily Ontario and Québec.

5.6.3.6 Conclusions of the Cost/Benefit Analysis

Directed programs of government assistance are needed for all the projects which are selected, as much as mechanisms for the management of the technology development by government as for risk reduction.

TABLE 5.3
NUMBER OF PRODUCTS/SERVICES/TECHNOLOGIES
INVOLVED IN EACH POTENTIAL PROJECT
BY REGION

	Personal Mobile	Hubless VSAT ISDN	Rem Sens Data Rly	ISL
Atlantic	2	0	1	1
Quebec	5	1	6	7
Ontario	5	2	3	4
Prairies	1	0	0	0
British Columbia	2	0	1	1

Systems Design and Operation is considered as one Service.

In the early stages of development, the transfer of government-developed technology and shared cost R&D programs are likely to be most effective. In the later stages, full price contracts followed by shared cost marketing are likely to be most effective.

The cost-benefit analysis indicates that personal communications at Ka band is expected to be the most beneficial development, followed by the hubless VSAT technology. The inter-satellite link and remote sensing data relay projects have the lowest benefit to cost ratio.

Combining the results of the cost/benefit analysis with the evaluation in terms of the evaluation criteria, the ranking of the projects in decreasing order of preference for inclusion in a long-term satellite communications strategy are:

1. Personal Communications at Ka Band
2. Hubless VSAT
3. Inter-Satellite Links
4. Remote Sensing Data Relay

5.7 Recommendations for a Strategy

Based upon the findings and conclusions of this study, the project team recommends the following eleven key elements or planks of a long term strategy for satellite communications:

- The overall strategy, and its funding, should be long-term, pro-active and flexible rather than relying on short-term reactive responses and funding.
- The government should undertake a continuing series of government projects aimed specifically toward satellite communications.
- There should be a policy of the government being "first buyer" of new Canadian satellite communications technology directed at the international market, thus enhancing international credibility.
- Where appropriate, the government should contract for the "first orbit" of new Canadian technology.
- The government should continue to carry out and sponsor directed basic research in specific satellite communications disciplines to provide a research reservoir from which Canadian industry can draw.

- The government should work toward modification of the current regulatory environment in order to remove existing disincentives with respect to the full use of satellite technology by domestic telecommunications carriers.

- The confirmation, as a policy, of the establishment or maintenance of close linkages with Europe, especially with ESA and Japan, as these two trading blocks have the funds, the will and the public support for continuing development of satellite communications technology. At the same time, the current strong ties with NASA and the U.S. space industry in general should not be neglected.

- The government should continue to encourage the maturation of the Canadian satellite communications prime contractor capability.

- Canada should continue to use its strengths in international spectrum and other fora to further Canada's satellite communications strategic policy.

- The government should continue and simplify the program for Research and Development Tax Credits.

- In implementing a strategy to maintain and strengthen Canada's current world position in satellite communications, the government should concentrate on improving international competitiveness and the development of new world markets for satellite technology, products and services.

- In all government programs impacting on satellite communications, the government should, as a policy, avoid splitting or diversifying the industry, and should concentrate on strengthening the industries by building on current skills in areas of appropriate labour availability.

In the opinion of the project team, any truly viable long-term satellite communications strategy must contain all of these elements.

* * *

Appendix A

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Appendix B

SATELLITE BASED PERSONAL COMMUNICATIONS

* * *

Satellite Based Personal Communications

1.0 Introduction

Over the past six years the field of mobile communications has seen exceptional growth which does not seem to be abating. Many new applications have developed including but not limited to mobile fax, mobile data retrieval systems, advanced train control systems, and cellular communications. The need of humans for ubiquitous communications has moved the telecommunications terminal from a fixed location (desktop telephone) in the office to the vehicle and is now moving on to the person for complete mobility. Ultimately, it is envisaged that the mobile portable terminal may be able to offer an assortment of services in voice, data and even video. Considerable progress has been made towards development of this type of personal communications and its interface with the cellular system. Concurrently, the cellular mobile communications system developed from an analog speech system to a digital system, and the interfacing of the mobile terminal with the public switched network (PSTN) public data services network (PDSN), and integrated services digital network (ISDN) have become a reality.

The present and even the near future terrestrial cellular mobile communication system are not expected to provide global coverage within designated service areas. Major cellular system operators direct their terrestrial services to populated areas because implementation of these systems are uneconomic in sparsely populated areas. For the population living in areas not covered by these networks, satellite communications is the only way to provide reliable and ubiquitous mobile communication service. The proposed mobile satellite service may be regarded as an extension to the terrestrial land mobile personal network. Just as personal and portable communication is regarded as an extension to the second generation digital cellular system, ubiquitous personal services are a natural extension to the services to be provided by the mobile satellites of the future.

During the past several years, the second generation cellular communication systems have been studied extensively and firm design principles have been established. These principles are being applied in planing and development of terrestrial personal communication networks. Fully integrated personal communication systems are still five to seven years away. In Europe, steps have already been taken towards providing such services. For example, tele-point services in the UK, though not fully mature as it does not allow access to the portable, is an important step towards the right direction. The extension of personal communications to satellite communication requires the solving of a number of problems, some of which are similar to the ones confronting terrestrial portable systems, while others have a character unique to satellite channels.

2.0 Design Considerations

The satellite based personal communication system network design requires considerations of network architecture, signalling, mobile terminal, satellite architecture and on-board processor, and transmission techniques, all similar to those for terrestrial personal networks. A major change from the terrestrial network is the satellite segment which could be considered as a replacement of the mobile switching center. The following main design points will be considered:

Frequency and propagation considerations;

Personal terminal architecture;

Transmission techniques;

Space segment;

Overall network architecture, control, management.

3.0 Frequency and Propagation Considerations

At present, L Band frequencies are allocated to the mobile satellite system. It is desirable from the point of view of network and equipment compatibility that maximum number of sub-systems be common between the mobile satellite communication and proposed personal systems. However a number of problems are associated with this requirement. The first and the foremost requirement is that the personal terminal should be small, inexpensive and has power consumption which does not necessitate replacement of battery often. Propagation losses have a major impact on the design of portable terminals. The RF circuit miniaturization, transmission power, antenna gain required for acceptable reception are major factors. The frequency allocations for mobile satellite communications is unlikely to be sufficient to provide personal communications for future users which are expected in many hundreds of thousands. It is predicted therefore that this frequency band will be used exclusively for vehicle based systems with larger terminal size. For personal communications a new frequency band has to be explored.

To choose a suitable band, miniaturization and antenna size play important roles. The antenna size can be considerably reduced if we move the band from L Band to Ka

Band. Although the propagation loss os likely to be increased by more than 20 dB this may not be of overwhelming consequence since phased array antennas are becoming a practical reality. At this frequency the antenna size becomes manageable and highly portable. The other important advantage of this higher band is that miniaturization of circuit components (MMIC) becomes feasible and the mobile terminal is then truly portable. It has also been suggested that MMIC components are cheaper than those for L Band. Systems operating at 19-21 GHz (down link) and 29-31 GHz (uplink) have been suggested.

4.0 Personal Terminal Architecture

The personal receiver will consist of a high gain antenna, a LNA, and a very large scale integrated (VLSI) implementation of the down converter, a baseband signal processor and a control unit/Vocoder. Packaging into the small size required is a major challenge. It is also envisaged that the personal communicator should handle not only voice but data rates ranging from 4.8 kbits/sec to up to about 144 kbits/sec. To make the terminals small the uplink FDMA may be necessary. In the down link TDM stream of 1.544 Mbits/sec may be considered to be suitable. A receive system with a nose figure of around 1.5 dB (G/T of 6 dB) will provide adequate protection against excessive battery drain. RF power transmission requirements of 4.8, 64 and 144 kbits would be 300 mW, 3.5 W, and 8 W respectively. To conserve power, an adaptive power technique is necessary. The power control allows use of higher power when necessary (when the channel is experiencing difficult propagation conditions) to maintain error rate performance.

The personal communication receiver will essentially consist of three subsystems; RF and down converter; signal processor (detection/demodulation and decision) followed by an error detection and correction subsystem. These sub-assemblies are controlled by a receiver controller unit which is also responsible for maintaining the link, providing status and for other management functions. All these functions are within the current and near future state-of-the-art in electronics and VLSI.

The most difficult aspect of the portable terminal is the antenna which must provide sufficient gain despite its small size required for manageability. To achieve high gain, a narrow beam is necessary. To maintain the link connection from all terminal orientations, an electronically or mechanically steerable antenna will be necessary. Phased arrays with active elements allow versatility, design shape, and could be made highly portable because of possibility of their being folded. Since the distance between the elements of a phased array is a function of wavelength, small phased arrays are more suited to frequencies in the Ka Band. Phased arrays built into a helmet have been suggested. However, it is doubtful that the helmet design will be acceptable to the users.

5.0 Transmission Techniques

The marginal link budget dictates that fade countermeasures be provided through the use of efficient modulation and coding schemes. PSK is the ideal modulation scheme for this purpose since it requires minimum carrier to noise ratio for a predetermined error rate when compared to all other modulation schemes. Since considerable gain is required from the coding process therefore low rate coding is necessary. Reed Solomon (RS) codes have been suggested for the portable links because of their capability of correcting bursts which may accrue due to the considerable shadowing expected in the link. The other advantage of RS code is its ability to correct both random and burst errors.

Interleaving is also found to be of considerable importance because of its effectiveness against shadowing and burst errors.

6.0 Space Segment (Satellite Payload)

Because of weight, size and battery capacity considerations the portable terminals can transmit only a limited power. Moreover it is inconceivable that the mobile can provide sufficient gain to overcome high propagation loss. These constraints suggest that the satellite must have considerable power available for transmission and/or must have high antenna gain. The size of the satellite will inevitably be large. For high antenna gain large antenna size is necessary and for this purpose furlable or inflatable antennas have been suggested. Multiple narrow beam satellite antennas must be designed to meet link budget requirements when operating with the low G/T portable terminals.

On board processing is perhaps a prerequisite for personal communications. The processing can either be limited to signal generation and routing or extended to include network management functions. The latter option is more attractive because it allows portable to portable call handling. Digital Signal Processors (DSP) or Surface Acoustic Wave Devices (SAW) are likely to be used as signal processing elements. The SAW devices require precise traffic pattern which lead to limited services and are not recommended.

For routing purposes either microwave or baseband switching can be used. Channel to beam switching may be necessary to provide effective routing capability.

7.0 Overall Network Architecture, Control and Management

The system architecture envisioned is very similar to that for the present day VSAT networks or mobile satellite systems with the exception that communication becomes more difficult because of the small link margins. The overall network configuration will be envisioned to be a virtual mesh with portable to portable, routing and management functions are embedded in the satellite. In order to provide interconnection to PSTN, PSDN and ISDN, transcoding may be required at the terminal for compatibility. Initially the system would only be able to support low data rates. SCPC/DAMA/FDMA transmission access allows both the space and ground segments to operate at saturation for maximum power efficiency. On the uplink FDMA scheme is found to be more suitable for high power utilization of the ground portable terminals. For high data rate access, TDMA could also be considered though it would incur link budget penalty other access schemes such as TDMA/MF (TDMA/multiple frequencies) have been suggested to accommodate different types of services. One advantage of this technique is to provide some degree of frequency diversity. In addition the demodulator in the satellite is a smaller unit. In the more mature stages the terminals must support higher data rates. The initial frame structure must therefore reflect that it must provide for both high and low rate data channels. TDM is considered to be most suitable for the down link because the satellite power amplifiers can be used to saturation. Possible data rate around 1.544 Mbits/sec have been proposed.

Integration with the terrestrial systems is another important issue. This required decisions on the number of beams, and upon location of management center and its functions such as routing, traffic monitor and network integrity monitoring. Because of large number of terminals and requirements for high efficiency of channel utilization, algorithms for traffic scheduling are also becoming important.

It is seen from the discussion in the preceding sections that it will be of considerable advantage to house routing and network management functions to the satellite. Secondary functions such as billing, network diagnostics and functions related to network integrity can be given to chosen ground terminal(s).

8.0 Conclusions

The case of satellite aided personal communication has been discussed and it is concluded that such service will be a natural extension to the current MSAT systems and will provide ubiquitous service to remote areas. There is a possibility that this service can be integrated with the digital cellular systems at present being planned.

While there are a number of hurdles which have to be crossed to make the proposed system a reality; access, modulation coding and antenna designs have been identified to be of critical importance.

* * *

Appendix C

HIGHLIGHTS OF IMPORTANT GOVERNMENT ASSISTANCE PROGRAMS

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Program	Source	Funding	Ceiling	Objectives	Conditions	Practicalities
GRANTS AND SHARED COST						
IRAP-L	NRC	From IRAP fieldnets $35M	Lesser of 5k or 65%	Short Term Needs	50% Shared Total Project less than 12k 200 employees max product oriented solving technical problems	Company owns rights
IRAP-M	NRC	From IRAP fieldnets $35M	$100k	Medium R&D Projects not possible otherwise. New or improved products.	50% shared 200 employees max. Assistance is for technical salaries in-house or out. 24 month sunset on projects	firm owns rights. Novelty technical risks potential commercial benefits commitment of the firm.
IRAP-R	NRC	$30M	negotiable >$1M goes to TB	complex projects collaborative with Cdn. univ's, govt labs, or Cdn or foreign research institutions high technical risk excellent commercial promise	50% shared Support is for salary costs of S&T personnel + sub - contracts to e.g. univ's, govt, other research inst's some travel supported quality mgt. at the firm essential. Exploitation by firm and subs in Canada	firm owns rights; subs own their own Economic/social benefits Enhanced R&D base Advance scientific knowledge Firm cannot bear the whole cost but has financial strength for major portion.
TIP	DEA	$ 2 . 2 M rising in 89/90	n.a., typically $2-10K now. Up to $50K in early years.	high-risk and not otherwise possible support unique company initiative. Provide the final link in a chain of support.	No standard engineering Technology acquisition only No hardware or software Incremental to the whole project financing structure	air fares and local travel including visit of foreign rep to Canada. Short term visits sponsor from Govt. science-based dept. sought Salaries of S&T personnel if familiarization needed
PEMD	DEA	$20M in 87/88	typically $7K	increase export sales of Cdn goods and services Encourage new exporters enter new geographical areas	50% shared, NOT A GRANT! repayable if sale successful. Commercial operations only Annual sales >$100,000 Exportable product or service Export-ready New clientele Enough sales to repay PEMD	Benefits to Canada Triggered by market changes, Riskiest yet in that market >60% Cdn content Cdn benefit on penetration of that market Reasonable prob. of success No used eqt. unless refurb in Canada, 4 approvals/yr or one mktg agreement for 1 or 2 year period
IDRP	DIST	n.a.	negotiable, most under $100K	assist Cdn industry with support allocated by regional need (4 tiers) R&D	50% max, tiers 3&4 develop/demo new products scientific risk	

Program	Source	Funding	Ceiling	Objectives	Conditions	Practicalities
				Modernization; acquire new machinery	IDRP support necessary to proceed	
DIPP	DIST	$247M in 85/86, $29M to elec	negotiable	develop/maintain production & advanced tech capability Establish new source Assist capital acquisition Assess market feasibility	50% shared Defence-related Comprehensive business plan	no deliverables except reports firm owns rights
MSDP	DIST	$60M for next 4 yrs	negotiable	enhance int'l competitiveness & growth CDN systems dev't firms and microelectr's component firms, users and sources Share risks in advanced micro tech'y & info tech'y and systems	50% shared Demonstrated int'l competitiveness Advanced levels of technology Demonstrated user applications	Firm owns rights No deliverables Special consideration for ind'y/univ collaboration Diffusion to other Cdn firms Possible exchange with foreign firms
TOEP	DIST	??	$10K	EXPIRED 31 MARCH 1989 Strengthen Cdn firms through development of new technology in Cdn firms and thru association with European firms Participation in EUREKA prime goal	50% shared Repayment for projects >500K unless firm's assets <$7.5M Help to investigate opportunities Help in a EUREKA project with a European partner, (Cdn costs only) R&D must be in a EUREKA-approved project	100% air fare + 50% legal/technical fees for agreement Must be incorporated No teaming with other govt assistance 10 years to repay No repayment if no commercial dvlpt.
ACOA	DIST	$1.5B	negotiable	long-term growth of Atlantic Canada Create development programs for small/med. firms Replaces IRDP in Atlantic for projects under $20M	Shared to approx 60% Commercial viability Economic benefits Assistance is necessary	Interest buy-downs Business support Studies Innovation assistance Expansion/modernization/new product
DIR	DND	$20M	negotiable	Promote research in Cdn defence industry	50% shared Applied research to bring a concept to a stage where application is feasible Emphasis on advancing state of the art Generally excludes dev't of hdwe and sw	May require security clearances No deliverables except reports Projects must complement current DND initiatives OR be suitable for international exchange
WDPD	IST	$1.2B	negotiable	Since 1987, Western version of IRDP for western diversification	50% shared, repayment for commercially Successful projects Work performed in Western Canada Full business plan	No deliverables except reports firm owns intellectual property
STAP	DIST	$200M	negotiable	Strategic Technology Alliances among univ's, govt and industry Create networks to share costs and risks while accelerating development Transborder alliances supported Pre-competitive R&D	Information technologies Biotechnology Advanced materials 50% shared	

Program	Source	Funding	Ceiling	Objectives	Conditions	Practicalities
Sector Competitive-ness	DIST	??	??	Individually tailored plans to assist industry sectors to become more competitive internationally	Shared Export promotion drives Selective investment promotion	Technology applications for new/improved products
CDA/QUE PGMs A,B,C,	JOINT	??	??	Stimulate research in Que firms Support firms that invest in tech devt. Promote research related to industry needs Encourage univ/govt/ind'y cooperation	NEW! RESEARCH PARTNERSHIP pgm: NSERC & Govt dept match ind'y commitment to a ceiling of 50K each DOC not in yet Supports grads & pdf's 2-3 yrs AGCAN unit has $1M	NSERC supports: Coop R&D; shared eqpt; ind research chairs; visiting fellowships; ind post-grad fellowships; ind undergrad student research Shared contributions and matching grants
CONTRACTS						
UPP	DSS	$30M	negotiable	Respond to ind'y R&D initiatives that match a departmental objective Provide bridging funds to a dept to get a project started Promote govt. contracting-out	100% funded Must have sponsor dept (not DSS) Unique proposal to waive normal contracting rules Deliverables to sponsoring dept. Crown owns rights	DOC now short of funds to share with DSS DOC supports 10 to 60 received per yr.
SCAP	DOC	$1.7M	negotiable	Tech transfer Ind support Info exchange Dev new services and technologies	100% funded Related to satcom applications (Other comms also, soon) Deliverables Crown owns rights	Main focus is tech applications Field trials; pilot projects; demos; in areas like telehealth; tele-education and future satcom technology Oriented to DOC objectives
MILCOM	DND	EHF 50M SBR 50M 5-year	negotiable	Meet DND R&D objectives develop Cdn sources if feasible	100% funded DND issues rfp's	
MSAT	DOC	50 M in 7 years	negotiable	Implement commercial mobile satellite service	100% funded Tech/product dev't support Sponsor field trials Cdn ind'y only	
NEW PROGRAMS						
TDP	DIST	??	negotiable	Start up technology centres Tech diffusion to small/med firms Sustain technology centers	50% - averaged over 5 yrs Can be 100% in early years Annual reports	Capital eqt included Land costs excluded
OTHER PROGRAMS						
Goodwill	DOC/CRC NRC	n.a.	n.a.	Ad hoc tech transfer Assist Cdn ind'y Maintain contact with ind.		