EXECUTIVE SUMMARY

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A STUDY OF EHF COMMUNICATIONS REQUIREMENTS AND TECHNOLOGY DEVELOPMENT

CANADIAN ASTRONAUTICS LIMITED

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A STUDY OF EHF COMMUNICATIONS REQUIREMENTS AND TECHNOLOGY DEVELOPMENT

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DEPARTMENT OF COMMUNICATIONS - OTTAWA - CANADA

SPACE PROGRAM

TITLE: A STUDY TO DETERMINE THE REQUIREMENT FOR, AND AREAS OF, TECHNOLOGICAL DEVELOPMENT OF EHF SATELLITE COMMUNICATIONS SYSTEMS IN CANADA

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1.0 INTRODUCTION

Two areas of technology that have had a most profound effect on the development of civilization in the first three quarters of the twentieth century have been communications and transportation. In the last quarter of this century, it is probable that there will be a decrease in personal transportation because of the increasing environmental and economic cost of energy. At the same time there have been and will continue to be great improvements in the methods and technologies used in the transfer of information. These new technologies will create needs for transfer of new kinds of information, such as electronic fund transfer or electronic mail. For these reasons there is expected to be a significant increase in demand for communications traffic. This report, like similar studies performed for the United States' NASA, predict a very rapid increase in demands for quantity and diversity of information transfer.

The primary purpose of this study was to provide quantitative predictions on the amount of long distance voice, data and video traffic which could logically be carried on geostationary satellites, and to evaluate the need for development of a 20/30 GHz (EHF) communications satellite technology.

In predictive studies of this type, the eventual accuracy of the predictions depends upon the models used; the historical data base that is available to the researchers; and the acuity of the judgements of the researchers in evaluation of the social, technological, economic and political trends. The models that were used to develop the predictions on commercial voice and data were similar to the models used by ITT in their study for traffic demands in the United States' environment. In Canada video traffic is the largest user of long distance carriers. To predict the video traffic all foreseen sources were identified, their potential for growth was evaluated, and the channels required simply counted.

In the commercial sector a reasonable data base was available although the common carriers were reluctant to provide information on their own projections. Where practical, the models included minimum, average, and maximum cases.

There is very limited information available on the Canadian military requirements in general and military satellite communications in particular. This stems from the classified nature of some material which makes it unavailable for a study of this nature. Whenever any information was obtained, it was purely as a personal opinion. Hence, information included in this report or possible scenarios suggested are our own views based on these personal opinions and our interpretation of them and in no way constitutes DND policy.

In all predictions there is an element of subjective judgement. In predictions of voice traffic, the distance above which traffic could logically be carried by satellites, or for electronic mail the percentage of letters to be converted are two examples of subjective judgement. In the main report, and to a lesser extent, in this summary such points of subjective judgements are identified and explained.

Another objective of this report was to assess the global status of development of EHF technology and Canada's relative position in this field. In the US, Japan and Europe EHF device and system technology is being very actively pursued. Canada's role is relatively minor and the Canadian technological contribution is relatively low. It also appears that nationalism plays a major role in the award of contracts for new technology.

If Canada is to develop a viable EHF technology base, government assistance will undoubtedly be required.

The report compares the predicted traffic demands with available satellite capacity. It is apparent that, if all seven orbit slots that are presently allocated for Canada's use under the new two degree orbital spacing environment were utilized, then even for a maximum predicted traffic model situation there would be no commercially driven need for an EHF satellite by the year 2000.

However, the EHF band offers advantages in high traffic density corridors, or in some scientific applications, or for purely military communications.

Collectively such applications might justify development of a pure EHF experimental satellite like HERMES, or a hybrid package on a future ANIK mission.

2.0 GLOBAL EHF SYSTEMS

The development of EHF components and systems was surveyed on a global basis and the findings are presented in chapter 2 of the main report. EHF, or millimeter waves, are a relatively new and developing technology with many potential applications. But some of the attendant difficulties, such as the cost required for technology development, and an uncertain market have kept millimeter wave system development "just around the corner". In the past, companies have not felt that a sufficient market existed that would justify the costs for development of the new devices. Potential systems developers did not plan millimeter wave systems because no components were available.

However, the past five or six years have witnessed increasing levels of interest in the development and use of the EHF spectrum. This active interest has been spurred by the concern that the capacity of the lower frequency bands (4/6 GHz, 12/14 GHz) and the geostationary orbit space might be used up in the not-too-distant future. Reports, published in 1979, by ITT and Western Union predicted that traffic demand would exceed available satellite capacity in the 4/6 and 12/14 GHz bands, for the US, in the 1990s. Military considerations and specific purpose applications have also accelerated this interest.

The major countries or administrations which are actively experimenting with EHF spectrum use are Italy, Japan, the USA and the European Space Agency (ESA). No information is available on the Russian or Communist Block Countries' activities, hence any possible EHF systems there are not addressed.

Some of the major existing and planned EHF satellite programs are tabulated in Table 1. From this table, it is apparent that most of the satellites launched up to now, or currently planned, are of an experimental nature. The table also illustrates the active role played by Military satellites, which normally acts as a catalyst in technology development. The main report discusses the present developments and future plans in the US, Japan, and Europe.

Table 1 Global EHF Satellite Projects

PROJECT	FREQUENCIES	LAUNCH DATE	
US ATS-V/VI	32/30, 20 GHz	1970	Experimental
LES 8/9	38/36 GHz	1976	Experimental Military
MILSTAR	44/20	1987/88	Military
ACTS	30/20	1987/88	Experimental
FLEETSAT VII	44/20	1988	Proto-operational Military
JAPANESE ETS-II(KIKU-2)	35/32 GHz	1977	Experimental
CSI ("SAKURA")	30/20 GHz	1977	Experimental
CS II	30/20 GHz	1983	Communication Commercial
ECS	34.5 GHz	1977	Experimental
ITALIAN ITALSAT	30/20 GHz 50/40 GHz	1987	Domestic Communication Propagation Expts.
SWEDISH "TRUCKSAT" ON TELE-X SATELLITE	30/20 GHz	1986	30/20 GHz Technology Experiments
ESA'S LSAT	30/20 GHz	1986	Experimental
UK SKYNET	44/7 GHz	1986	Experimental Military
CANADA'S MSAT	44/22 GHz	1986	Experimental Military

In some cases, system developers had to build their own major components. However, the military's and communications' push into the millimeter waves have resulted in technology development programs on a larger scale. The biggest development program is perhaps the US Department of Defense (DOD) one to develop technology and components suitable for MILSATCOM at EHF. DOD has funded many companies to develop TWTs and other sources, receivers, flight hardware, etc. All these have, however, been directed solely to U.S. companies. NASA has a similar program on the ACTS, whereby they have awarded contracts to several companies to develop techniques and components for EHF SATCOM. Countries tend to buy systems and components internally, particularly for military objectives.

The Japanese are quickly acquiring the expertise to the point where all their satellites would be built exclusively by Japanese companies. For example, the CS-2 transponder is wholly NTT built. Likewise, all the contracts on ITALSAT has been awarded to Italian companies, although a fair amount of subcontracting is expected. Unfortunately, Canada has neither a developed technology that could be sold internationally because of unique features or excellence of design, nor do we have a commitment to an EHF mission other than the preliminary plans for MSAT.

A few foreign companies have carried on their own in-house development programs to acquire marketable capabilities. Among these are Siemens, Hughes, AIL, Microwave Associates, AEL, Thomson-CSF, Raytheon and Watkins-Johnson. As more companies are convinced that millimeter waves have finally come of age and that the market exists, there will be more and more development programs with the eventual proliferation of components and lowering of costs.

3.0 COMPONENT & SUBSYSTEM SUPPLIERS

One of the tasks in this report was a survey of the current state of components that are available at EHF frequencies and technologies that are critical to the implementation of an EHF satellite communications system.

The assessment in this survey was limited to communication systems. However, it should be mentioned that technology for remote sensing radiometry, radio astronomy, and microwave interferometry, seems to be quite mature, since it has preceded communications. Advances have also been made in the other areas, such as radar and military ECM, ECCM and ESM. All these areas share similar state-of-the-art technology and considerable technology borrowing will occur.

In Chapter 3 of the main report, the critical products are identified and the manufacturers are listed. Unfortunately, the component manufacturers are almost all foreign. There are few Canadian suppliers of hardware in the EHF band. Canadian industry, as industry in other countries, has never been quite convinced that a viable market for EHF components and subsystems does exist. They have been reading and hearing for the past 15 years or so that millimeter-wave technology is "just around the corner". To develop the necessary millimeter-wave technology requires a considerable cost investment and industry has to be quite sure that a large market exists to justify their investment. In our interview with Canadian industry, some companies said that although they feel they have EHF capability, they do not see any substantial market beyond the MSAT Project.

In other countries, development has been spurred by government projects such as the NASA ACTS, the Japanese MOPT CS program and Italy's National Space Plan. Other development has been by large companies such as Hughes, Siemens, Watkins Johnson, with large R&D budgets. Most Canadian companies do not have large R&D budgets to start in-house EHF development programs. The R&D portion of Canadian companies is typically 5-15% of sales. Military contracts have helped tremendously to evolve EHF capability in the US, for example the MIT's LES 8/9 satellites with EHF payloads was DOD supported. In Canada, a limited number of government contracts, mainly DND-related, have been completed by Canadian industry or are in progress. Andrew Antenna Company constructed a 6 ft. diameter dish antenna for the CRC ground terminal to communicate with LES 8/9 satellites. They are also currently developing a 20/44 GHz feed for DOC to go on the MSAT spacecraft. ComDev has experience with RF components, waveguide filters, couplers and ferrite devices at EHF, and are building up surface acoustic wave (SAW) capability. They have had contracts to supply components for the Japanese Broadcast Satellite and are currently building components for L-SAT satellites at 20 to 30 GHz.

There was a general consensus based on remarks from Industry that the Canadian Government should encourage industry to pursue development of EHF based communication systems as this will help them capture their fair share of the market especially in the joint U.S.-Canada military programs. Military EHF programs were considered the most likely application of EHF. Most countries are adopting a parochial view whereby they try to limit contracts on their programs to companies in their countries. Only in cases where there is a definite lack of capability within their industry would they consider allowing foreign competitors and even then they would most probably go with the "proven" manufacturers. It is therefore forecasted that Canadian Industry will find it difficult to capture any significant global EHF market. However, some local market will exist in the future, and something has to be done right now in order to prepare for it when it arrives and prevent losing to other countries even in local markets. It is clear, however, that Canadian Industry will require Government encouragement and financial assistance to develop the requisite EHF capability, and international reputation, and to promote international sales.

4.0 SURVEY OF TRAFFIC REQUIREMENTS

The prediction for communications traffic demands are presented in Chapter 4 of the main report. The prediction encompassed commercial voice, data and video; military and scientific traffic. The models, data bases, assumptions and resulting predictions have been presented in detail.

4.1 COMMERCIAL TRAFFIC REQUIREMENTS

Predictions were made for voice data and video traffic. These predictions were based upon models developed by the researchers and upon historical data bases. Where possible, the models incorporate minimum, average and maximum scenarios. Since the primary goal of this report is to determine the need for development of an EHF satellite, the models were designed to provide figures for the traffic that could logically be carried by satellites. Of course, only a portion of this potential traffic will be carried on satellites, the balance will be carried on terrestrial lines.

4.1.1 VOICE TRAFFIC PREDICTIONS

The model used for prediction of voice traffic demand is illustrated in Figure 1. The voice traffic that could logically be carried by satellites is listed in Tables 2 through 4 for minimum average and maximum scenarios. These tables include both public and private lines.

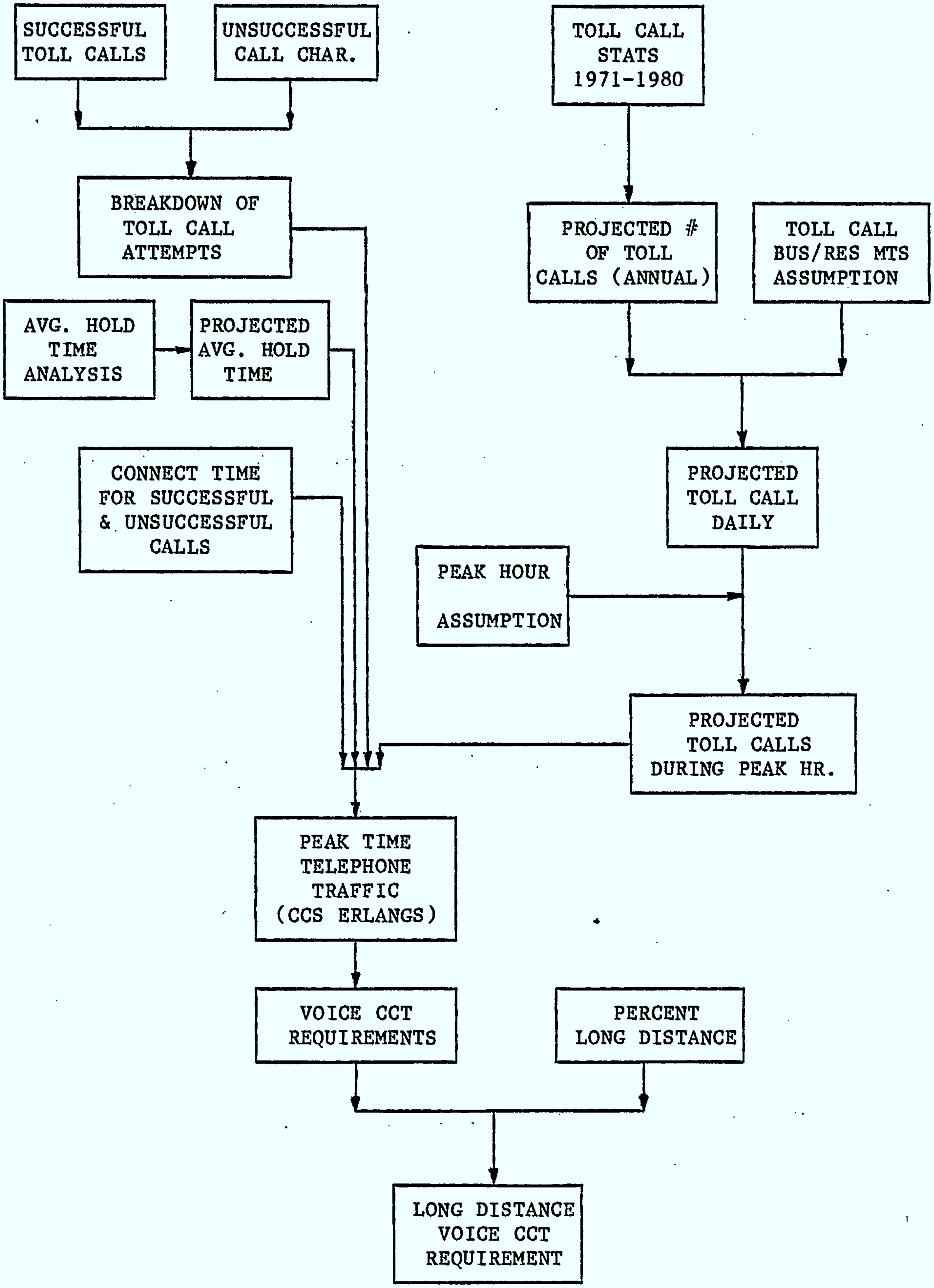

Figure 1 Methodology used in Prediction of Long Distance Voice Traffic

Table 2 Forecasted Number of Duplex Voice Circuits Required Under Minimum Scenario for Long Distance Calls over 500 Miles (1980-2000)

YEAR	MINIMUM NUMBER OF DUPLEX VOICE CIRCUITS REQUIRED ('000)			
	MTS & WATS	PRIVATE LINE	TOTAL	TOTAL CIRCUITS PER THOUSAND POPULATION
1980	4.8	1.0	5.8	.24
1985	8.1	1.8	9.9	.39
1990	13.6	3.0	16.6	.62
1995	21.6	4.8	26.4	.94
2000	32.9	7.2	40.1	1.39

Table 3 Forecasted Number of Duplex Voice Circuits Required Under Average Scenario for Long Distance Calls over 400 Miles (1980-2000)

YEAR	AVERAGE NUMBER OF DUPLEX VOICE CIRCUITS REQUIRED ('000)			
	MTS & WATS	PRIVATE LINE	TOTAL	TOTAL CIRCUITS PER THOUSAND POPULATION
1980	8.46	1.99	10.45	.44
1985	14.15	3.32	17.47	.69
1990	23.72	5.57	29.29	1.09
1995	37.82	8.89	46.71	1.67
2000	57.51	13.51	71.02	2.45

Table 4 Forecasted Number of Duplex Voice Circuits Required Under Maximum Scenario for Long Distance Calls over 300 Miles (1980-2000)

YEAR	MAXIMUM NUMBER OF DUPLEX VOICE CIRCUITS REQUIRED ('000)			
	MTS & WATS	PRIVATE LINE	TOTAL	TOTAL CIRCUITS PER THOUSAND POPULATION
1980	23.3	5.8	29.1	1.22
1985	39.0	9.8	48.8	1.92
1990	65.2	16.3	81.5	3.04
1995	103.9	26.0	129.9	4.64
2000	158.1	39.5	197.6	6.83

4.1.2 DATA PREDICTIONS

The predictions of data traffic were made for four kinds of data transmission: telex/TWX; Facsimile; Electronic Mail; and Computer Communications.

The research predicted a small increase in telex/TWX demand until 1985 then a slow decrease to 2000. For all other services, a growth in demand much larger than the growth in population is predicted. The authors did not predict an explosive growth in electronic mail, as the comparable studies for US traffic did. This was a matter of personal judgement. Nor did the authors predict an extremely rapid increase in computer communications. The cost of computer hardware is decreasing as the computing power increases. Local processing of data and local data banks are increasingly attractive; this will tend towards less, not more, inter-computer information flow.

The predictions for the amount of data traffic that could be carried on satellites are given in Table 5.

Table 5 Summary Table of Data Rates Required During the Peak Hour For Long Distance Transmission (1980-2000) in Mbps

SERVICE CATEGORY	YEAR				
	1980	1985	1990	1995	2000
Telex/TWX	.12	.14	.12	.11	.07
Facsimile	.25	.53	2.10	3.38	8.70
Electronic Mail	0	2.3	3.3	5.9	8.3
Computer Communications	5.3	14.3	30.6	53.2	85.7
TOTAL	5.67	17.27	36.12	62.6	102.77
TOTAL PER CAPITA bps/person	.23	.68	1.34	2.23	3.55

4.1.3 VIDEO TRAFFIC

The continuing demand for video and radio broadcasting services was previously thought to be the main driver in the future demand for EHF bandwidth. Recent regulatory decisions in Canada and the United States have transformed the broadcasting field into a dynamically evolving telecommunications service. The introduction of a single service type has the potential of using large quanities of bandwidth, as evidenced by the eight 36 MHz satellite RF channels requirement of CANCOM in the extension of services to the remote and underserved communities in Canada. The large variety of potential services indicates a siginificant demand for bandwidth in the future.

Probably the most important factor in the decision body on the future of video and radio broadcast services is regulatory policy. The types and quantity of services to be provided, the service desirability and introduction date, the financial and feasibility for support of the new service and the impact on existing services will be subject to regulatory influence which must be taken into account if a realistic projection of video and radio broadcasting services is to be obtained.

Chapter 4 of the main report discusses the following video and broadcasting services under the influence of economics, technology and regulatory policies:

- i) network broadcast - national and provincial,
- ii) tele-education,
- iii) extension of television services to remote and underserved communities,
- iv) pay television,
- v) services viable under a direct broadcast system, and
- vi) video conferencing.

The estimates for the first four categories was largely a matter of counting the number of well publicized current and planned services.

The services provided under a direct broadcasting system involved more subjective judgements. The evolution of a direct broadcast satellite (DBS) from a concept to reality continues to progress slowly as program requirements become identified, the necessary technology developed, and the funds required are made available. The concept of a DBS has received critical review throughout the world, particularly in Japan, the US, Western Europe and Canada. The experiments of the US/Canadian Communication Technology Satellite (CTS) have proven the feasibility of direct-to-home broadcasting and have demonstrated the potential of its services.

Services addressed in this category include:

Audio Services: this is a relatively low demand estimated at 1 channel through 2000.

Narrowcasting: provides television to a small and/or select audience, for example, re-education for professionals. This service would be natural for EHF but the estimated demand is small.

Telidon: as presently designed, Telidon does not use a separate television channel

High Definition Television (HDTV): the technology necessary for production of high definition TV is available now. However, the acceptance of HDTV by the commercial stations and by the public is very uncertain. The cost of conversion will undoutedly be high. In the author's judgement, if HDTV becomes accepted commercially, it will replace existing channels rather than add to them. If the HDTV were to be transmitted using current techniques, the bandwidths required would be about four times the bandwidth of a conventional TV. However, sophisticated data processing techniques are being developed that reduce bandwidths required for HDTV to values comparable to conventional TV. For all of these reasons, no extra demand was allocated for high definition television.

Providing an accurate estimate of the demand for videoconferencing will be no simple task. The service is still relatively new and how well it performs on the market still remains to be seen. To arrive at a figure for future demand, estimates of public acceptance were made based on opinion polls. Then, based on projections of airline travel and an empirical formula, the number of conferences and potential video conferences were calculated. These figures are provided in Table 6.

Table 6 Forecast of Number of Videoconferences (1980-2000)

	NUMBER OF CONFERENCES (N_C) ANNUALLY (10^6)			POTENTIAL NUMBER OF VIDEO-CONFERENCES (N_V) ANNUALLY (10^3)			ESTIMATE OF PERCENTAGE CAPTURE BY SATELLITES			RELIZABLE NUMBER OF TWO-WAY VIDEOCONFERENCES CARRIED BY SATELLITE ANNUALLY (10^3)	
YEAR	MIN.	MID.	MAX.	MIN.	MID.	MAX.	MIN.	MID.	MAX.	MID-VALUE	PEAK HOUR DEMAND
1980	6.47	6.47	6.47	861	861	861	--	--	--	--	--
1985	6.86	7.70	7.90	912	1024	1051	4.5	5.8	10.15	59.4	29.7
1990	7.24	8.75	9.51	963	1164	1265	9.0	11.6	20.3	135.0	67.5
1995	7.53	9.83	11.13	1001	1308	1504	13.5	17.4	30.45	227.6	113.8
2000	7.80	10.88	12.75	1037	1447	1694	18.0	23.2	40.6	335.7	167.8

Video compression techniques will be used for successful videoconferencing because costs must be considerably lower than full rate television. AT&T is reportedly ready to offer a videoconference service that uses their DS-1 lines which has a data rate of 1.544 Mbps. A standard 36 MHz transponder will carry data at a rate of 60.6 Mbps. If the transponders can be utilized to 75% of maximum capacity, than 30 one-way or 15 two-way videoconferences could be carried on each transponder. Table 7 summarizes transponder requirements.

Table 7 Videoconferencing Transponder Requirement (1980-2000)

YEAR	TRANSPONDERS REQUIRED			NO. OF 2-WAY CONFERENCES PER TRANSPONDER
	MINIMUM	MID-VALUE	MAXIMUM	
1980	-	-	-	-
1985	2.1	3.0	5.3	10
1990	2.9	4.5	8.6	15
1995	4.5	7.6	15.3	15
2000	6.2	11.2	22.9	15

4.1.3.1 Summary of Video and Audio Broadcast Requirements

A summary of the video and audio broadcast requirements, by service type, is listed in Table 8. Network television broadcast has the greatest demand with 21 satellite TV channels by the year 2000. Roughly two-thirds of this demand is from the CBC. The major growth in this category will occur during the next few years.

Table 8 Projected Satellite TV Channels Required by Service Type (1983-2000)

SERVICE CATEGORY	FREQ. BAND (GHz)	PROJECTED SATELLITE TV CHANNELS REQUIRED				
		1983	1985	1990	1995	2000
1) NETWORK:						
CBC	4/6	10	13	13	14	14
CTV	4/6	*	1	2	2	2
GLOBAL	4/6	-	1	1	1	1
TVA	4/6	*	1	1	1	1
ATV-2	12/14	1	1	1	1	1
LA SETTE	12/14	1	2	2	2	2
TOTAL		14	19	20	21	21
2) TELE-EDUCATION:						
KNOWLEDGE NTWK	12/14	1	2	2	2	2
ACCESS	12/14	**	1	1	1	1
TVO/OECA	12/14	**	1	1	1	1
RADIO-QUEBEC	12/14	-	1	1	1	1
FUTURE SERVICES	12/14	2	3	3	4	4
TOTAL		5	8	8	9	9
3) EXTENSION OF SERVICE:						
CANCOM	4/6	8	10	11	11	11
NTV	12/14	**	1	1	1	1
TOTAL		9	11	12	12	12
4) PAY TELEVISION:						
FIRST CHOICE (ENG)	12/14	2	2	2	2	2
FIRST CHOICE (FR)	12/14	2	2	2	2	2
SUPERCHANNEL (ALTA)	12/14	1	1	1	1	1
SUPERCHANNEL (ONT)	12/14	1	1	1	1	1
STAR CHANNEL	12/14	1	1	1	1	1
C CHANNEL	12/14	2	2	2	2	2
WORLD VIEW	12/14	1	1	1	1	1
FUTURE SERVICES	12/14	2	2	4	6	6
TOTAL		12	12	14	16	16
5) ADDITIONAL DBS RELATED:						
AUDIO	4/6	-	1	1	1	1
NARROWCASTING	12/14	-	1	2	3	4
TELIDON	12/14	-	1	1	1	1
HDTV	12/14	N/A	N/A	N/A	N/A	N/A
TOTAL		-	3	4	5	6
6) VIDEOCONFERENCING	12/14	-	3	5	8	12

* INTERIM USE OF 1

**DOC PILOT PROJECT

4.2 POTENTIAL CANADIAN MILITARY REQUIREMENTS

There is very limited information available on the Canadian military requirements in general and military satellite communications in particular. This stems from the classified nature of some material which makes it unavailable for a study of this nature, and the lack of any articulated DND policy on satellite communications. It can only be inferred that there is some perceived potential in EHF and SATCOM in general, based on the fact that DND is supporting MSAT (interested in a 44/20 GHz package), is purchasing or planning to purchase radios to interoperate with the US, and is supporting experiments at CRC on the Shirley-Bay Kingsmere terrestrial EHF link. Whenever any information was obtained, it was purely as a personal opinion. Hence, information included in this report or possible scenarios suggested are our own views based on these personal opinions, and our interpretation of them in no way constitutes DND policy.

The Canadian Forces have four major roles:

- Surveillance and protection of our soverign territory and coastlines.
- Defence of North America in co-operation with US Forces.
- Fulfillment of such NATO commitments as may be agreed upon.
- Performance of such international peacekeeping roles as [Canada] may from time-to-time assume.

In addition, the military in other countries, notably the US, fulfills an additional role of acting as an initiator and leader for technology development by industry. The Canadian military could also be fulfilling this role in a more concerted way as this would lead to a symbiotic relationship where both DND and industry would benefit. Other countries, such as the US and the UK, have defense communications systems, experimental and operational, which utilize a variety of transmission media, including satellite EHF. As these countries develop operational EHF capabilities, it will be necessary for Canada to have compatible systems.

It is understood that DND is considering funding some spacecraft EHF development work on MSAT, and is planning some extensive EHF propagation experiments in the Ottawa area. While the military is without a specific policy on the use of space, and while a requirements quantification is beyond the scope of this study, some recommendations can nevertheless be offered based on the collection of expert opinion gathered during the interviews. The focus here will mainly be in the area of military satellite communications because it seems to be on the threshold of Canadian-funded EHF technology development.

The military could most usefully exploit EHF technology to provide tactical communications, employing wideband Spread Spectrum (SS) secure services. Strategic links may be more economically supplied using the SHF bands, while still providing secure robust communications.

The baseband equipment mentioned above may have some commonality with that being developed for MSAT. This leads to another recommendation, and that is, components (sources, filters, mixers, etc.) which Canada have, or is developing a capability, are required in all the previously mentioned technology development areas. For example, components developed for use on radiation hardened spacecraft and ground equipment have a direct use in the commercial satellite industry; and not only in communications but may have additional spin-offs, such as non-space military and civil electronics systems protection, personnel dosimetry, and medical radiation therapy. As another example, RF components developed for EHF purposes may be suitable as IF components for higher frequency systems such as laser inter-satellite links.

In summary, while the military requirements are not specifically defined, there is, nonetheless, a need on the part of the Canadian military to use EHF technology just to interoperate with our allies. Some specific areas have been noted where military support is needed to establish or strengthen the Canadian industrial capability, in return for offset benefits that will accrue through foreign sales.

4.3 SCIENTIFIC REQUIREMENTS

Apart from military applications, other non-commercial uses of millimetre wavelengths exist. These are mostly of a scientific nature and are being actively pursued by universities and government departments. Systems falling into this (scientific) classification may consist of space-to-earth data transmission for spaceborne research payloads related to remote sensing of the earth, geophysical applications, and stellar mapping.

4.3.1 RADIO ASTRONOMY

There is a great interest in the Canadian radio astronomy community for astronomical observations in the millimeter wave region between 1 and 16 mm (300 GHz to 19 GHz). Technologies developed for communications at EHF may be expected to find application in radio astronomy. Although the requirements on receivers and antennas used for astronomy are more stringent, the technology base developed for commercial communications would greatly benefit the astronomers. Of course, the opposite is true, developments made for astronomical observations will be directly applicable to communications.

There are currently a number of projects in millimeter astronomy in Canada. For example, NRCC together with universities across Canada are actively trying to realize the Canadian Long Baseline Array (CLBA) project, which would be the most powerful telescope of its kind in the world.

The CLBA would produce the largest quantity of data for transmission to research centres. Each of the eight sites could transmit 96 Mb/s in real time. In addition, each site is linked to the central control facility via a dedicated 9.6 kb/s line for command and telemetry. Hence, there is a potential of 76.8 kb/s of command and telemetry data. However, at the present time, financial constraints have led to a decision to record the 768 Mb/s of raw data on tape instead. Hence, the data transmission requirement from the CLBA is expected to be negligible.

4.3.2 REMOTE SENSING

Canada does not have its own earth sensing satellite, and the Federal Department of Energy, Mines and Resources (EMR) is pursuing the possibility of acquiring one. Canada is interested in launching Radarsat, a remote sensing satellite, probably in the early 1990's. This would carry a C-band synthetic aperture radar (SAR) as the primary sensor for sea-ice monitoring and a secondary sensor, either an X band scatterometer (ocean winds, etc.) or a visible-infrared (VIR) instrument primarily for land resources use. Data will be downlinked from Radarsat to ground stations at rates in the range of 100 to 120 Megabits per second. At the present time, there are no plans to relay these data through a geostationary spacecraft although the concept is entirely feasible particularly on an EHF link.

Other countries, notably the US and Russia, have been active in remote sensing in the 20 to 60 GHz range. The techniques appear to be well developed but they could undoubtedly be improved as larger antennas, better tracking systems and more sensitive receivers are developed.

4.3.3 GEOPHYSICAL AND OTHER APPLICATIONS

The Department of Energy, Mines and Resources is involved in several areas of geophysical research, such as geophysical survey with applications for positioning, ship navigation, geodetic survey, etc. The earth scientists collect reasonably large amounts of data which is typically in the north or remote fields. These data then have to be transmitted to the major centres for analysis. Data from the north and other research regions can be transmitted to the satellite in a global beam, then beamed to a major centre (say Ottawa) via a narrow spot beam. The global beam could be in the C or Ku-band whereas the spot beam might be an EHF one.

Other scientific applications include medical video and other tele-health applications. These were considered in the section dealing with video data. In order to estimate the amount of data transmitted by the scientific community, the authors examined several potential applications. For example, Radarsat, earth resources satellites, weather satellites, and emergency planning. While these programs can generate large amounts of data, the baseline designs were structured to transmit their raw data directly to a ground station or central collection point. Data are processed at this site before being distributed. Investigations have established that in such a design the rate of transmission of processed data is one to two orders of magnitude less than the raw data. It is the processed data that would be transmitted through the satellite network. Given the fact that the potential applications will not be mature until the late 1980's to early 1990's and given that processed data rates will not be as high as first thought, it is the authors' estimation that scientific demand will not exceed one ANIK channel, which is equivalent to 90 Mb/s by 1990. Therefore, one video channel has been allocated for transmission of scientific data in 1990 and two channels in 1995 and three in 2000.

5.0 THE SUPPLY SIDE

5.1 SPACE SEGMENT

In Canada, a domestic satellite telecommunications network is provided solely by Telesat Canada. Since the launch of ANIK A, in November 1972, Telesat Canada has launched a total of six spacecraft into geostationary orbits. Four more satellites are scheduled to be flown by October 1985. Of the six in orbit spacecraft, only five are currently capable of providing services. These are the ANIKs A3, B1, and the newly launched C3, C2 and D1. ANIK A1 and A2 had fulfilled their design life and have, just recently, been retired. Figure 2 shows the launch schedule and design life for the ANIK A through D series.

The new generation of Telesat satellites, the ANIK C's and D'S, are designed to meet the existing and projected market demands from various users. The 6/4 GHz ANIK D series are replacement satellites for the three ANIK A's, the last of which is expected to be out of service by early 1984 and for ANIK B, scheduled to be retired by 1986. The ANIK C series, operating at 14/12 GHz, are designed to meet the expanded market demand growth in the late 1980's and early 1990's. In addition, existing services currently provided by the 14/12 GHz portion of the ANIK B will also be adopted by the ANIK C's when ANIK B reaches end of life in 1986. The next generation of spacecraft will have to be in service by 1990 or 1992. It is very likely that the next generation of spacecraft will be much more sophisticated than the current ANIK C and D series. They will be designed to make maximum use of the frequency allocation and to operate in the new environment with two degree orbital spacing.

Telesat now has seven orbital positions, as shown on Table 9, for operation in the fixed satellite communications bands.

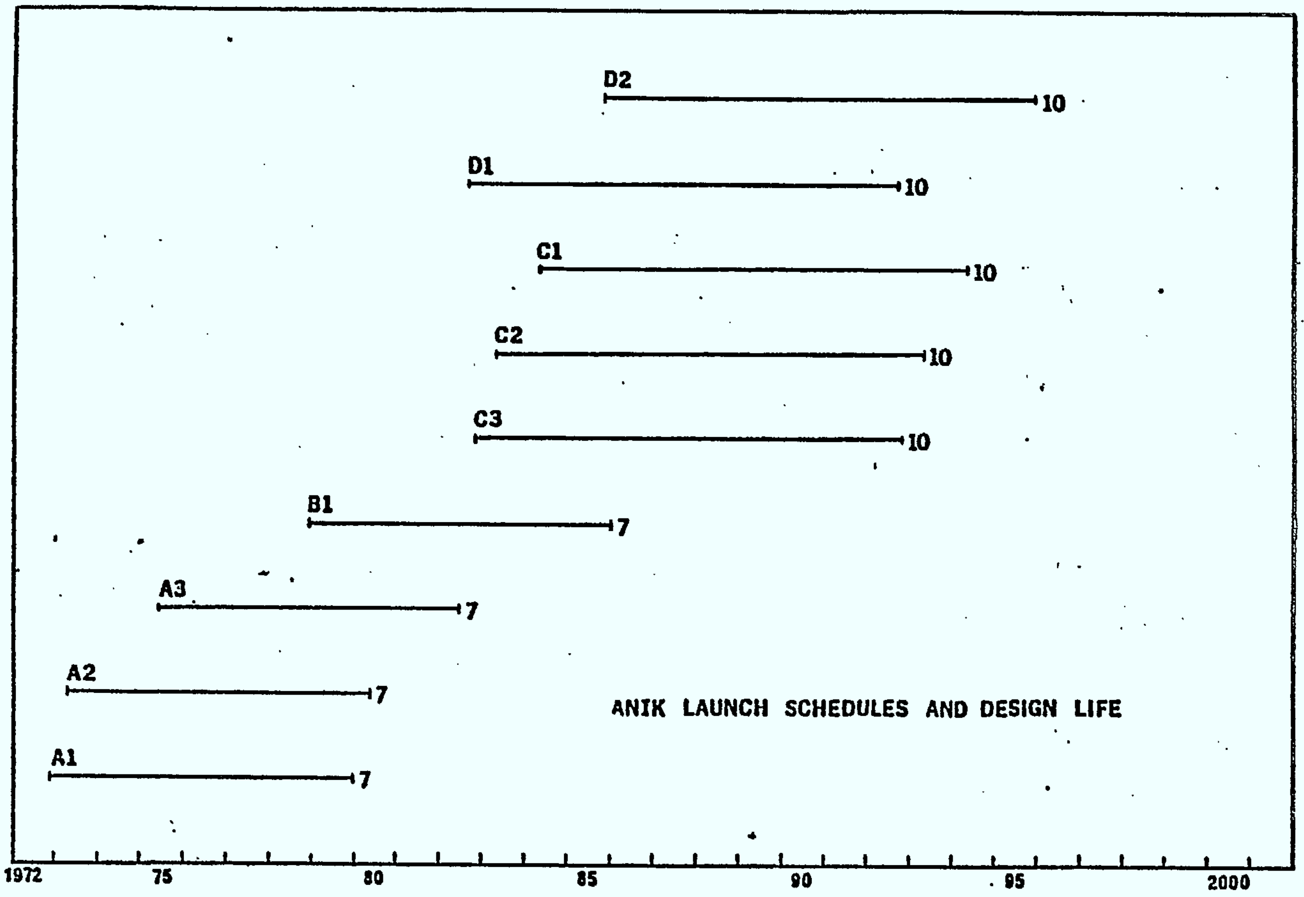

Figure 2 Currently Planned Schedule of Launches of the ANIK Spacecraft (The numbers at the ends of the lines are design lifetimes)

Table 9 Orbit Position Allocations for Canada

	ORBIT LOCATION	FREQUENCY
1	117.5°W	12/14
2	112.5	12/14
3	111.5	4/6
4	110	12/14
5	108	4/6
6	107.5	12/14
7	104.5	4/6

5.1.1 COMMUNICATION CAPACITY OF THE ANIKS

The communication capacity of the ANIK system, as it evolved from the original A series to the current C and D series, had increased many fold within a relatively short timeframe of ten years. By the year 1984, the ANIKs C and D will have a total combined usable bandwidth of 4032 MHz as opposed to that of 1080 MHz provided by the three ANIK A's. This growth demonstrates the increasingly higher demand for information distribution and exchange on a national scale, where the versatility of country-wide coverage is most feasible from a satellite point of view.

The 6/4 GHz communication systems are categorized into heavy, medium and thin route message facilities. In the heavy route traffic, each RF channel is capable of handling 960 one-way multiplexed voice circuits, frequency modulated single access. In the medium density message traffic, each RF channel can operate under one of two modes. These are: a) frequency modulation, frequency division multiple access (FM/FDMA); or, b) pulse code modulation, time division multiple access (PCM/TDMA). In each case, up to 200 two-way voice circuits can be carried using FDMA, and up to 300 (two-way) in the TDMA mode. The thin route message facility operates under single channel per carrier mode (SCPC/FDMA). In this case, each voice circuit modulates an RF carrier using phase shift keying (PSK) with delta encoding technique and up to 360 two-way circuits can be carried in one satellite transponder.

The 14/12 GHz transponder in ANIK C has a bandwidth of 54 MHz, unlike the 36 MHz in ANIKs A and D, and the 72 MHz in the 14/12 portion of ANIK B. The digital data handling capability of the ANIK C transponder is two DS-3 bit streams at a composite rate of 91 Mbps using QPSK modulation. The equivalent telephony capacity is 1344 one-way voice channels per transponder. Table 10 summarizes the overall communication capacity performance of the ANIKS.

Table 10 Anik Communication Capacity Summary

Anik Series	Freq. (GHz)	No. of Transponders (RF Channels) Total On-Board	No. of Transponders (RF Channels) At Any Given Time	RF Channel Bandwidth (MHz)	Total Useable Bandwidth (MHz)	Communication Capacity (Per RF Channel)
A	6/4	12	10	36	360	960 FM/FDM one-way voice channels or 1 TV signal
B	6/4	12	10	36	360	Same as Anik A
B	14/12	4	2	72	144	Nominal 2, or max. 3 TV signals
C	14/12	20	16	54	864	91 Mbps using QPSK, or 1344 voice channels, or 2 TV signals plus 2 radio programs
D	6/4	24	20	36	720	60 Mbps, or 960 one-way heavy route or 200 two-way FDMA/FM, or 300 two-way TDMA, or 360 two-way SCPC voice-circuits

5.1.2 ANIK CAPACITY IN YEAR 2000

The ANIK C's and D's, which are to be launched in the early to mid-1980's, are designed for a minimum mission life of eight years with an expected life of ten years. Replacement satellites in the form of ANIK E and ANIK F operating in the C and Ku bands will be required, at the mid-1990 timeframe, to take over the existing traffic carried by ANIK C and D. The projected increase in traffic demand strongly indicates a need for more sophisticated satellite transponders optimized for transponding digital data. It is not unreasonable to assume that all seven orbit slots will be required for the Canadian service. Furthermore, depending on the feasibility and state of technology in high frequency development (EHF), the additional system may be envisaged as one of hybrid type. With a concept similar to that of the ANIK B, the new system may carry a secondary payload consisting of a 30/20 GHz transponder. The hybrid satellite, in addition to supplying the excess demand using the C (or Ku) band primary payload, could, at the same time, be employed to investigate operationally new 30/20 GHz applications. High Definition Television (HDTV), which demands a wide bandwidth for operation (approximately 100 MHz), is one possible service that could be experimentally explored with such a system.

However, in the foreseeable future, the established domestic satellite communication system will still be centered on the C and Ku bands. Until such time that capacity of these bands is saturated, it will neither be likely nor economically feasible to have full operation of a 30/20 GHz system. The cost impact, especially upon the ground segment end of the system, will be so significant that unless drastic changes in demand occur, a 30/20 GHz system will only be playing a secondary role at the most to the frequency bands presently in use.

5.2 TERRESTRIAL NETWORKS

5.2.1 EXISTING FACILITIES

Long-haul transmission facilities in Canada are managed and operated by TCTS and CNCP. Unlike the US, Canada's long-haul facilities are almost all terrestrial microwave radio operating in the 4, 6 and 8 GHz frequency bands. There is a trend, in Canada, to replace all existing analog long-haul facilities with digital facilities since the digital terminal costs are less than analog and it is cheaper to terminate a digital switch with a digital facility. Section 4.2.2.1 of the main report provides figures for the current capacities of terrestrial links.

5.2.2 FUTURE FACILITIES

Various systems are under investigation by the telephone companies to meet the traffic demands in the 1985-1990 timeframe. Two digital radio systems are being examined for long-haul transmission, operating in a unified 4 GHz digital band and a lower 6 GHz digital band. Section 4.2.2.2 of the main report provides figures on projected growth of the terrestrial lines.

It should be noted that the effective circuit capacity can be increased if more efficient techniques are used for transmission of speech and data. The move towards all digital links is driven by the decreasing costs, increasing speed and increasing reliability of digital electronics. During our discussions with telephone industry personnel, it was felt that more efficient techniques could effectively increase capacity by approximately 50%.

Based on current traffic forecasts, the terrestrial networks, excluding the high density corridors such as Montreal-Toronto-Ottawa-Windsor, are capable of handling the growth to year 2000 and probably to years 2005 to 2010.

5.3 FIBER OPTICS

The technology of fibre optics, after twelve years of research and development, had emerged from the laboratory to become an aggressive competitor to existing commercial systems. The technology and applications are developing very rapidly and have already found establishment in certain segments of the telecommunication industry. Because of its inherent capability to carry vast amounts of information, fibre optics will present an increasing challenge to the existing terrestrial and satellite microwave systems. It will complement, if not totally replace, those service areas where conventional systems are either stretching the limit of their capability, or are just not cost or performance effective. Several countries, including Canada, have experimental and prototype optics communications networks with plans for expansion into operational systems. The most attractive application for fibre optics links is a relatively short high density route such as the Québec City to Windsor. The U.S. plans include a high capacity cable between New York and Washington. The use of fibre optics on long distance links is also attractive. AT&T plans to include single mode fibre optics lines in the next trans-Atlantic cable (TAT8), due for completion in 1988. Fibre optics will have a very significant impact on the demand for satellite communications. In a recent evaluation of the impact of fibre optics on demand for satellite transponders in the year 2000, the Space WARC reduced estimates of the number of necessary transponders by 30%.

Currently, the more competitive market trend for fibre optics is to provide local network distribution and to carry high density data and voice traffic over busy routes for point-to-point transmission. In field trial systems using single mode fibre, repeaters were placed 30 km apart with data rates of 400 Mbps. Laboratory demonstrations have shown remarkably high data rates over long fibres, 420 Mbps over an 84 km fibre, without repeaters. Because of the high data rate and point-to-point nature of the fibre optics, it is much more competitive with foreseen EHF applications than with the wide area coverage supplied by 4/6 and 12/14 services. It is expected that fibre optics will penetrate every communication market segment except in areas where only thin route is in demand, or in communication systems which are highly distributive and/or mobile in nature.

The main report presents a thumbnail sketch of the potential impact of fibre optics on the communications industry. A more comprehensive study would be a valuable adjunct to this report.

6.0 CONSOLIDATION OF DEMANDS

This section consolidates the demands for communication traffic by commercial, military and scientific users. It must be remembered that the demand is only for that traffic which could logically be carried on communications spacecraft in geostationary orbit.

Although no specific scientific project was identified that would require significant traffic, there are a number of potential applications; therefore, a relatively small allowance was made for scientific users.

The military uses commercial carriers, or private telephone lines and this use has been included in the data base from which the commercial demand figures were developed. Therefore military use has been included in the predictions for commercial traffic. The military is presently without a specific policy on space although there are pressures to create such a policy and to develop a communications spacecraft, and/or to participate in the M-SAT program. The development of EHF satellite communications by NATO and the United States will make it necessary for Canada to have some capabilities in this band. No separate allowance was made for military traffic, pending decisions on Military policy.

Commercial uses dominate the traffic requirements. The figures for Voice and data traffic are listed in Tables 11 and 12 for average and maximum scenarios.

Because of the trend to all digital formatting all demands were converted to equivalent Megabits per second (Mbps). The reader is referred to the main report, section 4.3, for an explanation of this conversion.

Table 11 Forecasted Satellite Capture of Voice and Data Portion of Commercial Demand (1980-2000) in Mbps: Average Scenario

YEAR	FORECASTED VOICE AND DATA DEMAND			VOICE AND DATA SATELLITE CAPTURED DEMAND		
	VOICE a	DATA b	TOTAL Mbps	VOICE .189a*	DATA .8b*	TOTAL Mbps
1980	1338	5.7	1343	253	4.6	258
1985	2236	17.2	2253	422	13.4	435
1990	3749	36.0	3785	708	28.8	737
1995	5979	62.5	6042	1129	50.0	1179
2000	9091	102.7	9194	1716	82.2	1798

Table 12 Forecasted Satellite Capture of Voice and Data Portion of Commercial Demand (1980-2000) in Mbps: Maximum Scenario

YEAR	FORECASTED VOICE AND DATA DEMAND			VOICE AND DATA SATELLITE CAPTURED DEMAND		
	VOICE a	DATA b	TOTAL Mbps	VOICE .151a*	DATA .8b*	TOTAL Mpbs
1980	3725	6.5	3731	563	5.2	568
1985	6246	19.1	6265	949	15.3	961
1990	10432	40.0	10472	1581	32.0	1613
1995	16627	77.9	16705	2523	62.3	2585
2000	25293	113.6	25406	3836	90.8	3927

Tables 11 and 12 also provide our estimates of the amount of traffic that will be captured by satellites. Again the reader is referred to the main report, section 4.3, for an explanation of the capture ratio.

* The reader is referred to the main report for explanations of these satellite capture ratios.

Table 13 depicts the video portion of the commercial demand. A digitization rate for a single video channel of 42 Mbps is regulated. The video channel requirements have been categorized by frequency band. To account for transponder loading, the C-band signals (4/6 GHz) have been adjusted to use 60.6 Mbps, i.e., the full transponder. For the Ku-band signals (12/14 GHz), a full 54 MHz (91 Mbps) transponder can accommodate two video signals. Hence, the Ku-band signals were adjusted to use 45.5 Mbps each.

Table 13 Forecasted Satellite Capture of Video Portion of Commercial Demand (1983-2000) in Mbps

YEAR	FORECASTED VIDEO DEMAND calculated at 42 Mbps/channel			SATELLITE CAPTURED VIDEO DEMAND		
	C-Band	Ku-Band	TOTAL	C-Band 60.6 Mbps/C	Ku-Band 45.5 Mbps/C	TOTAL
1983	840	840	1680	1212	910	2122
1985	1134	1218	2352	1636	1319	2955
1990	1218	1428	2644	1757	1547	3304
1995	1260	1722	2982	1818	1865	3683
2000	1260	1932	3192	1818	2093	3911

The supply of satellite resources was described in section 5 of this report and in much more detail in section 4.2 of the main report. By the end of 1985, it is expected that the three Anik Cs and the two Anik Ds will provide an in-orbit capacity of 6792 Mbps. Full utilization of the parking orbits available to Canada would provide a maximum capability of 9.5 Gbps. Under an average scenario, it can be seen from Table 15 that the supply exceeds the projected demand. Under the maximum scenario, the projected demand is 92% of capacity at 14/12 and 6/4 GHz, assuming that the satellites to be launched in the 1990's are duplicates of the current ANIK C and D.

The forecasted demand for satellite service is not the total traffic but is only a percentage of the total traffic that will be carried over distances of 500, 400 and 300 miles for minimum, average and maximum scenarios, respectively. It was further assumed that satellites will carry 20% of traffic over 500 miles, 15% of traffic between 400 and 500 miles, and 10% of traffic between 300 and 400 miles.

Table 14 Number of ANIK Satellites in Orbit, Number of Transponders and Available Bandwidth, Maximum Supply Scenario

YEAR	SATELLITES	TRANSPONDERS @ BW (MHz)	TOTAL BW (MHz)	TOTAL Mbps
1980	A3 + B1	20 @ 36 + 2 @ 72	864	1454
1985	3C + 2D	40 @ 36 + 48 @ 54	4032	6792
1990	3C + 3D	60 @ 36 + 48 @ 54	4752	8004
1995	4C + 3D	60 @ 36 + 64 @ 54	5616	9463
2000	4C + 3D	60 @ 36 + 64 @ 54	5616	9463

The demands for commercial voice, data and video, and scientific traffic are added in Tables 15 and 16 and these data are compared to forecasted capacity on ANIK C and D type spacecraft. According to the analysis presented in this report the projected needs for all kinds of traffic can be accommodated by conventional spacecraft which occupy the orbit positions currently allocated for Canadian use. It is also very probable that the ANIKs launched after 1992 will be more sophisticated and will have more capacity than the current set of ANIKs C and D.

However, prior to drawing our final conclusions, the impact of terrestrial network traffic spillover and compression techniques should be reviewed. Earlier discussions on terrestrial facilities estimated that saturation of these networks is not expected prior to the year 2000. Thus, little if any, traffic is expected to spill over from the terrestrial networks. New competing technologies, in particular fibre optics, will in all probability, reduce the demand for traffic to be carried by spacecraft.

Table 15 Forecasted Total Satellite Telecommunications Demand Under an Average Scenario (1980-2000)

YEAR	COMMERCIAL		SCIENTIFIC & MILITARY (Mbps)	TOTAL DEMAND (Mpbs)	FORECASTED SUPPLY (Mbps)	POSSIBLE SATELLITE CONFIGURATION
	VOICE & DATA (Mbps)	VIDEO (Mbps)				
1980	258	846	-	1104	1454	A3 + B1
1985	435	2955*	-	3390	5700	2C + 2D
1990	737	3304	100	4141	6792	3C + 2D
1995	1179	3683	200	5062	6792	3C + 2D
2000	1798	3911	300	6009	6792	3C + 2D

*The increase between 1980 and 1985 is due to Pay TV, Educational TV, and CANCOM

Table 16 Forecasted Total Satellite Telecommunications Demand Under The Maximum Scenario (1980-2000)

YEAR	COMMERCIAL		SCIENTIFIC & MILITARY (Mbps)	TOTAL DEMAND (Mpbs)	FORECASTED SUPPLY (Mbps)
	VOICE & DATA (Mbps)	VIDEO (Mbps)			
1980	568	846*	-	1414	1454
1985	961	3092	-	4053	6792
1990	1613	3486	200	5299	8004
1995	2585	4047	400	7032	9463
2000	3927	4411	400	8738	9463

*The 2 - 14/12 channels on ANIK B plus 10 - 4/6 channels used by the CBC.

Compression techniques will also reduce the requirements of space resources. Video compression techniques are currently under development and are showing good progress. It is expected that a compression ratio of 2:1 for full video will be achieved and implemented by 1990. With video requirements generating over half of the overall satellite traffic, the impact would be substantial. Compression techniques, such as DSI, for terrestrial facilities also threatens to reduce satellite traffic. However, their impact will be limited by TCTS policy. What DSI ensures is that no terrestrial spillover traffic will be created through postponing the saturation of the terrestrial network.

The slow acceptance of teleconferencing has spurred development of video compression techniques that promise to reduce the costs significantly. AT&T is reportedly ready to market a videoconferencing service that uses only 1.544 Mbps. Widergren Communications reported development of a system that utilizes only 56 Kbps. Widergren reports that if more than 10% of the image changes from frame to frame blurring occurs.

In light of these discussions, the conclusion of this analysis is that there exists no general traffic driven need for an EHF band on commercial communications satellites before the year 2000, provided all seven allocated orbital slots are occupied with satellites equivalent to the present ANIK C and ANIK D.

7.0 COMPARISON OF THE DATA FROM THE ITT AND WESTERN UNION REPORTS

In 1979 ITT and Western Union published reports on the projected demands for communications traffic in the United States .

The projections for traffic in the U.S. should be roughly ten times the Canadian figures, simple based upon the relative populations.

The predictions of traffic which could logically be carried by geostationary spacecraft, in the U.S.A. and Canada are summarized in Table 17. Considering the totals, the CAL maximum scenario is approximately 1/10th of the ITT figures but only 1/30th of the Western Union data. The Western Union predictions for voice traffic are extremely, and in the authors judgement, unrealistically high.

Both ITT and Western Union have predicted much higher data traffic than CAL. The authors simply do not foresee the explosive growth in data traffic predicted by Western Union. The total long distance data traffic predicted by CAL is equivalent to approximately 600 pages of data per person per year, in the year 2000. This is calculated as follows:

$$\text{Bits/year} = \frac{1.03 \times 10^8 \text{ bps} \times (3600 \times 8 \times 250) \text{ s/year}}{1.5 \text{ peak hr/av. hr}} = 4.94 \times 10^{14} \text{ b/y}$$

$$\text{Pages/year} = \frac{4.94 \times 10^{14} \text{ b/y}}{7 \text{ b/char.} \times 80 \text{ char./line} \times 50 \text{ lines/page}} = 1.76 \times 10^{10}$$

$$\text{Pages/year/person} = \frac{1.76 \times 10^{10}}{29.0 \times 10^6} = 600$$

The cost of computer hardware is steadily decreasing as computing power and data storage are increasing. Therefore, local processing of data becomes more attractive and economical. Further, packetization on data lines will improve the utilization of communications links.

Table 17 Comparison of Predicted Traffic Demands (Mbps)

TRAFFIC TYPE	REPORT	1980	1990	2000
Voice	ITT	44,800	107,500	202,200
	WU	134,300	340,160	881,340
	CAL (Avg)	1,338	3,749	9,091
	(Max)	3,686	10,304	24,986
Video	ITT	2,899	13,660	36,239
	WU	8,800	12,625	18,774
	CAL (Avg)	846	3,304	3,911
	(Max)	846	3,486	4,411
Data	ITT	45	800	1,323
	WU	226	1,448	5,740
	CAL (Avg)	5.7	36	103
	(Max)	6.5	40	114
TOTALS	ITT	47,744	121,960	239,762
	WU	143,326	354,233	905,854
	CAL (Avg)	2,189	7,089	13,105
	(Max)	4,538	13,830	29,511
Per Capita Traffic bits/s per person	CAL (Avg)	91	264	453
	CAL (Max)	190	516	1020

8.0 CANADIAN EHF MISSION MODEL

8.1 MISSION MODEL

Based on the results of our study, it appears that Canadian Communication traffic demand will not be sufficient to compel satellite systems suppliers to develop EHF capability. Present (ANIK B, C and D) satellites along with additional satellites at C and Ku band to occupy fully the available orbital slots will meet all foreseen traffic for the next two decades, except in the unlikely event that video conferencing services demand grow at a phenomenal rate. Furthermore, if an unregulated marketplace is assumed, the satellite capture ratio would be expected to drop. Fibre optics communication systems promise to offer severe competition. Some special services, such as military needs for robust anti-jam systems with low probability of intercept and perhaps some scientific uses, may be best served by EHF. Such services, however, cannot by themselves provide economic justification for development of EHF technology in Canada. A decision based on factors other than cost effectiveness would have to be made to have an EHF satellite serve such needs.

The capacity of an EHF satellite far exceeds present Canadian communication traffic needs. It is estimated that a single EHF satellite could, if capacity alone were considered, replace a number of lower frequency satellites. It must be remembered; however, that EHF would not provide adequate services to some areas, such as the extreme north, due to high attenuations associated with low elevation angles and narrow beamwidths. Also the cost of such a system would be significantly higher than that of present systems. In any scenario where the advantages of EHF could be put to best use the satellite would be relatively expensive compared to an ANIK or even a CTS type.

However, if the government were to build and launch an EHF communication satellite, it might open up new horizons and push the communications industry into drastic changes of perspective. The available capacity could open up new markets for new and presently unforeseen demands much in the same way as did the 14/12 GHz band on HERMES. It is expected that the satellite might be best used for the following services:

- military systems
- High Definition Television (HDTV)
- Spot beam point-to-point communications on high traffic routes.
- Transfer of high rate scientific data, e.g. Canadian Long Baseline Array (CLBA) or relay of RADARSAT raw data
- Emergency Planning
- Satellite to Satellite communications.
- Wide area data collection to a central point (a 4/6 to EHF link)

These services would be well suited to an EHF system, since they share common characteristics of high data rate, high spatial resolution and large bandwidth. An EHF capability might also stimulate cross border markets although politics will definitely be a factor here. There might be a possibility for a Canada - U.S. combined effort in EHF. An EHF satellite would provide far more capacity than Canadian needs, and the U.S. market (if it could be tapped) could be a catalyst for the establishment of one. However, the United States' plans for their own EHF system, the ACTS, are well under way.

The system architecture to satisfy Canadian needs would more usefully involve multiple spot beams and on-board switching. SS-TDMA would most likely be used. A potential solution would be to use a dual frequency band satellite with EHF spot beams covering the main centre and a global beam at C or Ku band to provide service to wide areas.

The need, if any, for such a satellite is most likley to occur in the 21st century. By the time Canadian need for EHF comes along, global EHF technologies will have come of age and components will be readily available at relatively low cost. If Canadian technology has to be used, availability of components will be doubtful unless development is started very soon.

8.2 REGULATORY POLICIES

The significance of govermental regulatory policies upon the Canadian Communications Industry cannot be over stated. In terms of the development of satellite systems, government policy decisions have been crucial to the inception, technological advance and traffic (and hence revenue) loading of present and planned satellite systems. The effect of deregulation, of course, depends upon the extent to which deregulation is applied. As can be seen from the recent decision to allow private reception of satellite signals, and of the acceptance by Telesat Canada of the practice of uplinking to a satellite from a source not controlled by Telesat, the previously strict regulation of satellite communications is being partially relaxed. While, it is not anticipated that the industry will ever become totally deregulated, it is not possible for the authors to anticipate the extent to which regulation will continue to be applied in the future.

The rationale and figures derived in the main body of the report assume that there will be no fundamental change in the regulatory conditions in force at the time of writing.

In order to evaluate the effects of deregulation, it was decided to investigate what fundamental changes in the market, as applicable to satellite communications, in general, and EHF systems, in particular, would take place if total deregulation were to occur. In this fashion, the reader will be able to understand the directions in which deregulation will direct the requirements for EHF in the extreme case.

In the author's opinion, the effects of total deregulation will be as follows:

1) The common carriers will move to load the terrestrial system to its maximum cost effective usage by off-loading their traffic from Telesat's satellite systems.

2) There will be a substantial push towards -

   a) Fibre optics systems for short haul traffic corridors and for local distribution.

   b) Capacity enhancing techniques to better utilize available bandwidth.

      e.g. Digital Speech Interpolation (DSI), and data packetization.

It is expected in such a scenario, Telesat would be forced to reduce its rates and/or expand the nature of its services within Canada and expand into the United States market or else it would have to maintain a substantial number of unused channels. In either case, the need for more capacity, especially capacity in the amounts as can be expected to be provided by an EHF system, will not be present. In the longer haul, Telesat may move to recover its competitive position by the launch of an EHF system in which vast capacity becomes available for the costs of a single launch. (Note that an EHF transponder is expected to provide bandwidth an order of magnitude greater than C or K band existing systems). However, the development of such a system to the operational level would take approximately seven to eight years from the time that the deregulated scenario is accepted. Delays of this kind lead the authors to assume that, even in the very unlikely event that total deregulation occured, any EHF system considered acceptable at that time would suffer a substantial delay until such time as the existing systems moved towards saturation, and from the results of this study services available at 6/4 and 14/12 will not saturate until after the year 2000.

From the above scenario, it can be seen that the effects of deregulation upon EHF will be to reduce the need for such a system, and hence, to delay its development.

9.0 CONCLUSIONS

In point form the conclusion of this study into EHF communications requirements and technology development are as follows:

- The U.S., Japan and Europe have experimental, operational, or military spacecraft carrying EHF payloads in orbit or on the drawing board.

- Canada's current plans include a military EHF transponder on M-SAT.

- The U.S. and Japan are developing a fairly wide technological base in EHF systems and components. Developments in Canadian companies are limited to a few relatively low technology devices.

- Most countries are adopting a parochial view in awarding contracts in new technological areas, like EHF. Unless Canadian companies, with government support, develop some unique or excellent capability there is little hope of significant foreign sales. Without a sizeable and continuing market Canadian industries are unlikely to invest the large sums of money needed for this development of EHF components and systems.

- Predictions were made for Commercial voice, data and video, military and scientific communications traffic that could logically be carried on satellites, up to the year 2000. These predictions were compared to the potentially available supply of satellite transporters.

- Comparison of the the traffic demand against the supply showed that there is no commercially driven demand for the EHF band.

- It must be remembered that old ideas are not necessarily static, new techniques in video compression, data packetization and interleaving of voice signals will enable the next generation of ANIK spacecraft to increase their effective per channel capacities.

- The Canadian military will need to develop an EHF communications capability to be interoperable with the systems now under development in the United States and NATO.

- The EHF band does have certain unique advantages, for example wide bandwidth, high data capacity, narrow beamwidth, and small (but expensive) ground terminals. These advantages make the EHF band suitable for applications such as:

    - military, coded or spread spectrum links
    - spot beam point to point (city to city) on high traffic routes
    - high data rate scientific applications, e.g., RADARSAT
    - emergency planning
    - satellite to satellite communications
    - wide area data collection (on C band) to a certain collection point (EHF).

Collectively these uses could well justify the development of a pure EHF spacecraft and ground system, similar to the HERMES program, or at least inclusion of an EHF payload on a future ANIK in a mission like ANIK B. If the government were to support such a development, Canadian industry would have the incentive for expenditure of the necessary time and resources.

A STUDY OF EHF COMMUNICATIONS REQUIREMENTS AND TECHNOLOGY DEVELOPMENT