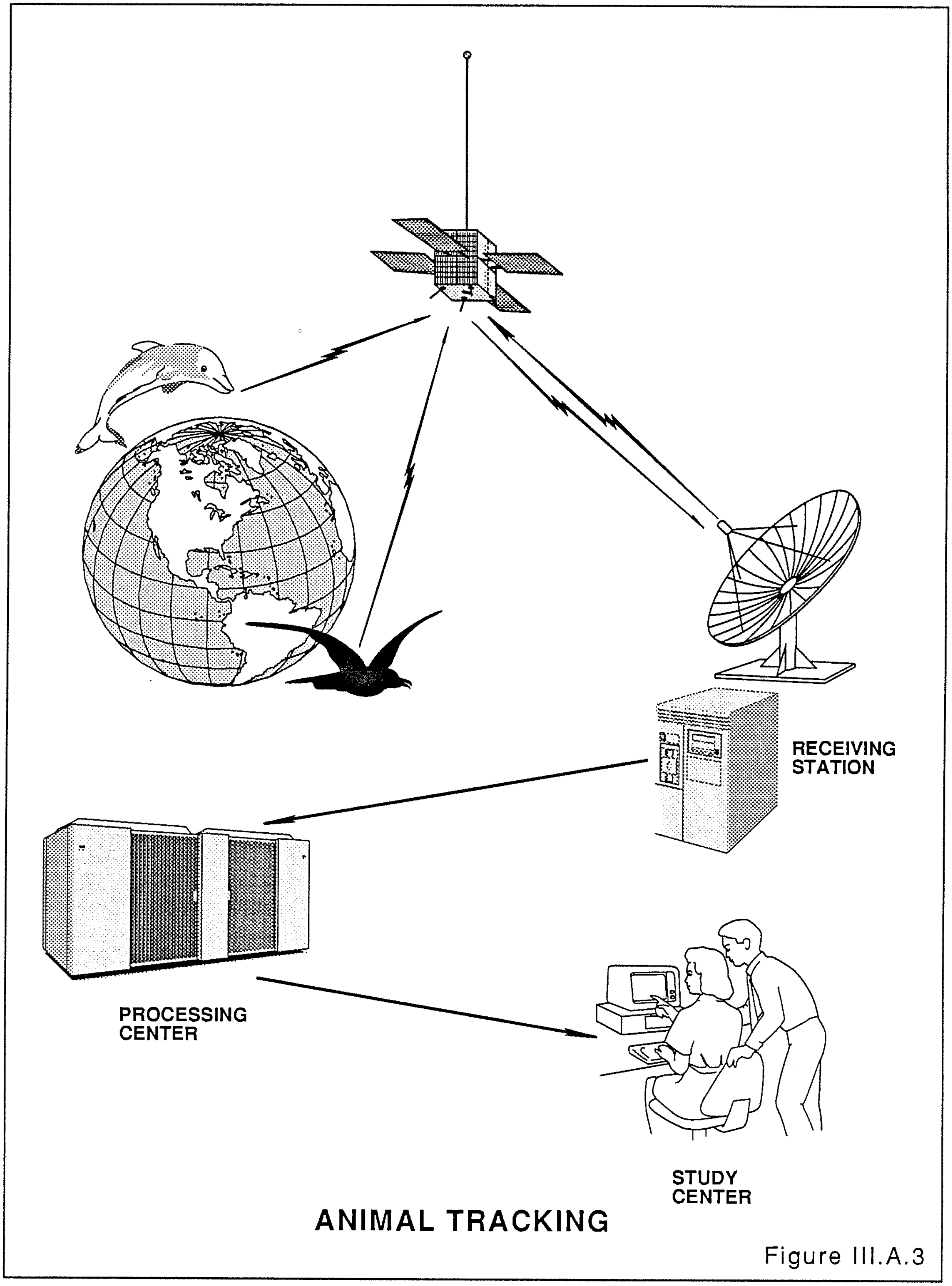


Figure III.A.3

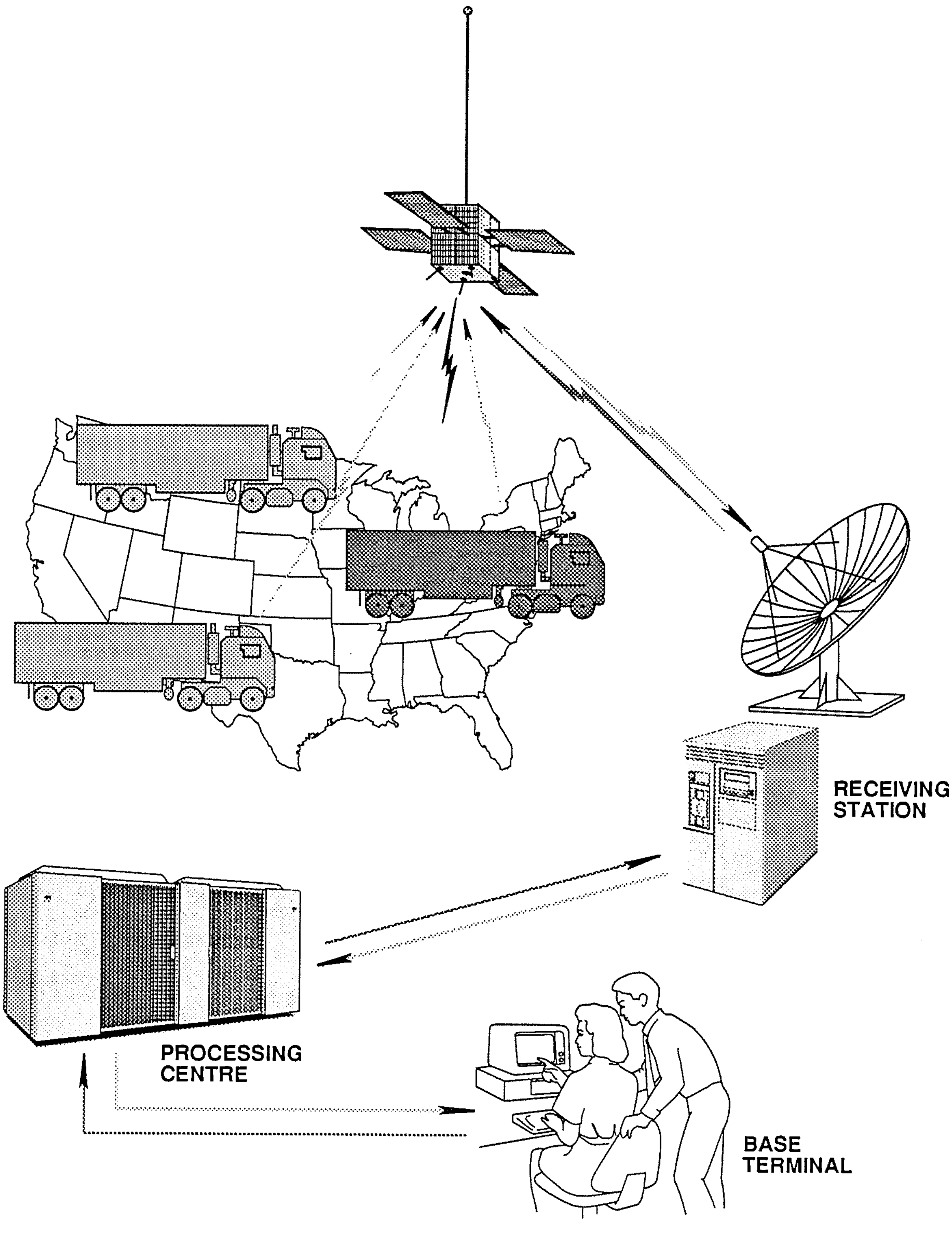
requirements. However, small outfits have a difficult time justifying the multi-thousand dollar expense of a geostationary satellite system. The STARNET system proposed herein can readily fill this niche as a "just-in-time" telecommunications technology for the smaller factories and transport firms in America (see Figure III.B.1).

It is important to recognize that STARNET is not competitive with the Geostar, Locstar, Qualcomm or Rockwell RDSS and LMSS systems. Products selling for $75 (STARNET) and $4000 (others) are geared to entirely different market segments. The geostationary systems are designed for regular, hourly use, with messages up to 24,000 characters (10 pages typed) long. STARSYS, Inc. is, however, directly competitive with Argos and Orbital Communications Corporation, both of which are targeted at low rate use and very inexpensive user terminals.

2. Impact of Mobile Communications on Transport

The impact of mobile communications on transport has been documented in numerous studies. Both Geostar and Qualcomm have reported publicly that transport users of their systems save enough money to recover the $4-5,000 user terminal cost in about one year. These savings include avoiding wasted time and fuel from making unnecessary trips, waiting at phone booths to check in with the dispatch center, and driver recruitment and retraining costs. Driver retraining is expensive in the transport sector because 100% employment turnover rates per year are common. Rather surprisingly, transport vehicles equipped with mobile communications have shown much lower driver turnover than the same class vehicles without two-way radio.

Research has also shown that regardless of the economic benefits of mobile communications systems, transport sector business managers will not spend much more than 5% of vehicle costs on telecommunications. This relatively low statistic may reflect the brief tenure of a vehicle in the typical transport sector fleet - often



FLEET MANAGEMENT

Figure III.B.1

less than three years and rarely more than five. In any event, a large market segment exists among small, low-end transport sector vehicles, such as those costing under $20,000. Geostationary satellite systems are not projected to reach $1,000 (5% of vehicle costs) even in their follow-on stages, implying an entirely separate market segment for LEO MSS systems such as STARNET. This serves the public interest by ensuring broad, democratic access by all strata of the transport sector to the benefits of mobile communications.

3. The Public Interest Is For The Public To Get The Most Cost-Effective Service, Not For Hardware Suppliers To Get A Protected Market

It is important to recognize that the public interest refers to the general public, and not to the business interests of any particular company or companies. Sometimes it is easy to confuse the definition of "who is the public." A time-honored guideline is that the more people that are benefiting, the more likely that the "public interest" is being served.

The STARNET system design is the most cost-effective design for LEO MSS that has ever been proposed. Furthermore, the extensive decade-long experience LEO operating experience of Applicant makes it much more likely that the proposed system will actually be implemented. Most unexperienced satellite applicants have ended up turning their licenses back in to the FCC. Finally, the private satellite operator regulatory structure requested by Applicant has been shown to produce the most market-responsive mix of telecommunications products and services. Hence it seems likely that the beneficiaries of STARNET will be a very broad and general public.

C. THE STARNET SYSTEM WILL FURTHER THE DEVELOPMENT OF A FREE AND OPEN GLOBAL MARKET IN TELECOMMUNICATIONS SERVICES

The STARNET system would be the world's first satellite system that is generally available worldwide. Furthermore, the private satellite regulatory structure applied for herein permits an unlimited array of possibilities for the "packaging" of LEO MSS service as part of other products or services. This same structure permits nearly all types of separate or interrelated national arrangements for the delivery of STARNET service to end users. As such, the STARNET system could make an historically unique contribution to the development of a free and open telecommunications services.

D. THE STARNET SYSTEM WILL PROVIDE AN INFRASTRUCTURE FOR GREATER GLOBAL ECONOMIC INTEGRATION

It is fundamental to our economic system that greater global economic integration is in the public interest. The reason for this is that the public then gets its "pick of the world" in obtaining the most cost-effective goods and services. Since the STARNET system is uniquely able to provide an integrated telecommunications link anywhere in the world, it is a key infrastructure system for the globe-circling enterprises of the 1990s and beyond.

1. As an Inherently Global System, STARNET will Help Multi-national Companies Integrate Their Operations

Recent studies have shown that multinationalism is the trend in modern business. Ever-increasing numbers of U.S. companies obtain more than 50% of their profits from overseas operations. STARNET will be extremely valuable to such firms since it enables employees or company property to be linked with a simple, ultra-low-cost radio, regardless of location, anywhere in the world. This unique capability of STARNET is in the public interest by providing multi-national companies with a basic business productivity tool that is not otherwise available today.

2. As the Volume of Global Shipping Increases, the World Needs More Communications Technology

The level of communications equipment adequate for a lower level of global transport activity is not going to be sufficient as that volume rises significantly year after year. Although the volume of international shipping has more than doubled during the past ten years, Inmarsat has remained the only source of globally operable mobile communications technology. Even with Inmarsat, "globally operable" has generally referred only to marine areas, and only with extremely expensive user equipment. The public interest will benefit from the introduction of a new, low-cost, globally operable mobile communications system.

E. THE STARNET SYSTEM IS AN EXTRAORDINARILY EFFICIENT USER OF THE FREQUENCY SPECTRUM

Efficiency of frequency spectrum utilization is a very important measure of service to the public interest. With the useful radio bands so limited and congested, any non-efficient use should be — and traditionally have been — discouraged. See, e.g., Licensing of Space Stations in the Domestic Fixed-Satellite Service, 54 R.R.2d 577 (1983) ("Reduced Orbital Spacing"), recon. in part 57 R.R.2d 653 (1985). By this yardstick, the STARNET system represents one of the most efficient uses of the electromagnetic spectrum that has ever been proposed to the Commission. Its ratio of potential users to hertz of spectrum is much greater than one. For example:

SPECTRUM EFFICIENCY = CAPACITY FOR USERS

HERTZ OF SPECTRUM

SPECTRUM USER	**SPECTRUM EFFICIENCY RATIO**
LEO MSS	40 Million Terminals/2 Million Hertz = 20
BROADCASTING	250 Million TV Sets/66 Million VHF Hertz = 4
CELLULAR	20 Million Phones/78 Million UHF Hertz = 0.25
AMSC	1.5 Million Users/30 Million L-Band Hertz - 0.05

As the above table indicates, the public interest in spectrum efficiency should certainly favor STARNET by comparison with other familiar radio systems.

F. THE STARNET SYSTEM'S PRIVATE SATELLITE OPERATOR STRUCTURE WILL ENHANCE COMPETITIVENESS AND MARKET RESPONSIVENESS IN THE MOBILE COMMUNICATIONS BUSINESS SECTOR

The public interest is clearly served when the incentives for competition and market responsiveness are present. The private non-common carrier structure proposed herein will enable a maximum amount of market responsiveness within LEO MSS capabilities. Since the entire capacity of the STARNET system will be sold to organizations which operate directly in STARSYS, Inc. markets, such capacity will be delivered to the end-users by those firms most in tune with market requirements. For example, Applicant believes that automobile manufacturers will be a primary STARNET bulk capacity purchaser for the LEO MSS automotive market.

The promotion of competition is fundamental to United States telecommunications policy. The Commission has taken numerous actions to introduce competition in the provision of international and domestic communications services. The multiple public interest benefits most frequently touted by the Commission, as well as the courts, include: improving service and enhancing the economic and efficient provision of communications services, providing users with increased choice (and thereby fostering the provision of technically superior service to customers), enhancing the efficient use of facilities, producing downward pressure on costs and rates for specific services, and encouraging more equipment manufacturers to enter the market. See, e.g., FCC v. RCA, 346 U.S. 86, 96 (1952); Domestic Communication Satellite Facilities, 22 F.C.C.2d 86 (1970); 35 F.C.C.2d 844, recon. in part, 38 F.C.C.2d 665 (1972); Domestic Fixed-Satellite Transponder Sales, 90 F.C.C.2d 1238 (1982), aff'd sub nom. Wold Communications, Inc. v. FCC, 735 F.2d 1465 (D.C. Cir. 1984); Establishment of Satellite Systems Providing International Communications, 101 F.C.C.2d 1046 (1985).

Experience has repeatedly shown that when operators are freed to price and package services with a minimum of regulatory restraint, in a market as competitive as the mobile satellite communications market promises to be, there is almost no limit to the variety of services and offerings that can and will be made available. Applicant believes that with its private, non-common carrier structure, it is uniquely positioned to maximize the public interest benefits that are attainable with the multi-market technologies that are embodied within and represented by its STARNET system.

PART IV

THE STARNET SYSTEM COMPLIES WITH DOMESTIC AND INTERNATIONAL LEGAL REQUIREMENTS

The STARNET system is designed to comply with all domestic and international legal requirements. In particular, domestic satellite and FCC policies are supportive of the regulatory approvals requested herein. Also, international treaty obligations are consistent with the service capabilities Applicant proposes to offer.

A. STARCOM'S CONTEMPLATED PRIVATE SATELLITE OPERATOR STRUCTURE IS FULLY CONSISTENT WITH THE COMMISSION'S TRANSPONDER SALES DECISIONS

Applicant's proposal to sell the capacity of its LEO MSS satellite system to users on a non-common carrier basis, in the manner described above, is fully consistent with Commission precedent, and will serve the public interest, convenience, and necessity. The first applications for authority to sell satellite capacity were granted by the Commission in 1982 to satellite operators in the domestic fixed-satellite service. Domestic Fixed-Satellite Transponder Sales, 90 F.C.C.2d 1238 (1982) ("Transponder Sales"), aff'd sub nom. Wold Communications, Inc. v. FCC, 735 F.2d 1465 (D.C. Cir. 1984).

Noting that "it is desirable to permit closer planning between the [satellite] operator and its customers[,]" the Commission stated that the transponder sales transactions would serve the public interest by, inter alia, providing sellers and prospective entrants with an alternative means of securing the large amounts of capital necessary to construct satellite facilities; by providing a device to share the risks peculiar to satellite technology; and a gauge by which to predict with some precision the demand for more efficient orbital and frequency spectrum usage by providing sellers with the ability to design satellite systems to meet particular user needs. Transponder Sales, 90 F.C.C.2d at 1251-52. It concluded by finding that "the certification of non-common carrier domsat systems is consistent with our policies fostering multiple satellite entry." Id. at 1255.

In subsequent transponder sales decisions, the Commission approved satellite operators' applications for authority to sell a satellite's entire complement of transponders to a single purchaser, and for authority to enter into a long-term transponder lease with an alien corporation. The Commission also applied the public interest rationale for domestic transponder sales, without caveat, to the proposals of international satellite system customers. See Hughes Communications, Inc., 94 F.C.C.2d 866 (1983) (Commission authorizes SBS to lease 5 transponders on the SBS III to British company; Section 310 foreign ownership requirements ruled inapplicable to non-licensee); Establishment of Satellite Systems Providing International Communications, supra, 101 F.C.C.2d at 1082.

Applicant's proposal to sell its STARNET system space segment capacity is fully consistent with the Commission decisions summarized above. Although the sales contemplated by Applicant will not technically be "transponder sales" due to the configuration of the LEO MSS system, but will instead be capacity sales in "Million Transmission" units, the bulk sale features of the proposal are identical in all salient respects to the features of the transponder sales proposals the Commission has approved in the past.

In addition, the private sales program envisioned by Applicant for its STARNET system will engender all of the public interest benefits to be realized by transponder sales. Such sales will permit Applicant to make tailored and flexible arrangements with its customers that are not possible under the regimen of a tariffed service offering; they will enable STARNET customers to make long-term plans for the use of the system with assurance as to the continued availability of the facilities and stability of price; transceivers and other system components will be able to be customized to meet idiosyncratic customer needs; and the direct and continuing contact between Applicant and its customers will stimulate the development of new and innovative service offerings. See Establishment of Satellite Systems Providing International

Communications, supra, 101 F.C.C.2d at 1082.

In short, Applicant, by requesting authority to offer its STARNET system capacity on a private, non-common carrier basis; by stating its intention to offer for sale all of the capacity on its system; and by stating outright that it is not and will not indiscriminately hold itself out to serve the user public within the parameters of the NARUC I decision, National Association of Regulatory Utility Commissioners v. FCC, 525 F.2d 620 (D.C. Cir.), cert. denied, 425 U.S. 992 (1976), has now made all of the showings required of applicants for satellite systems' space segment capacity on a non-common carrier basis. See Martin Marietta Communications System, Inc., 60 R.R.2d 779 (1986).

For all of these reasons, the Commission should, when it grants these applications, grant Applicant the authority necessary to allow it to sell the STARNET system capacity as proposed herein.

B. FCC ASSISTANCE IS REQUESTED TO OBTAIN FREQUENCY ALLOCATION AMENDMENTS AT THE 1992 WARC

The frequency bands requested by Applicant are allocated by the International Telecommunication Union for satellite services. However, the allocation does not specifically contemplate the generalized mobile satellite services proposed in this Application. Accordingly, Applicant requests the assistance of the FCC in amending the allocation table restrictions at the upcoming 1992 World Administrative Radio Conference (WARC). Specifically, Applicant requests FCC support to include Mobile Satellite Service (Low Earth Orbit) in the 137-138 MHz and 148-149 MHz bands.

PART V

FREQUENCY AND ORBITAL JUSTIFICATIONS

A. FREQUENCY BANDS

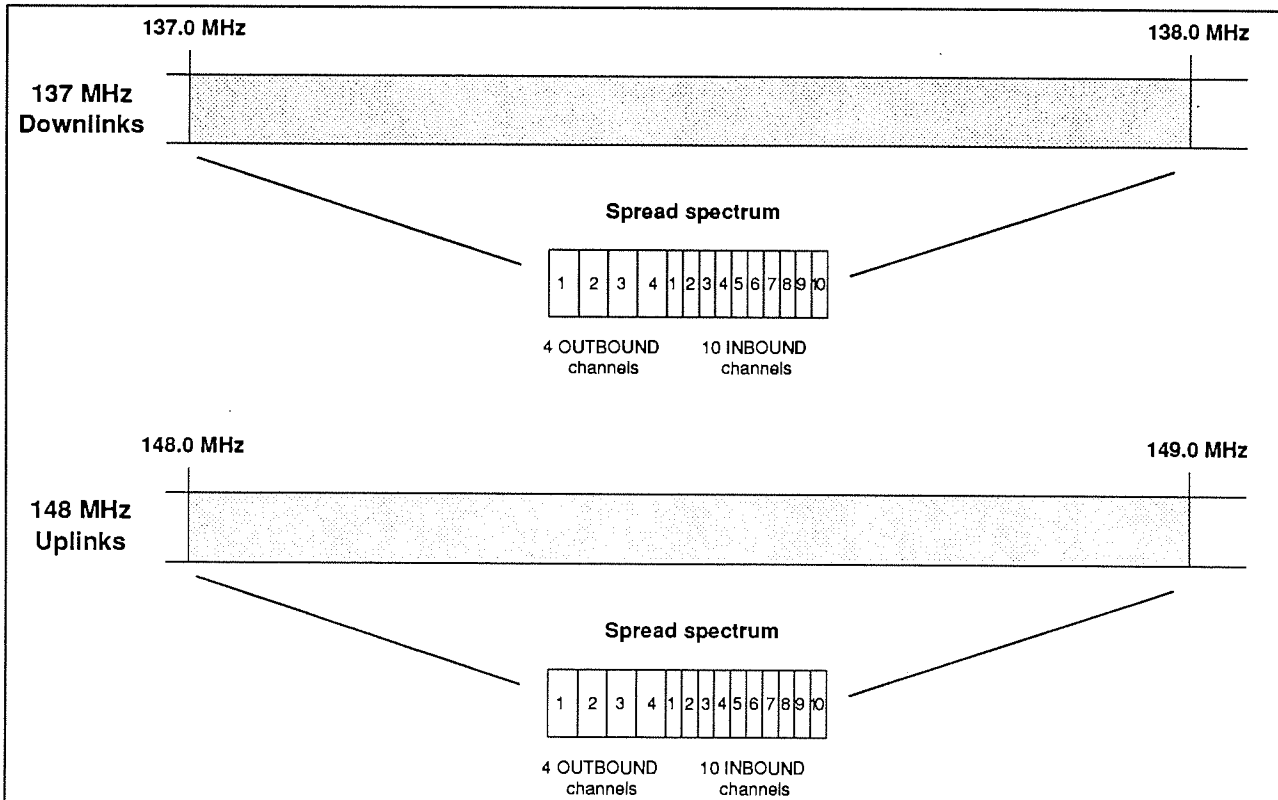
The complete frequency plan is discussed in Part VII-A.

1. SPECTRUM ALLOCATION

STARSYS, Inc. is requesting authorization to operate on a Modified Primary Basis in the U.S. on the following VHF bands:

Nominally using spread spectrum techniques (solution A)

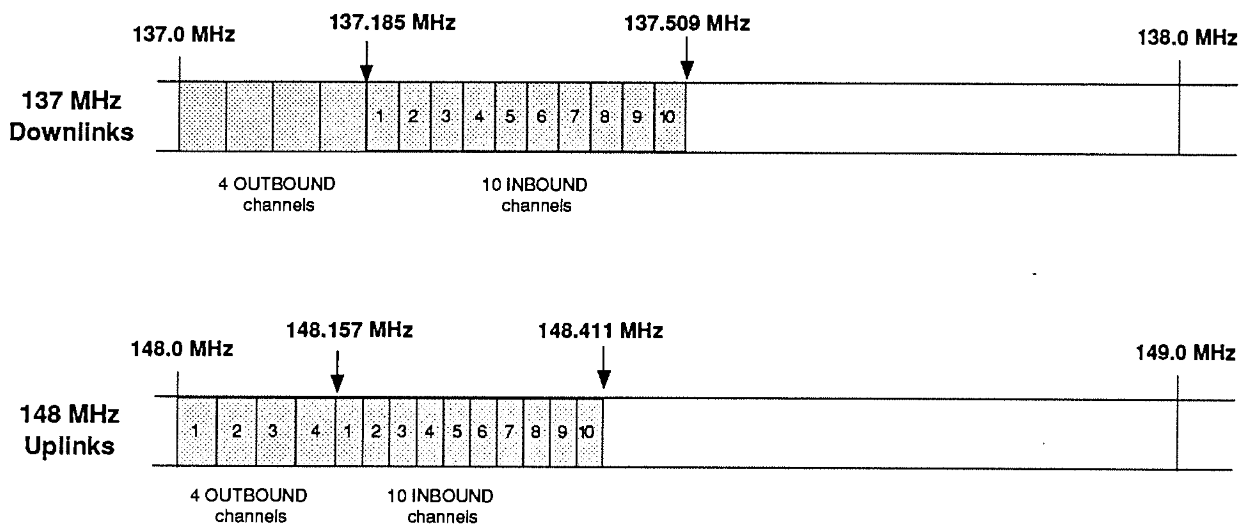
Earth to space (uplink)	148	to	149.0 MHz
Space to earth (downlink)	137	to	138.0 MHz



Base line STARNET spectrum proposal (solution A)

Or, alternatively, without using spread spectrum techniques (solution B)

Earth to space (uplink)	148	to	148.411 MHz
Space to earth (uplink)	137	to	137.509 MHz



Base line STARNET spectrum proposal (solution B)

The "Modified Primary" basis is such that the proposed system will not cause interference to presently authorized users in the same band and would be granted Primary Status against any new services.

B. ORBITAL PLANES

System coverage is detailed in Part VII - A.4 Orbital Network Coverage Network (see Figure V.B).

The Basic Orbital characteristics:

- LEO satellites at 1300 km (700 nmi) orbit altitude to provide a wide real-time coverage and the possibility of a world-wide service;

- 60° orbit inclination angle, optimized for the North American continent and still able to cover the polar zones;

- Randomly distributed orbital planes and non phased orbits to decrease spacecraft cost (no orbit control), as well as operational costs;

- Permanent coverage of the North American continent with a less than two minutes off-view time with the full system deployed.

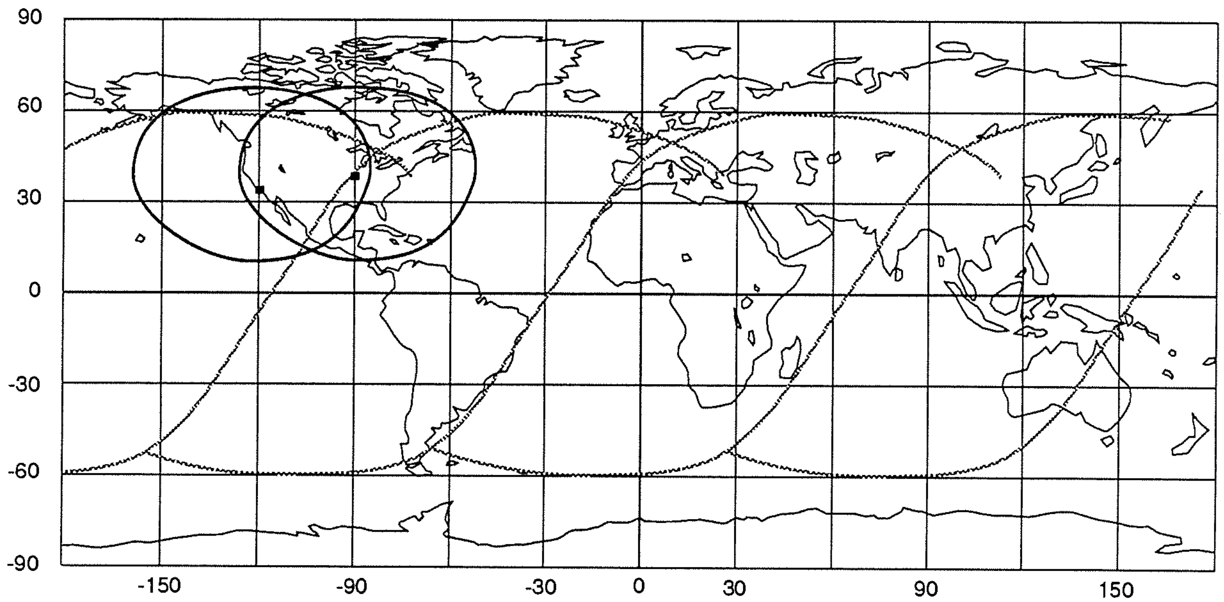


Figure V.B

PART VI

LEGAL AND FINANCIAL QUALIFICATIONS

Applicant demonstrates within this Application its full legal and financial qualifications to hold an FCC license for LEO MSS.

A. APPLICANT IS LEGALLY QUALIFIED TO BE A COMMISSION LICENSEE

STARSYS, Inc., the Applicant, is a newly-established Delaware Corporation whose primary purpose is to build, launch and operate a low earth orbit mobile satellite system to serve the U.S. public interest, including compliance with the requirements of the Communications Act of 1934. STARSYS, Inc. came into being from the experience its affiliate-corporations have gained in the past decade in operating low earth orbit mobile satellites. In particular, CLS, a French corporation, and its American affiliates, NACLS and Service Argos, have been the domestic and global leaders in developing this technology for scientific applications.

In deciding to bring to the American public the expertise these companies have developed, much care has been taken to structure STARSYS, Inc., so as to make use of the decade-long experience of its affiliates, and yet comform to the requirements of Section 310 of the Communications Act of 1934. Accordingly, STARSYS, Inc., will be led and controlled by U.S. citizens. By its Articles of Incorporation and its By-laws, the majority of STARSYS, Inc.'s Directors will be elected U.S. citizens. A majority of the members of its Board of Directors will always be U.S. citizens and independent of affiliate corporations. Appendix 6 to this Application contains the Articles of Incorporation for STARSYS, Inc.

FCC Form 430, Appendix 1 hereto, provides all the information necessary to demonstrate that Applicant is legally qualified to be authorized by the Commission to construct the STARNET system. Insofar as Applicant will be authorized as a private satellite operator (non-common carrier), Section 310(b) of the Communications Act is inapplicable to its proposal. Accordingly, pursuant to the Commission's decision in Establishment of Satellite Systems Providing International Communications, supra. 101 F.C.C.2d at 1164, Applicant has not responded to those questions on FCC Form 430 requesting information required by Section 310(b). Applicant, however, will supply any such information that the Commission deems necessary.

Individual applications for the spacecraft that comprise Applicant's STARNET system are included in Appendix hereto.

B. APPLICANT IS FINANCIALLY QUALIFIED TO BE A COMMISSION LICENSEE

Applicant has carefully studied the capital costs, operating expenses, revenue requirements and sources of funds for its proposed STARNET system. These financial parameters are summarized below. Appendices 3 and 4 demonstrate Applicant's affiliate's qualifications as the operator, for eleven years, of the sophisticated ARGOS LEO MSS system, with over 13,000 user terminals registered and many millions of dollars of system investment and market development. Shareholders of Applicant's affiliates include some of the largest banks in the world.

1. Capital Investment Costs

SEGMENT	UNIT COST	NUMBER	TOTAL COST	COMMENTS
Space	$4M	26 Sats	$104M	112 kg (247 lbs) Per Satellite*
Space	$3M	24	$72M	24 Launches
Space	$0.3M	24 Ins. Pr.	$8M	10-15% Rates
Control	$4M	2 PACC	$8M	Primary/Back-Up
Control	$1M	2 Regional	$2M	US Network
User	$3M	1 Time NRE	$3M	R&D; Tooling
	TOTAL		$197M**	

Launches shall occur at the rate of three satellites per quarter, commencing 40 months following FCC approval, until 24 satellites have been launched 64 months following authorization.

**Expenditures are at the rate of 10% Year 1 (year of FCC approval), 20% Year 2, 20%, Year 3, 20%, Year 4, 20%, Year 5, 10% Year 6.

The capital costs of Applicant's proposed STARNET system consist of space segment, control segment and user equipment development expenditures. The sum of these expenditures has been projected to be approximately $197 million.

2. Operating Expenses

Operating expenses for the STARNET system consist of payroll, general, and administrative expenses associated with maintaining the satellite network with maximum reliability. The historical experience of Applicant is such that costs are approximately 10% of system capital expenses per year, or an estimated $2.0 million per month for the STARNET system. Applicant anticipates a payroll of nearly 100 persons, and nearly 35,000 square feet of leasehold space. Applicant has determined that this $2.0 million per month budget will sufficiently cover all operating expenses with a reasonable contingency reserve as well.

3. Projected Revenue Requirements

Applicant's revenue requirements are calculated as its investment in the space and control segment, depreciated over five years, plus its annual operating expense budget. Additional variable expenses do not exist because Applicant intends to sell all of its capacity to end-market organizations, and its operating expense budget is sized to fifth year requirements.

Dividing Applicant's $197 Million capital outlay budget by its five year life before satellite replacement begins, yields a figure of $39 Million per year in revenue requirements to cover capital expenditures. In addition, $24 Million per year in operating expenses are forecast. Hence, total revenue requirements are $63 Million per year.

4. Source of Funds

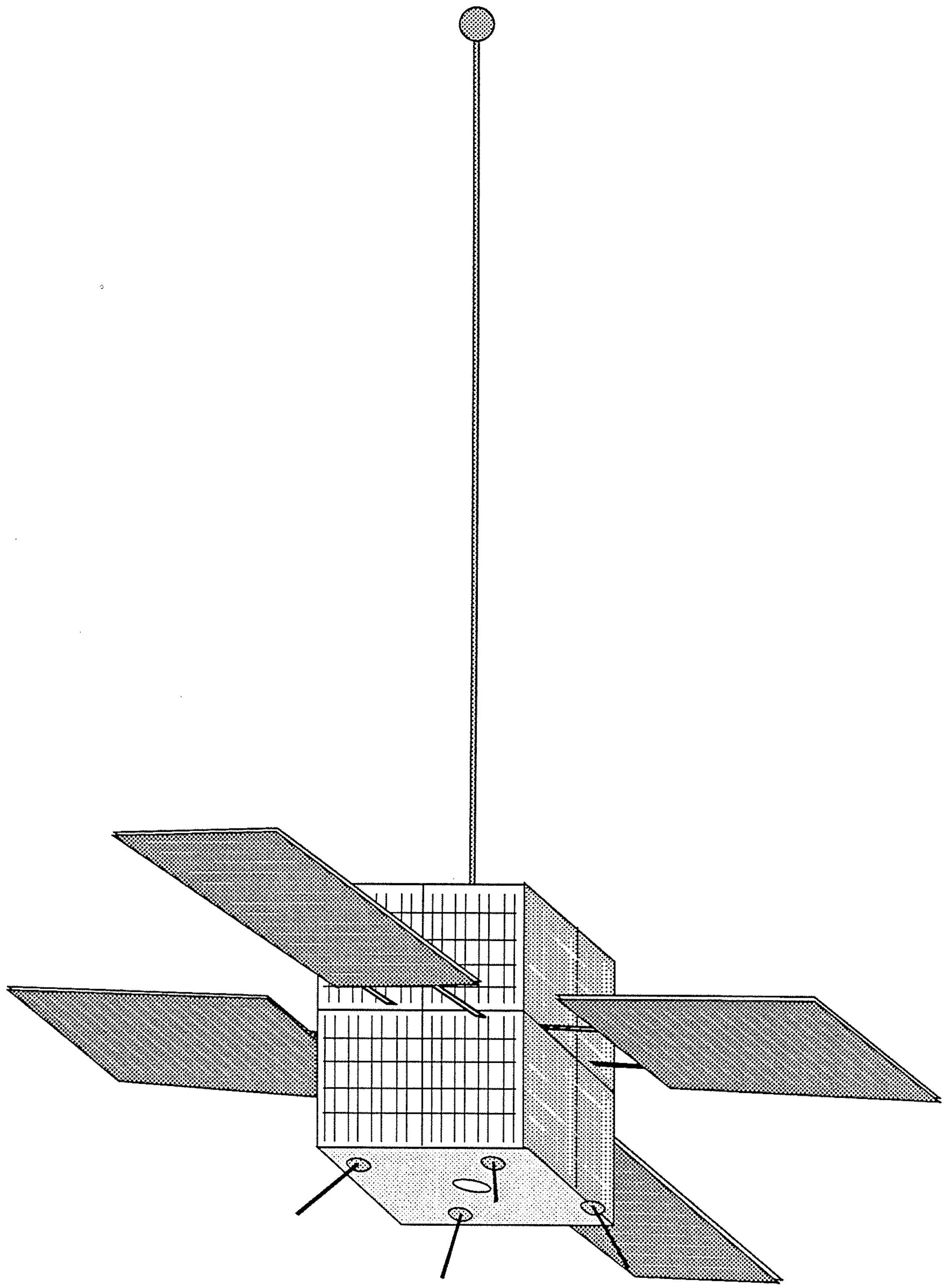
Applicant will obtain its revenue requirement funds by pre-selling its STARNET capacity in individually-negotiated transactions to major customer organizations such as automobile manufacturers, environmental technology firms, recreational electronics companies, and mobile communications suppliers. At an average price of $1 Million per 1 Million Transmission (MT) Units of capacity, Applicant's revenue requirements will be funded at 57% of its 100 MT units of annual capacity. This is reasonably within the breakeven experience of most other satellite service companies.

The funds for Applicant's capital expenditures will come from public and private capital markets, including the major sources of equity, debt and project financing. Applicant believes it will have no problem obtaining the necessary capital in light of its affiliates' 11-year history of balanced LEO MSS operations.

At this juncture, it is prudent for Applicant to note that it is applying for authority to construct a satellite system that will operate in spectrum that has yet to be allocated, and for which application standards — including the standard that will be employed to gauge an applicant's financial qualifications — remain unannounced. Past precedent would indicate that the Commission will most likely require applicants to show that they possess the current financial ability to meet the costs of construction and launch, and operating expenses for one year after launch, either before the construction permit is granted or at some specified point thereafter. See Establishment of Satellite Systems Providing International Communications, supra, 101 F.C.C.2d at 1165; Amendment to the Commission's Rules to Allocate Spectrum for, and to Establish Other Rules and Policies Pertaining to, a Radiodetermination Satellite Service, 104 F.C.C.2d 650 (1986). Until such time as a standard is adopted, however, Applicant cannot know with any certainty what guidelines the Commission will adopt.

See Aeronautical Radio, Inc., 4 FCC Rcd 6067, 6069 (1989) (construction permit applicant in service for which Commission had yet to adopt financial standard should not have been dismissed for failing to comply with an as-yet unadopted financial standard).

Here, Applicant has supplied the Commission with the estimated costs of the proposed construction and launch of its STARCOM system (along with other initial expenses for the proposed space station); estimated operating costs for one year after launch of the STARCOM system; and stated the potential sources of funding for its proposed system. While Applicant believes that such a showing would satisfy the "first-stage" showing required of separate international satellite system applicants, and warrant a finding that Applicant is qualified to receive a conditional construction permit, Applicant stands prepared to comply with whatever financial qualifications standard the Commission deems appropriate for application for this new and unproven, but extremely promising, new service.



PART VII

TECHNICAL SYSTEM DESCRIPTION AND QUALIFICATIONS

A. SYSTEM DESCRIPTION AND PERFORMANCE

1. Communications Paths

The following describes the communication paths between the three (3) basic system components:

- User terminals,
- Spacecraft payload,
- Ground station.

Transmission from the user terminals to the ground station through the spacecraft payload segment is called the "INBOUND link".

Transmission from the ground station to the user terminals is called the "OUTBOUND link".

The communication path starts with the OUTBOUND interrogation transmissions. These OUTBOUND transmissions provide time synchronization and query of each addressed user terminal to see if it requires a position determination or data.

The addressed user terminal, in synchronization with the OUTBOUND received channel and a pre-determined acknowledgement protocol, responds through an INBOUND channel to the ground station.

The world coverage of the system allows the choice of two (2) possibilities :

- Several regional determination/communication systems (CONUS, South America, Europe...),

- World-wide coverage determination/communication system.

  Differences between the two options are in the capability of the space segment.

The regional determination/communication system is a non-regenerative payload using repeaters on the VHF 137 MHz and 148 MHz links.

The system described hereafter is the regional coverage system. The INBOUND and OUTBOUND links are the same in the two options.

2. System Description

At VHF frequencies, there are a number of users who could interfere with the STARNET system. Presently, Applicant proposes two quite similar solutions differing by the type of modulation.

In order to limit interference between STARNET and existing systems, STARNET will nominally use pseudo-noise (PN) spread spectrum techniques to spread the energy of the communication channels :

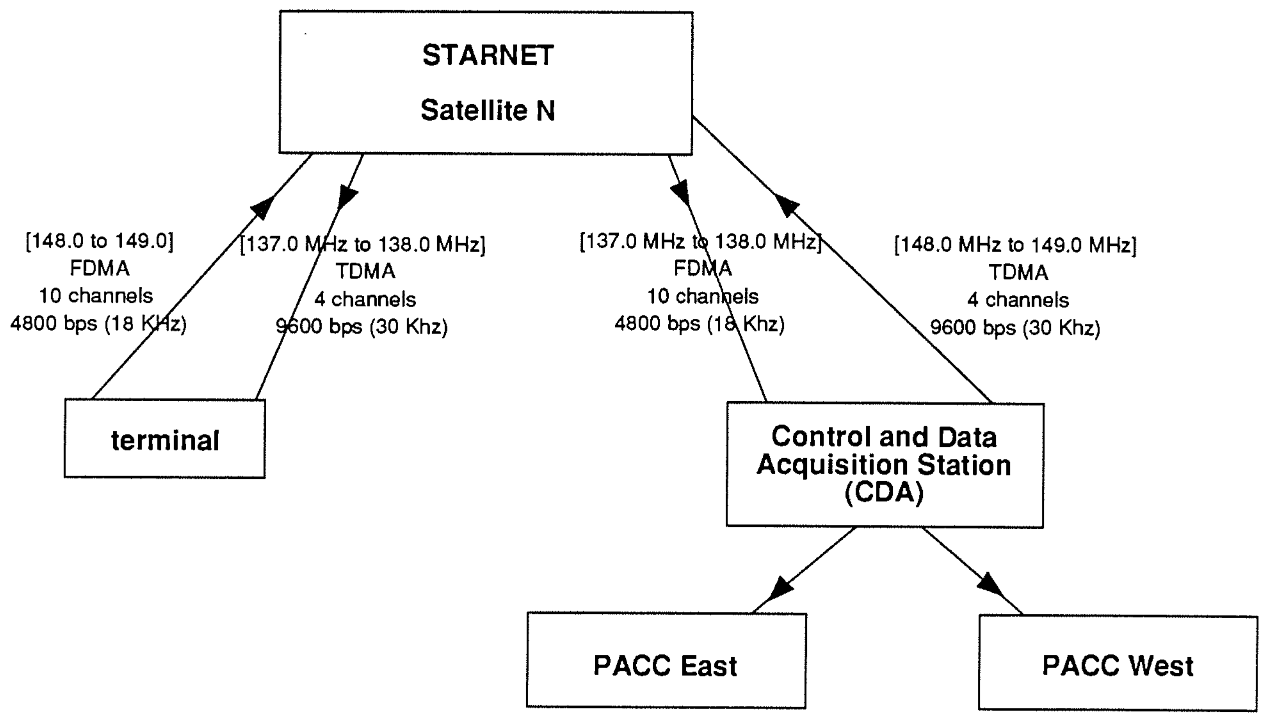
- in 1 MHz for the uplink channels (148 - 149 MHz),
- in 1 MHz for the downlink channels (137 - 138 MHz).

Note: The two following solutions have similar link budget and capacity. Link budget and capacity have been calculated for solution B.

2.1 Solution A

OUTBOUND and INBOUND links are spread to 1 MHz using the uplink (148 - 149 MHz) and downlink (137 - 138 MHz) VHF. Solution A organization with 10 INBOUND channels and 4 OUTBOUND channels also used in solution B.

Applicant is requesting for solution A authorization to operate on a modified primary basis in the US on the VHF bands between 148.0 and 149.0 MHz (uplink) and 137.0 and 138.0 MHz (downlink).



General Diagram
INBOUND OUTBOUND Links Solution A

Figure VII.A.2.1

2.1.1 Channel Bandwidth Requirements:

Inbound channels:

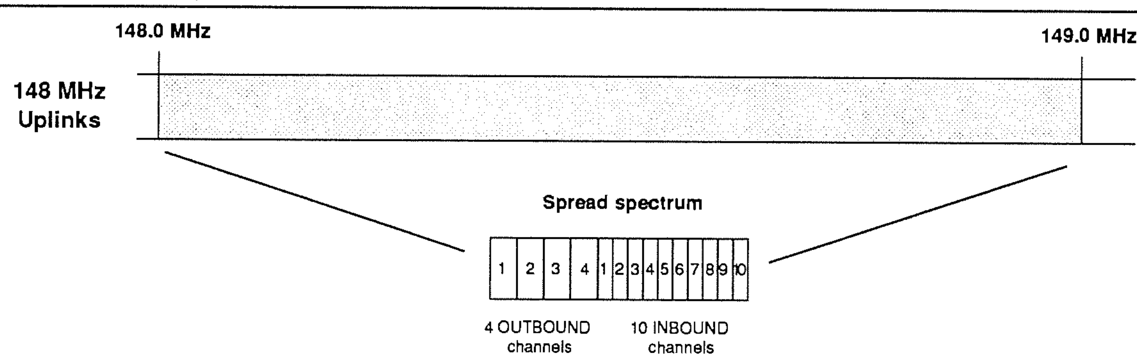
• Bit rate	:	4 800 bps
• Communication bandwidth	:	14 400 Hz
• Frequency error	:	3 000 Hz
		————————
		17 400 Hz
Channel bandwidth	:	18 kHz

Outbound channels:

• Bit rate	:	9 600 bps
• Communication bandwidth	:	28 800 Hz
• Frequency error	:	300 Hz
		————————
		29 100 Hz
Channel bandwidth	:	30 kHz

2.1.2 Uplink

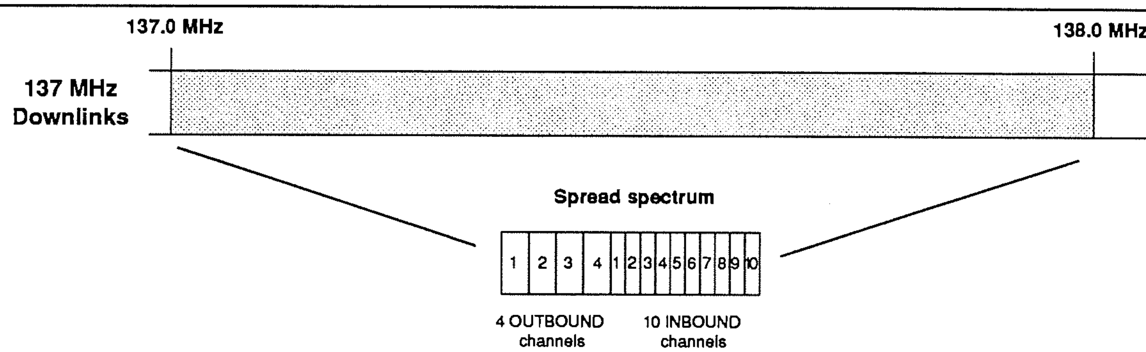
The spectrum assignment for the (148.0 - 149 MHz) uplink is shown below.



Base line STARNET spectrum proposal (solution A)

2.1.3 Downlink

The spectrum assignment for the (137 - 138 MHz) downlink is shown below :



Base line STARNET spectrum proposal (solution A)

2.2 Solution B (see Figure VII.A.2.2)

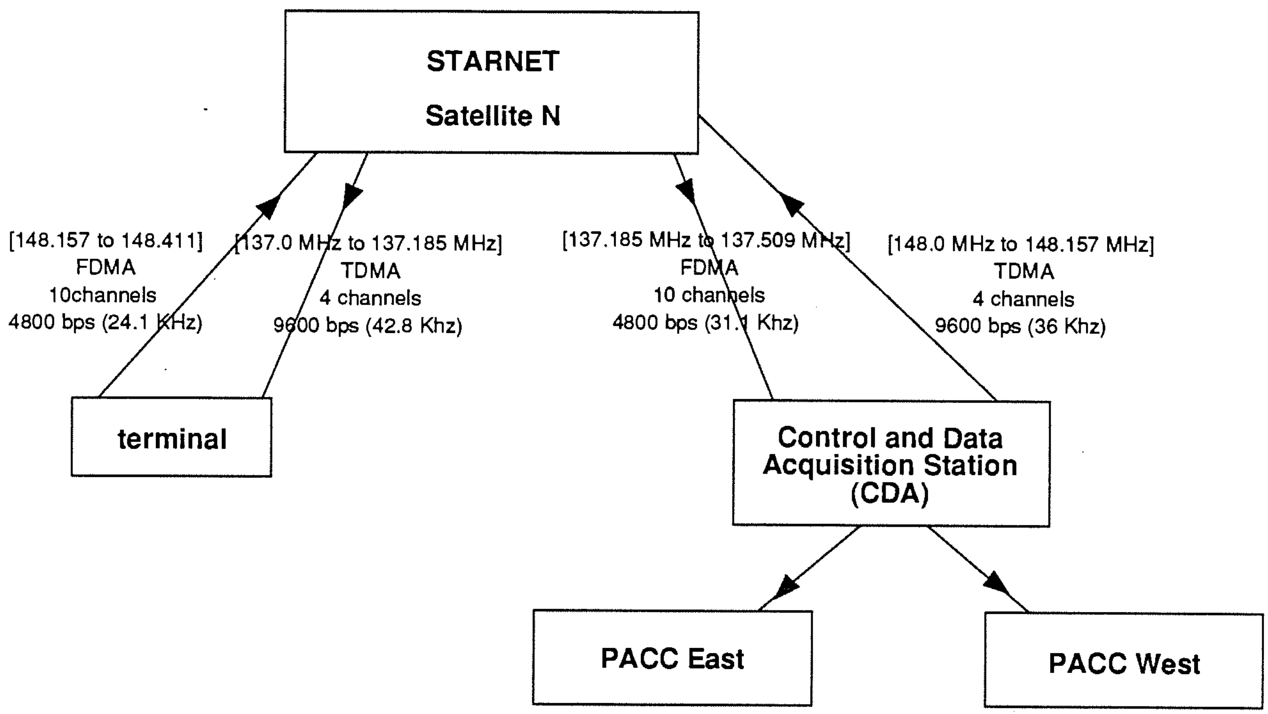
2.2.1 Outbound Link

Data in the OUTBOUND link, FFSK modulated, is structured in frames. Each frame is time logged, has a frame number, contains data and serves as a time epoch t_0 for response from the user's terminals.

Applicant is requesting authorization to operate on a modified primary basis in the US on the VHF bands between 148.0 and 148.385 MHz (uplink), and between 137.0 and 137.509 MHz (downlink). In order to increase the capacity of the system and to comply with the CCIR recommendations, the **OUTBOUND link will use four (4) different TDMA OUTBOUND channels** (9600 bps each).

Frequency bands used for the four OUTBOUND channels are :

- 148.0 -> 148.157 MHz (uplink between ground station and satellite),
- 137.0 -> 137.185 MHz (downlink between satellite and user's terminals).



General Diagram
INBOUND OUTBOUND Links Solution B

Figure VII.A.2.2

2.2.1.1 Outbound channels bandwidth requirements:

Outbound uplink channels characteristics (ground station -> satellite)

Total bandwidth used by the 4 channels:

- 148.0 MHz -> 148.157 MHz
  (13 KHz guard band)

• Bit rate	:	9600 bps
• Communication bandwidth	:	28 800 Hz
• Doppler shift	:	6 700 Hz
• Frequency error	:	300 Hz
		35 800 Hz

Outbound downlink channels characteristics (satellite -> user terminals)

Total bandwidth used by the 4 channels:

- 137.0 MHz -> 137.185 MHz
  (with 13.8 KHz guard band)

• Bit rate	:	9600 bps
• Communication bandwidth	:	28 800 Hz
• Doppler shift	:	13 000 Hz
• Frequency error	:	1 000 Hz
		42 800 Hz

2.2.1.2 Outbound link budgets (see Figure VII A.2.2.1)

Outbound uplink channels analysis (ground station -> satellite) :

- Ground station transmitting/channel : 12 dBW
- Ground station transmitter losses : -0.7 dB

- G/T : +16 dBi
- Max range (3500 km) : -146.6 dB
- G/T at 5° elevation angle : +5 dBi
- Satellite receiver loss : -2.5 dB
- Polarization loss : -3 dB
- To receiver : -201 dBW/Hz
- 9600 bps : 39.82 dBHz
- C/No : 80.20 dBHz
- Eb/No : +4.5 dB
- Uplink margin : > 30 dB

Outbound downlink channels analysis (satellite -> users terminals):

- Satellite transmitting/channel : 9 dBW (7.95 watts)
- Satellite transmitter loss : -0.7 dB
- G/T at 60° off-axis : +4 dBi
- Max range (3500 km) : -145.93 dB
- G/T at 5° elev. angle : +2.5 dB
- Terminal receiver loss : -2.5 dB
- Polarization loss : -3 dB
- To receiver : -200 dBW/Hz
- 9600 bps : 39.83 dBHz
- Eb/No with coding : +2.5 dB
- Downlink margin : +3 dB
- Power flux density at the ground : -141.50 $dBW/m^2/4$ kHz ($dBW/m^2/4$ kHz) (1300 km)

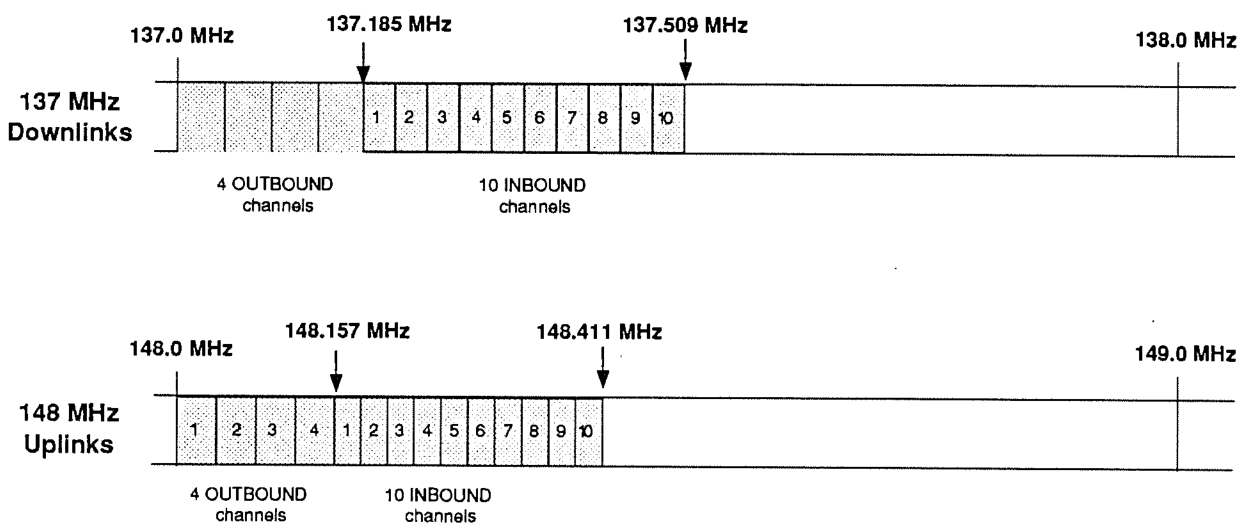
2.2.2 Inbound Link

User terminal data in the INBOUND link modulated FFSK is transmitted by short bursts (100 characters maximum) in synchronization with the received OUTBOUND link. Each response employs a frame structure including a synchronization preamble, an acquisition segment and data.

INBOUND link will be done on 10 different FDMA INBOUND channels (4800 bps each).

Frequency bands used for the ten INBOUND channels are :

- 148.157 MHz -> 148.411 MHz (uplink between terminals and satellite),
- 137.185 MHz -> 137.509 MHz (downlink between satellite and ground station).



Base line STARCOM spectrum proposal (solution B)

2.2.2.1 Inbound channels bandwidth requirements:

Inbound uplink channels characteristics (user's terminal -> satellite)
Total bandwidth used by the 10 channels:

- 148.157 MHz -> 148.411 MHz
  (with 13 KHz guard band)

• Bit rate	:	4800 bps
• Communication bandwidth	:	14 400 Hz
• Doppler shift	:	6 700 Hz
• Frequency error	:	3 000 Hz
		24 100 Hz

Inbound downlink channels characteristics (satellite -> ground station)
Total bandwidth used by the 10 channels :

- 137.185 MHz -> 137.509 MHz
  (with 13 KHz guard band)

• Bit rate	:	4800 bps
• Communication bandwidth	:	14 400 Hz
• Doppler shift	:	13 000 Hz
• Frequency error	:	3 700 Hz
		31 100 Hz

2.2.2.2 Inbound link budget:

Inbound uplink channels analysis (terminal -> satellite) :

- 148.157 MHz -> 148.411 MHz

• Ground terminal	:	0 dBW(1.0 watt)
• Terminal transmission loss	:	-0.7 dB
• G/T at 5° elevation angle	:	+3 dBi
• Max range (3500 km)	:	-146.6 dB
• Satellite G/T at 60° off-axis	:	+4 dBi
• Receiver loss	:	-2.5 dB
• Multipath propagation effect	:	-3 dB
• Polarization loss	:	-3 dB
• To satellite	:	-201 dBW/Hz
• 4800 bps	:	36.82 dBHz
• Eb/No (10^{-5}) with coding	:	+4.5 dB
• Uplink margin	:	+9.9 dB

Inbound downlink channels analysis (satellite -> ground station) :

• 137.185 -> 137.509 MHz		
• Satellite transmitter/channel	:	-3 dBW
• Satellite transmission losses	:	-0.7 dB
• G/T at 60° off-axis	:	+4 dBi
• Max range (3500 km)	:	-145.93 dB
• G/T	:	+16 dBi
• Ground station receiver loss	:	-2.5 dB
• Polarization loss	:	-3 dB
• To receiver	:	-200 dBW/Hz
• 4800 bps	:	36.83 dBHz
• Eb/No (10^{-5})	:	+4.5 dB
• Downlink margin	:	+5.5 dB
• Power flux density at the ground (dBW/m²/4 kHz) (1300 km)	:	-153.5 dBW/m²/4 kHz in any 4 kHz band

2.3 Capacity

Outbound link capacity:

Sufficient margin exists to support an 38 400 bits/s OUTBOUND link with one satellite. If we assume an efficiency factor of 0.7 to account for framing set-up, repetitions and queueing (0.9 framing efficiency, 0.74 repetition / queue efficiency) and a mean message of 32 characters, **we obtain an expected capacity for each satellite of 375 000 OUTBOUND messages per hour**.

Assuming that all the traffic is in continental areas, the following capacities can be expected:

- **a world-coverage capacity of about 3.10^6 messages/hour for the system (70 million users per day),**
- **a CONUS coverage capacity of greater than 350 000 OUTBOUND messages per hour or 8 million users per day;**

Inbound link capacity:

The INBOUND link capacity is driven by the number of simultaneous messages that can be received, and the average message length. In each INBOUND channel, messages are separated by Doppler shift.

The number of simultaneous messages N per second may be derived from the following formula :

$$N = - K (W/b) \cdot (1/M) \cdot \text{Log } P_{NC}$$

Where :

K = INBOUND channels (10),

W = bandwidth of each channel (25 000 Hz),

b = communication bandwidth of each channel (14 400 Hz),

M = message length (expected 60 ms at 4800 bps),

PNC = non-collision probability (PNC 0.6).

The number of simultaneous messages during M = 60 ms on the INBOUND link is thus N = 147. The INBOUND capacity per satellite is about 530 000 messages per hour, or more than 12 million users per day.

The above capacity is significantly increased when the spread spectrum technique is used. In that case, the inbound link capacity is driven by the number of simultaneous messages N that can be received assuming that we have sufficient supply of acquisition units and decoders to handle the link capacity.

The number of simultaneous messages depends on the inbound uplink margin and on the spreading gain (10 dB).

Eb/N0 margin	Simultaneous messages number	Average messages per second	Average messages per hour
3 dB	26	286	1.03×10^6
6 dB	40	440	1.59×10^6
9 dB	46	506	1.82×10^6

3. Space Payload

Use of satellites in non-geostationary orbits is motivated by the possibility of gaining the following system advantages :

- Low EIRP with 60° "field of visibility" antennas,
- Use of simpler spacecraft and launch vehicles.

3.1 General

A VHF (148 - 148.411 MHz) STARNET repeater receives the radiated signals from the ground stations and the user's terminal uplinks and retransmits the signals to the ground station and the user's terminal on the VHF downlinks (137 -> 137.509 MHz).

The ranging and the Doppler shift of the INBOUND link signal together with the knowledge of the satellite position and the OUTBOUND time epoch allow to determine the terminal position.

VHF 137 and 148 MHz spacecraft input

Spacecraft interface:

Parameter	Value	Comments
Receiver noise temperature	600°K	maximum over life of S/C
Input signals		
Maximum terminal input signal power flux density	-120 dBW/m2	assuming1300 km orbit
Nominal terminal input signal power flux density	-142 dBW/m2	assuming1300 km orbit
(random orientation of user terminal antenna with respect to spacecraft nadir)		

Unwanted signals

Integrated effective background noise :

Parameter	Value	Comments
. Expected maximum	10 000°K	industrial areas
. Expected nominal	6 000°K	
. Expected minimum	2 500°K	
. Voice signals		intermittent (short 25 watts emissions)

VHF 137 MHz spacecraft output

In the case of spread spectrum (solution A), the power output of the transmitter is 15.6 dBW in a 1 MHz band.

3.2 Satellite block diagram

Figure VII.A.3.2 shows the overall architecture of the LEO satellite. As can be seen, the two VHF potential sources (148 MHz) can be routed via the cross point switch to either of two possible outputs.

4. Orbital Network, Coverage Network

The satellite constellation is designed to give global coverage with minimum waiting time over the CONUS. The orbit altitude is constrained to assure adequate power from the solar-cell arrays over a seven-year lifetime. The consideration here is to select the orbit not only from coverage considerations, but also to satisfy a constraint on a tolerable flux of high-energy protons.

About twenty-four (24) satellites are distributed randomly on 50° to 60° inclined planes in circular orbits at 1300 km. The randomly distributed constellation does not necessitate a complex tracking and management scheme.

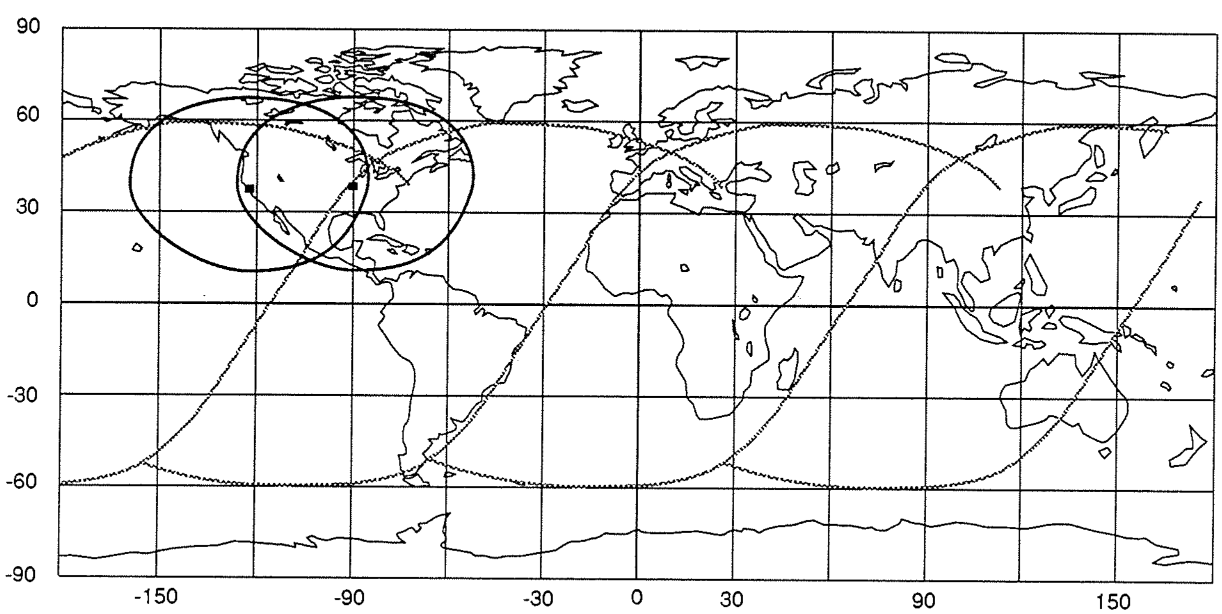
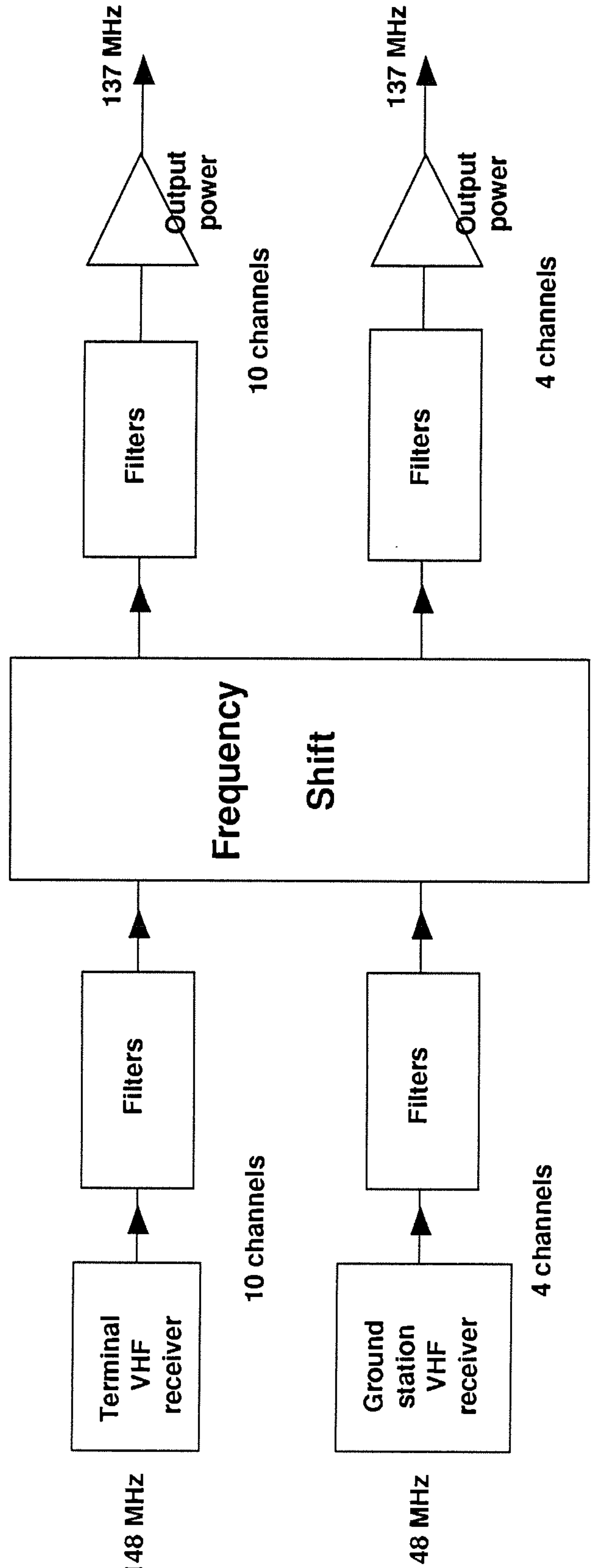


Figure VII.A.4(1)



Payload block diagram

Figure VII.A.3.2

Orbit parameters :

- Period : 1 h 51 mn 20 sec,
- Round trip signal delay : 8 msec.

Coverage performances :

The most subtle problem with the mission analysis is specifying the constellation to maximize the coverage. A key analytical tool in this study is the "central angle" C_v of the visibility cone ($C_v = 29°$ for $E_0 = 5°$ and altitude = 1300 km).

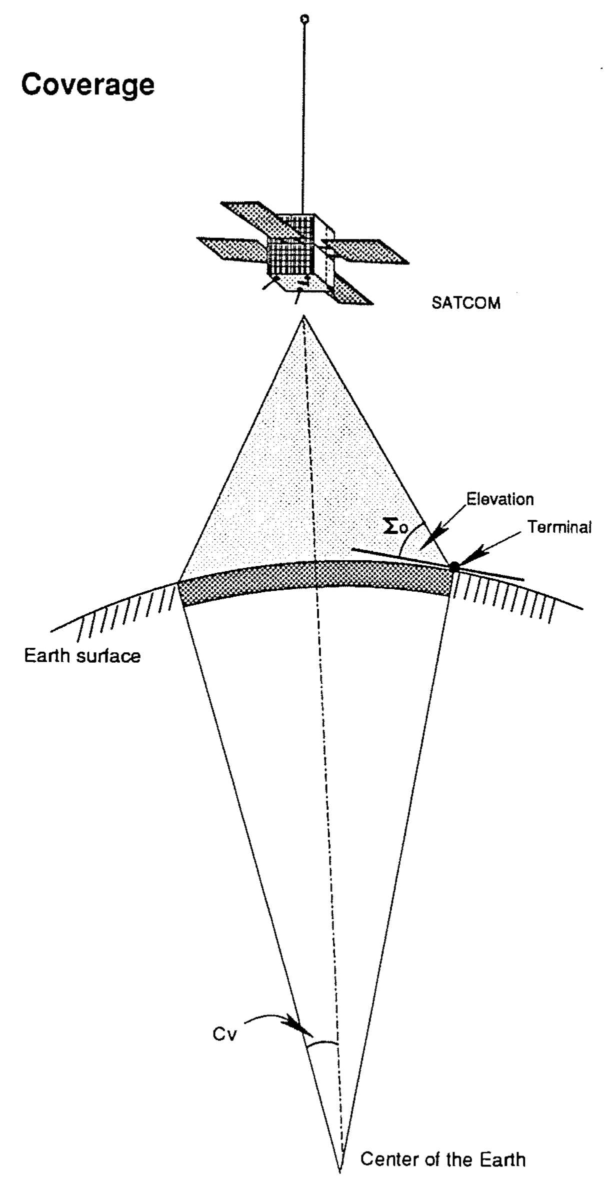


Figure VII.A.4(2)

Another important characteristic of the constellation is the maximum time that an activated terminal (anywhere on the earth) must wait to view the satellite. The mean waiting time for a terminal in the CONUS area is about 2 minutes. An example of the 24-satellite distribution coverage is given below.

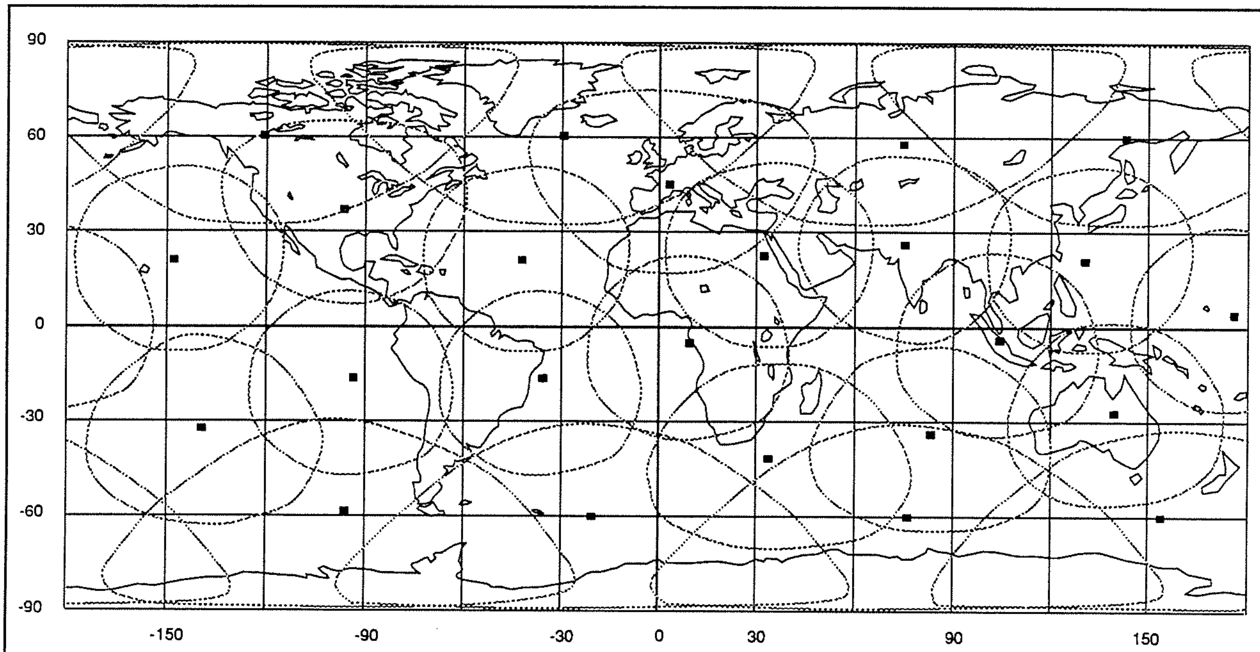


Figure VII.A.4(3)

Launch/flight sequence:

Different possibilities are presently considered for the launch of the STARNET satellite/payload :

- piggy-back on ARIANE launch (ASAP capability);
- payload piggy backing on LEO satellites (SPOT, EPOP, etc.);
- PEGASUS airplane launch technology;
- MicroSat Launch Systems (sounding rocket technology)

Orbital inclination from 50^{o} through 60^{o} at 1300 km (700 nmi) can be achieved using any available satellite of opportunity, i.e.: Ariane, Pegasus, etc. For a payload of about 112 kg (246 lbs) and a 1300 km circular polar orbit injection, accuracies are expected to be 37 km (20 nmi) deviation in altitude and + or - 0.2^{o} in inclination.

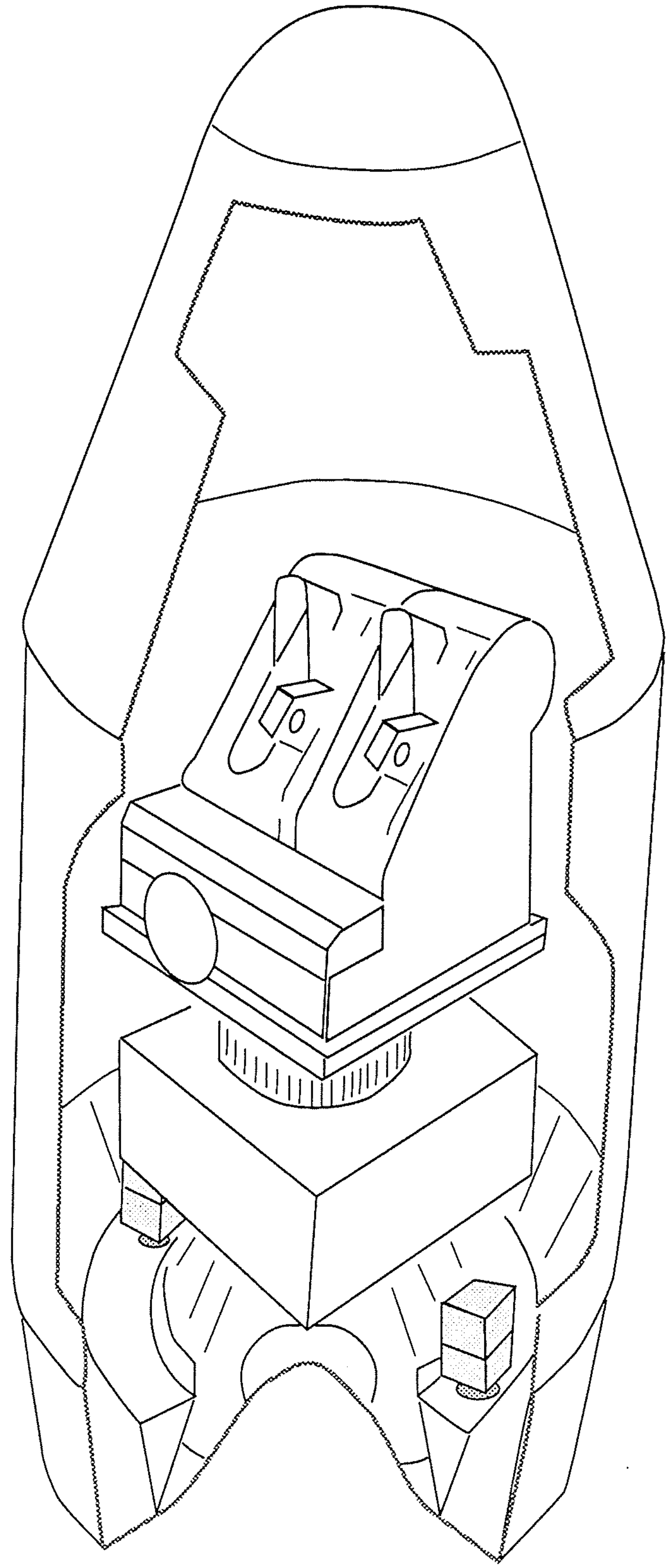


Figure VII.A.4(4)

5. Terminal Position Determination

Radio-determination will be obtained by using Ranging and Doppler measurements on received frequencies.

5.1 Principle

The Processing, Analysis and Control Centers (PACCs) will automatically assign each CDA station the task of tracking a specific spacecraft at specific times and manage conflicts in case of several spacecraft in the field of view.

When assigned to a specific spacecraft, the CDA station begins with acquisition and continues with tracking during the pass. The CDA station sends a time of reference in the OUTBOUND uplink.

When a terminal is on, it tries to synchronize on one OUTBOUND downlink. When synchronized, a light can be switched on, indicating that transmission is possible.

On a transmission request, the terminal indicates the number of the last time reference received, spacecraft ID on which it is synchronized, its own ID, type of message and data.

When this message arrives at one of the CDAs, time of arrival is measured with respect to the time reference of this CDA.

Note : Spacecraft A is synchronized by CDA station B. A user terminal is synchronized on spacecraft A. User terminal transmission can be received either by station B through spacecraft A or CDA station C, coming from spacecraft A or spacecraft D (synchronized by another CDA).

At arrival, the received frequency is also measured.

Using ranging and Doppler techniques, the user terminal position is computed when enough information is gathered.

5.2 Geometric Considerations

The first level of the positioning process is directly linked with the geometric intersection of possible positions :

- earth sphere or ellipsoid;
- sphere, the center being at the satellite's position, radius is determined by ranging;
- cone, the summit of it is also at the satellite's position, aperture is determinated by Doppler effect.

On one transmission, ranging and Doppler techniques lead to a position determination with the intersection of two spheres and one cone.

Preliminary studies show that the achieved accuracy is on the order of magnitude of 1 km, taking into account that ambiguity can be determined with supplementary information from terminal (region, ground/sea, preceding position, etc.). Positioning accuracy is directly connected with terminal performance as frequency stability.

This positioning method will be used during the first emergency phase. Then, minutes later, new information coming from the same spacecraft at a different geometric position, or another spacecraft, will allow positioning accuracy to less than 100 meters.

Influence of terminal altitude knowledge (Earth sphere radius) will be decreased using either terrain map or 3-axis computation depending on available measurements.

5.3 Filtering

When enough information is available, the same technique described above will be applied in conjunction with filtering techniques that will decrease the budget error due to noise in transmission or measurements.

5.4 Relative Positioning

Using a network of Reference Calibration Platforms (RCP's), at periodic intervals a geographical calibration of the system is performed. This allows for a compensation of systematic bias of the system due to propagation (ionospheric and tropospheric) and satellite positioning errors.

The final accuracy of STARNET positioning is better than 50 meters.

5.5 System Ultimate Accuracy

Using filtering techniques and relative positioning during several hours for a fixed terminal, final achieved accuracy will be better than 20 meters.

At this level of accuracy, one must be aware of the coordinate references used.

6. Spectrum Allocation

Applicant is requesting authorization to operate on a Modified Primary Basis in the U. S. on the following VHF bands :

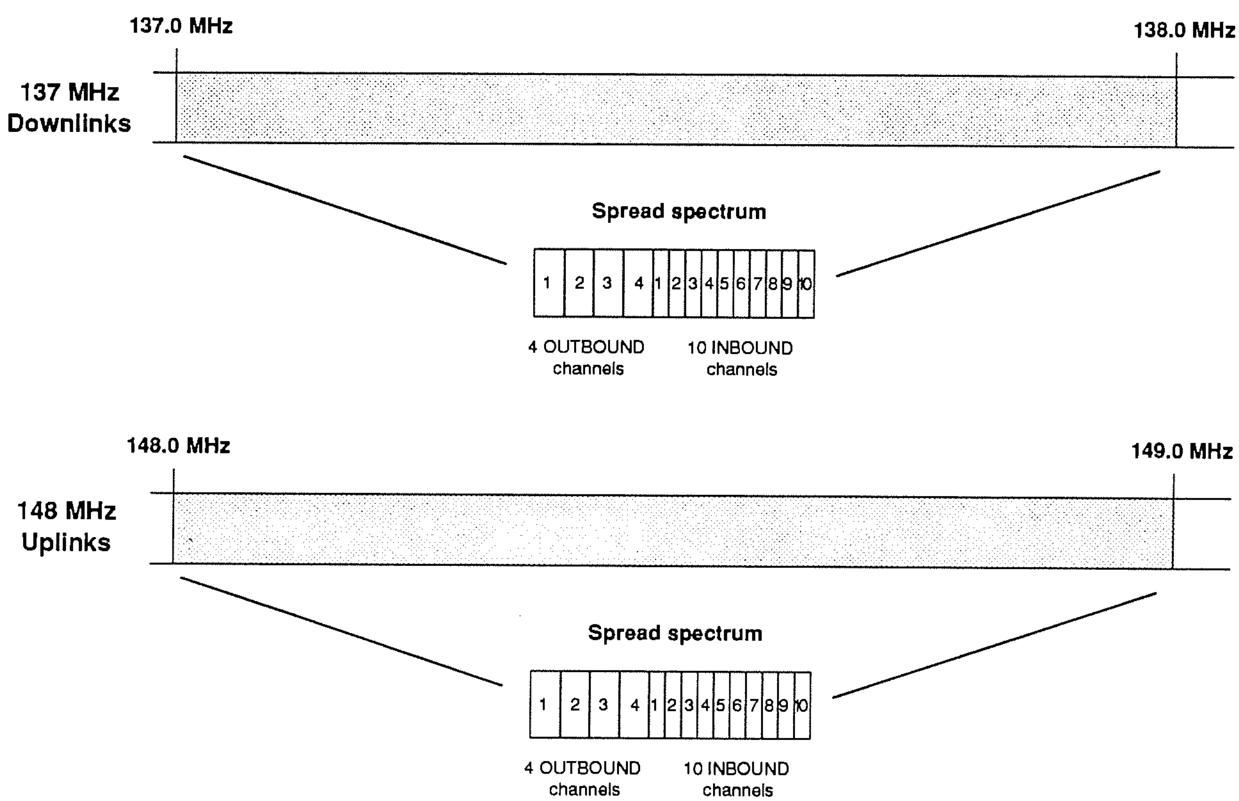
Nominally using spread spectrum techniques (Solution A)

Earth to space (uplink)	148	to	149.0 MHz
Space to earth (downlink)	137	to	138.0 MHz

Or alternatively without using spread spectrum techniques (Solution B)

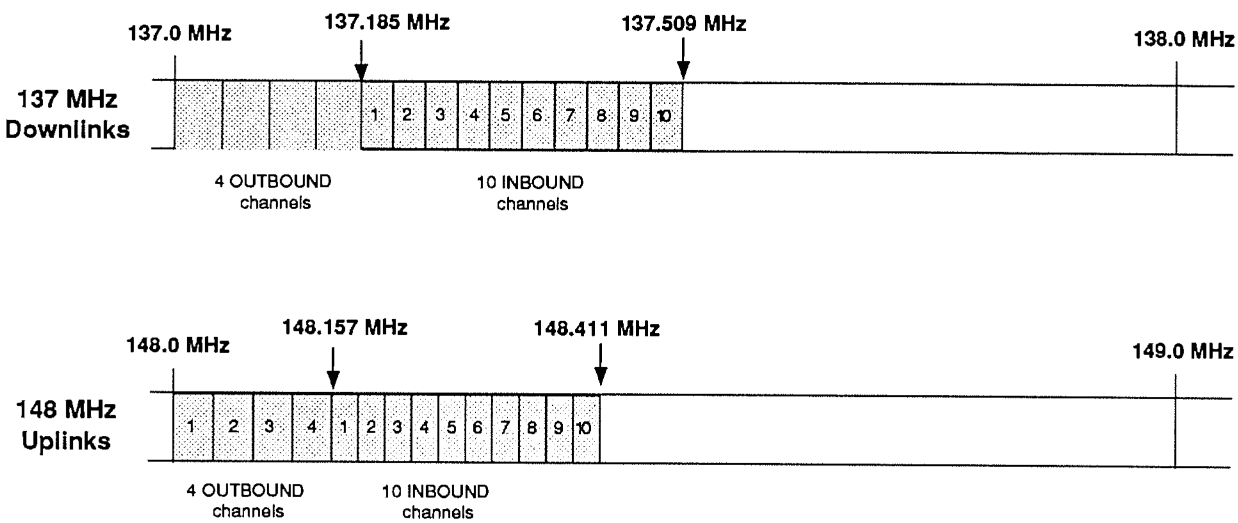
Earth to space (uplink)	148	to	148.411 MHz
Space to earth (downlink)	137	to	137.509 MHz

The "Modified Primary" basis is such that the proposed system will not cause interference to presently authorized users in the same band and would be granted Primary Status against any new services.



Base line STARNET spectrum proposal (solution A)

Figure VII.6(1)



Base line STARNET spectrum proposal (solution B)

Figure VII.6(1)

7. Interference Analysis

7.1 VHF Downlink Band (137 - 138 MHz) (spread spectrum)

This band is allocated on a Primary Basis to Space-to-Earth operations (TIROS, LANDSAT, IMP ... satellites).

7.1.1 Interference with Existing Services

The low Power Flux Density (- 141.5 dBW/m^2/ 4 kHz) of the outbound downlink referenced to a 4 kHz bandwith combined with spread spectrum should permit sharing the (137 - 138 MHz) VHF bandwith without coordination with other Space to Earth services.

7.1.2. Interference from Existing Services

STARNET user terminals are susceptible to interference from nearby fixed - mobile existing transmitters.

The potential for interference exists if transmitters are within the line of sight of the user's terminals. However, the mobile nature of the STARNET transceivers, the spread spectrum modulation used, and its acknowledgement-based protocol will minimize the operational effect of such interference.

7.2 VHF Uplink Band (148 - 149 MHz) (spread spectrum)

This band is allocated in Primary Basis to Fixed Services.

7.2.1. Interference with Existing Services

The low radiated power of the user's terminal transmitter (about 1 watt) combined with the short pulse nature of the signals and the spread spectrum modulation will help avoid interference with existing Fixed to Mobile Services.

The high directivity of the STARNET CDA station antennas will provide enough protection for existing Fixed to Mobile Services against STARNET outbound uplink.

7.2.2 Interference from Existing Services

The short pulse inbound uplink between user's terminals and the satellite, its acknowledgement-based protocol and the spectrum spreading will permit STARNET to share the inbound uplink frequency band with existing ground services.

The very important outbound uplink (ground station to satellite) margin with the spectrum spreading will help protect the outbound STARNET uplink against other services.

B. SPACE SEGMENT DESCRIPTION

The LEO satellites are designed to be small, lightweight and inexpensive. In the stowed position, the spacecraft measure dimensions are a 0.81^2 m, 1.2 m in height, weighing 112 kg and consuming, 115 watts.

In orbit, the solar panels and a gravity gradient boom will be deployed. The satellite dimensions will then be 3 x 8 m.

1. Basic Structure

The STARNET structure is illustrated in Figure VII.B, which shows the spacecraft in orbital configuration. Figure VII.B.1, shows the general arrangement of the spacecraft subsystems and the structural parts description.

The connection between the flange and adapter will be accomplished with a clamp strap. The release of the spacecraft from the adapter will be performed by the firing of squib-operated separation clamp bolt cutters. Upon release, separation springs impart the separation velocity.

The attach flange will be integrated with the "central conical tube" to support the "electronics deck". Truss assemblies extend from the attach flange of the central type to the perimeter of the electronics deck. They give diagonal support to the overhanging electronics deck and provide longitudinal stiffeners for the conical tube.

The electronics deck will be aluminium honeycomb panel mounted on top of the central tube. The deck will be a 32 inch square (.8 m square). The electronics packages associated with all of the spacecraft subsystems and communication equipment are mounted on

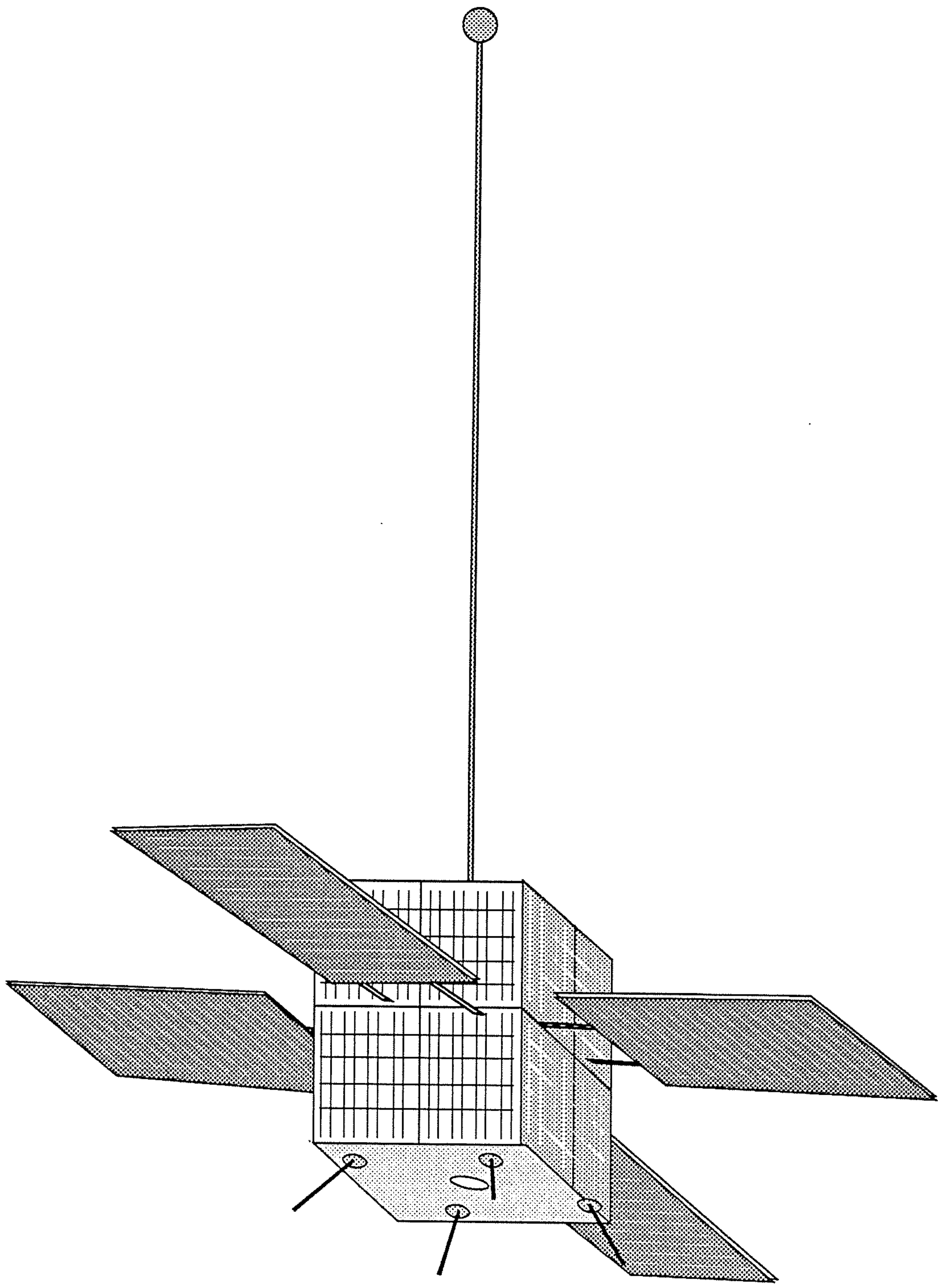


Figure VII.B

one side of this deck, with the gravity-gradient boom assemblies and the thermal louver assemblies on the other.

1.1 Solar panels

The solar array electrical requirements are discussed in Section 2.1. To meet these requirements, a deployable array will be designed. There will be four identical panels with cells on both sides. The solar cells are mounted on "substrates". To streamline the procurement process, the same cell layout will be used on all panels (and sides).

The deployment of the panels is driven by the helical springs and controlled by dampers which only act during the over-travel past the desired deployed position.

The deployed position is adjustable in the mechanism and does not depend on the spring which is still loaded at equilibrium. A positive stop is provided, beyond the expected range of motion, to prevent any contact of the panels with the spacecraft, or each other.

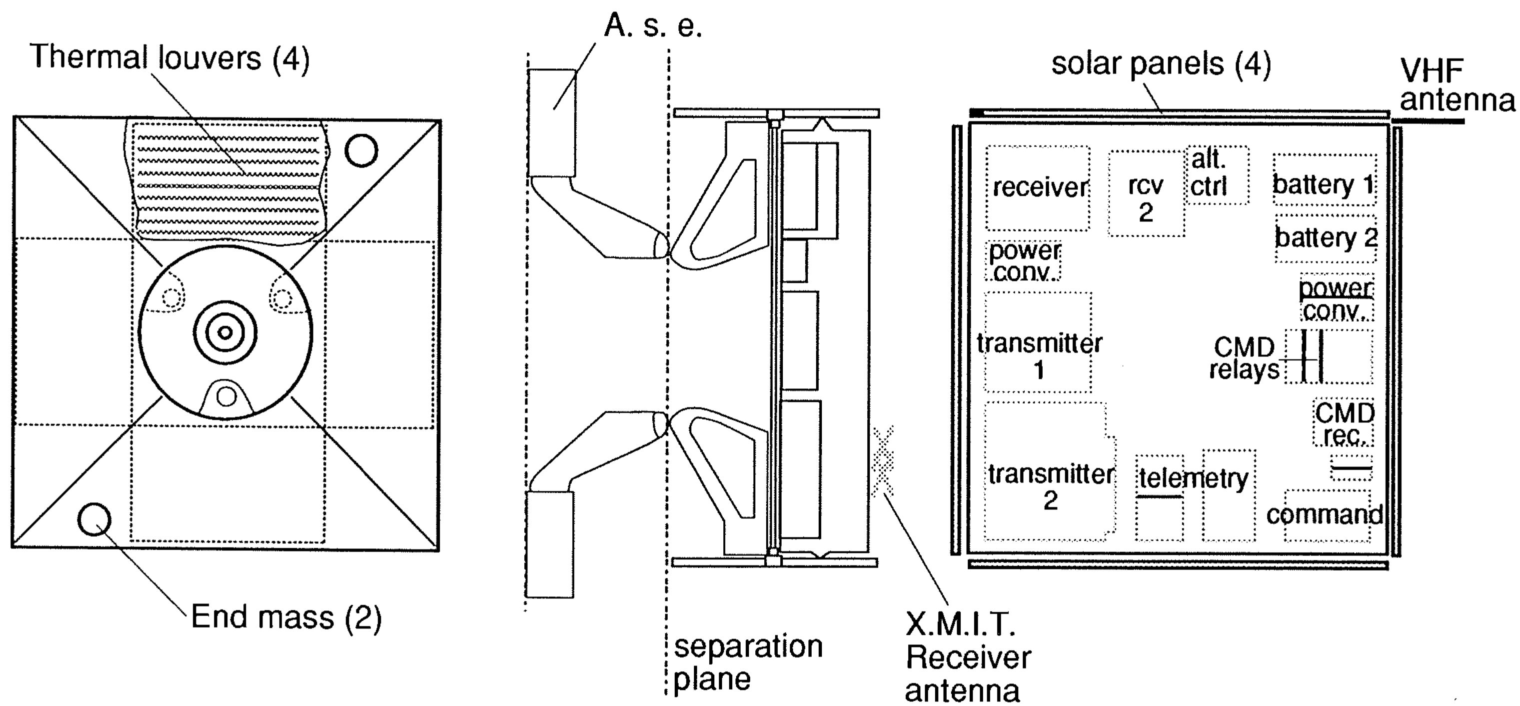
1.2 System Block Diagram and Power Budget

The satellite is composed of the following subsystems :

1. Power
2. Thermal
3. Command
4. Telemetry
5. Attitude
6. Antennas
7. Communication transmit and receive

Power evaluation is based on the following assumptions :

1. Converter efficiency is 85%.
2. Command converter efficiency is 75%.
3. The communication equipment has one power mode.



SATELLITE GENERAL ARRANGEMENT

Figure VII.B.1

4. The attitude system is turned off after the satellite is captured in the proper orbit.
5. Thermal control is cycled as required.

Spacecraft weight and power allocation :

Four (4) solar array panels will extend from four (4) sides on the top of the spacecraft. Each of the panels will be approximately 0.7 square meter.

The solar cells combined with two 10 AH Ni-cad batteries will supply sufficient energy to accommodate an average requirement of 115 watts (50% efficiency).

• Spacecraft structure	33 kg	
• Batteries	15 kg	
• Solar cells	15 kg	
• Power control unit	2 kg	7 Watts
• Thermal control	10 kg	14 Watts
• Attitude control	8 kg	10 Watts
• Gravity gradient boom	5 kg	
• VHF antennas	6 kg	
• RF payload and switching	10 kg	10 Watts
• Power stages (37 Watts, 50% efficiency)	8 kg	74 Watts
Total weight/power	112 kg	115 Watts

2. Power Subsystem

The power subsystem will be required to support an estimated average electrical load of approximately 125 watts during its five (5) year lifetime in orbit. The power subsystem to support this load will consist of a solar cell array for power generation, nickel cadmium batteries, battery charge regulators and DC/DC converters for conditioning power to selected loads.

The energy generating and storage systems will provide power to the main power bus at a nominal operating voltage of 28 volts.

2.1 Solar Array

The solar array will consist of four panels which, when deployed, will form an omni-directional turnstile array. Each of the four panels will mount high efficiency, shallow diffused, N/P solar cells on both sides. Each panel will have a platform area of approximately 1.4 square meter. The array is designed to accommodate the degradation in electrical performance anticipated after five (5) years in a high inclination orbit at an altitude in the range of from 1000 to 1300 km.

2.2 Batteries

The power system will incorporate redundant nickel cadmium batteries to supply peak energy demands in excess of instantaneous solar array generating capability and to power the spacecraft during periods of solar eclipse lasting up to approximately 45 minutes. Each battery will consist of 22 series 10 ampere-hour cells, operating at a nominal 28 volts. During normal spacecraft operation, both batteries will be available to provide power to the spacecraft main power bus. A total energy of approximately 672 watt-hours is therefore available when the batteries are fully charged.

Each battery may be individually removed from service by ground command for a periodic reconditioning cycle if desired. This reconditioning process, which removes memory effects, can be performed during periods of 100% sunlight exposure when energy storage demands are minimal (see Figure VII.B.2.2).

2.3 Battery Charge Control

Battery charge control is accomplished by a redundant, microprocessor-based, non-dissipative charge controller. The battery charge controller senses battery temperature, charge current, bus

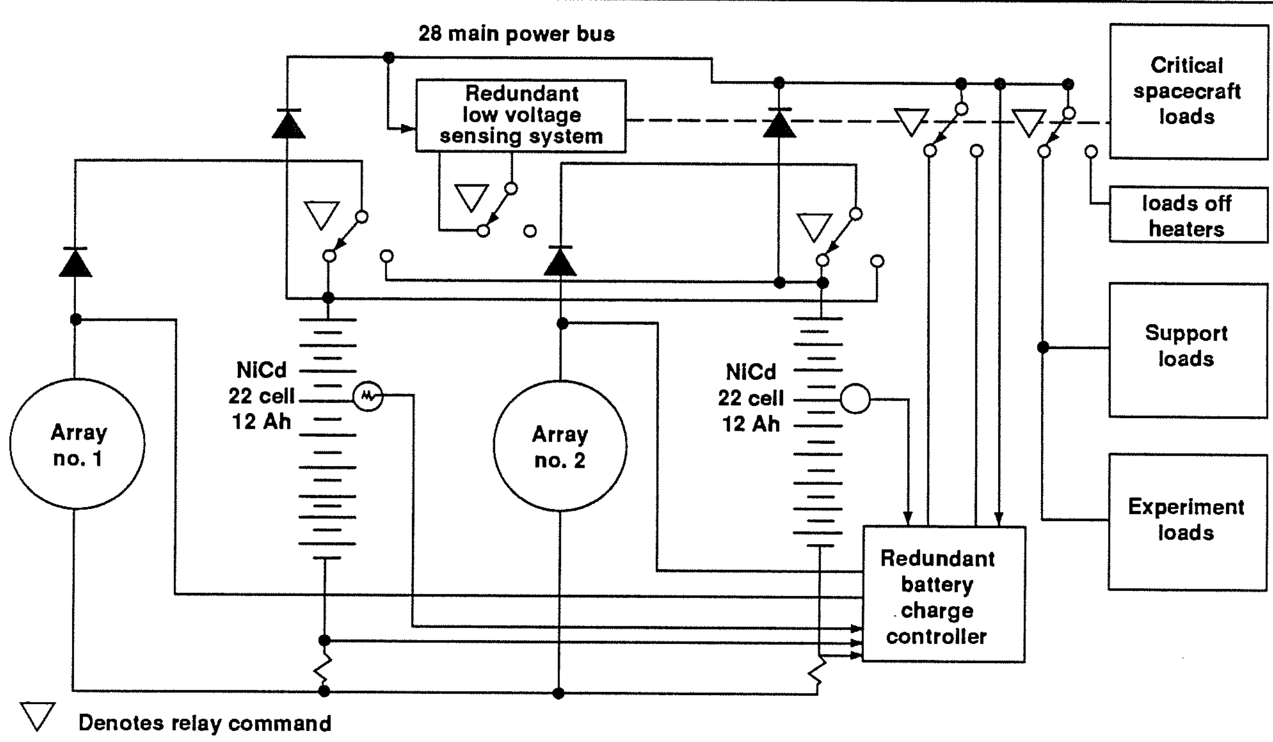


Figure VII.B.2.2

voltage, and integrates battery charge state. The controller will control battery charge current by selectively and incrementally short circuiting series strings of solar cells in the array until the desired battery-charge-current level or voltage limit has been surpassed. Assuming that array orientation to the sun is maintained constant and that equilibrium conditions are achieved within the power system, the controller would "dither" about the limit by shorting and unshorting the array element which produces the desired effect.

2.4 Low Voltage Sensing System

A redundant Low Voltage Sensing System (LVSS) will be incorporated in the power system to protect the spacecraft batteries from excessive and potentially damaging discharge. In the event of a low voltage fault on the main power bus, the LVSS, acting as a circuit breaker, disconnects all non-critical spacecraft electrical loads. Recovery from an under-voltage fault will be performed manually by ground controllers so that failure, if it occurred, may be identified and isolated. Should the under-voltage circuit breaker itself prove defective, its control may be overridden by ground command.

3. Thermal Control Subsystem

The thermal control subsystem proposed for the spacecraft is semi-active through the use of louvers to control the heat loss to space. In addition, electrical heaters are used as necessary for heating the boom mechanisms before deployment and for more precise battery temperature control. All these heaters are commandable on or off. Active thermal control techniques are required. Louvers are operated by bimetallic elements, thus they require no power. The precise need will be established by detailed analysis during the design phase. Battery heaters are normally needed because of the close temperature control required.

Radiators located above the louvers will use surfaces with low solar absorptivity and high infrared emissivity. The remainder of the spacecraft will be covered with multilayer insulation blankets.

4. Command Subsystem

4.1 Subsystem Features

The fully redundant command subsystem proposed is shown in Figure VII.B.4. Two dipole antennas channel uplink command signals to respective receivers. Each receiver demodulates the VHF command signal and outputs the Fast Frequency Shift Keyed (FFSK) command baseband to respective FFSK bit detectors. Each bit detector demodulates the FFSK uplink message and outputs command data to its respective command processor which will be microprocessor based. Both command processors will act on the uplink message but only one processor, via an address select, will output the desired command signals.

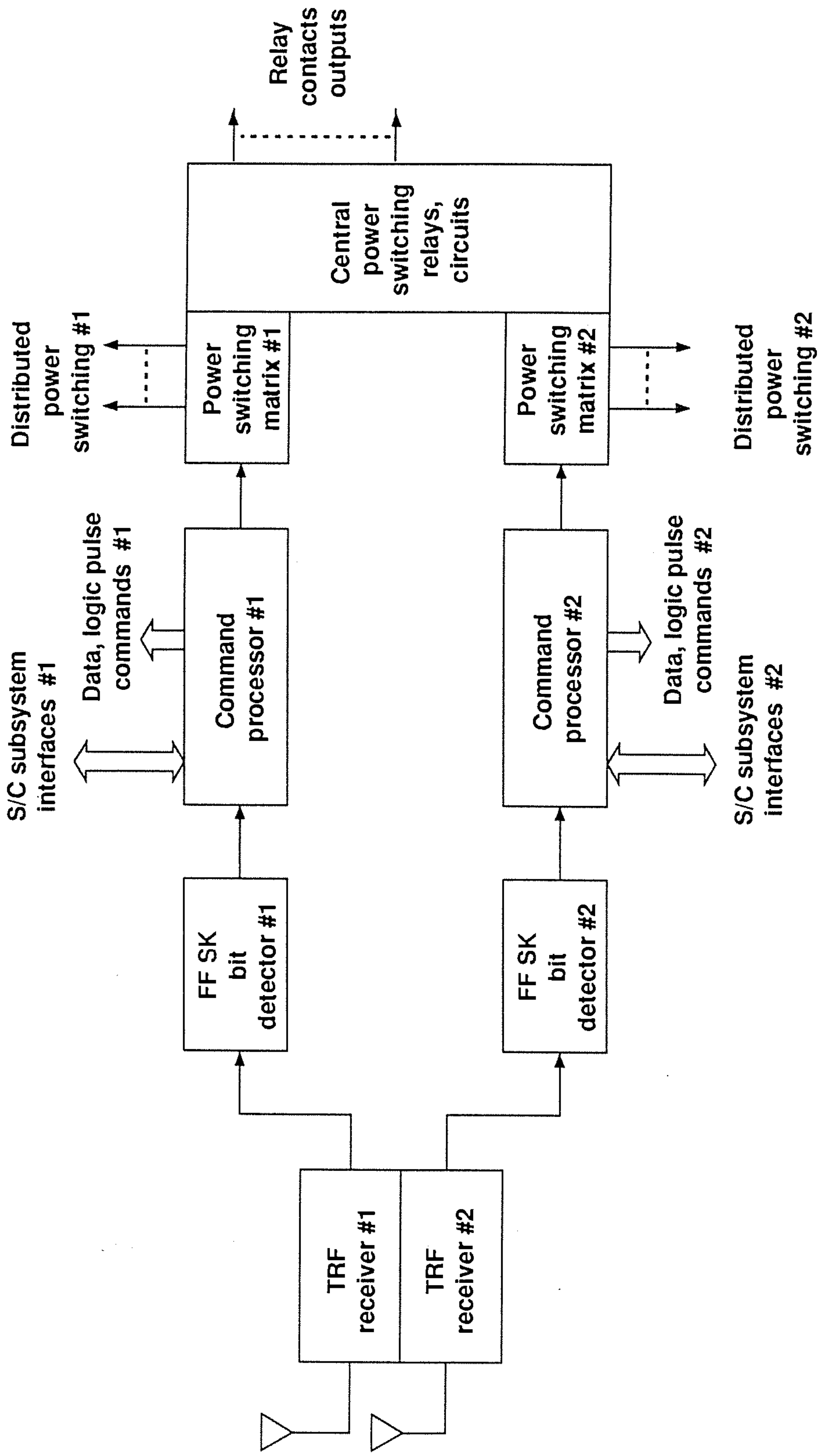


Figure VII.B.4

The types of commands include the following: relay, pulse, data, memory loading, memory load verification, and logic level. A central core of power switching will be provided with other power switching functions being distributed as required. Commands can be executed on a real time or delayed basis. A bi-directional active interface with the telemetry system will provide for various semi-autonomous satellite operations.

4.2 Command Uplink

To capitalize on equipment developed for, and proven by, other space programs over the years, a VHF command uplink has been chosen. The characteristics of the command link (standard uplink channel) are shown in Table 4. The receiver antennas will be mounted on the ends of the solar panels.

Table 4

Command link characteristics

Center frequency	Approximately 148 MHz
Peak power	12 dBWatts
Carrier modulation	FFSK = 4.8 kpbs
Ground Antenna	8-turn Helix, gain = 16 dBi
Spacecraft antenna	Gain -10 dBi over 90% of sphere
Receiver type	Tuned RF
Receiver power required for <<10^{-6} BER errors	> or = -95 dBm

The link is capable of providing > or = - 75 dBm to the command receiver for a STARNET altitude of 1300 km at ground station elevation angles at 5^{o} or above, thus providing a minimum command margin greater than 15 dB.

5. Telemetry Subsystem

5.1 Subsystem Features

The fully redundant telemetry subsystem proposed is shown in Figure VII.B.5.1. Each channel will be micro-processor based. A telemetry channel will be selected via the command system to process the downlink data. Each telemetry processor will control its respective multiplexers to gather analog and digital housekeeping information for subsequent formatting and transmission back to earth. Each telemetry processor will generate clock and timing signals as required by other on-board systems.

The telemetry subsystem will include programs for analysis of collected data. An interface with the command processors will allow semi-autonomous operations by requesting action resulting from analysis of designated telemetry data. This same interface will also function to perform command memory load verification.

5.2 Spacecraft telemetry link design

A standard downlink 137 MHz VHF channel is proposed. Baseline parameters for the spacecraft telemetry link are given in Table 5.

Table 5
Telemetry link characteristics

Center frequency	Approximately 137 MHz
Transmitter power	9 dBWatts
Data rate	9600 bps
Modulation	FFSK
Spacecraft Antenna	> or = -6 dBi over 80% of sphere
Ground antenna	Gain = 16 dBi

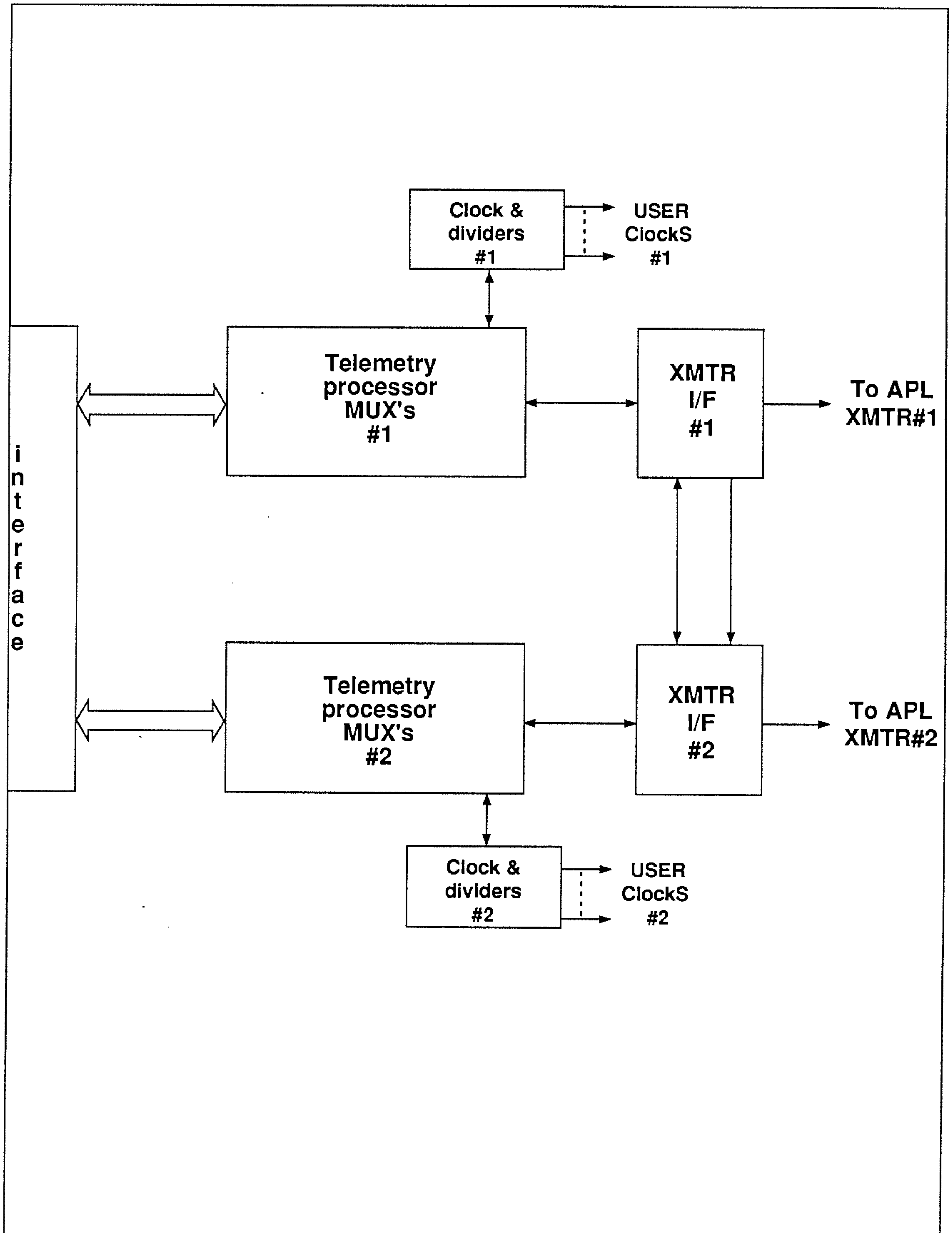


Figure VII.B.5.1

The STARNET spacecraft will contain redundant low-power telemetry transmitters connected to solar panel mounted antennas. Prior to gravity-gradient stabilization, the spacecraft may be in any attitude. As a consequence, an omni-directional antenna system is required. Coverage over a large percentage of the sphere about the satellite can be obtained by arraying the quadrifilar helix antennas and a dipole antenna which individually supply hemispherical coverage.

With the link parameters indicated in Table 5, recovery of spacecraft telemetry with a bit error rate less than 10^{-5} will be provided for an altitude of 1300 km at ground station elevation angles of 10^{o} or above. An additional margin of approximately 6 dB could be obtained after gravity-gradient stabilization by switching to the earth-looking antenna only.

6. Attitude Subsystem

The mission requires orientation of the antennas to approximate local vertical, with no requirement for yaw stability. Pitch and roll will be held to less than + or - 5^{o} by gravity-gradient stabilization. A motorized boom will provide the necessary inertia configuration for gravity-gradient orientation. Energy dissipation for stability is provided by four passive magnetic hysteresis rods, one in each solar panel spar. Passive gravity-gradient stabilization such as this has been demonstrated on numerous spacecraft.

Energy dissipation to assure stability will be provided by two passive ball-in-tube nutation dampers.

Attitude knowledge is required to perform the maneuvers necessary for the stabilization adjustment phase. This is provided by a three-axis vector magnetometer and digital sun sensors. Magnetometer and sun sensor data are telemetered and ground processing enables attitude determination.

7. Antenna Subsystem

The system will operate simultaneously in the VHF frequency bands between space and earth. A single antenna structure will be used for the downlink at 148 MHz and the uplink antenna at 137 MHz will use a separate antenna.

In all cases, the antennas are helixes designed for broad beamwidths (FOV = 70°) and circular polarization to support VHF earth terminals with 5° elevation angles.

C. GROUND SEGMENT

1. General

For the United States, the ground segment basically comprises two (2) Processing, Analysis and Control Center (PACCs), and four (4) Command and Data Acquisition (CDA) stations to communicate with the STARNET satellites and the user terminals (see Figure VII.C.1(1)).

The ground segment was designed to produce a high degree of reliability and redundancy. Each subsystem has a modular architecture to handle anticipated use of the system, (see Figure VII.C(2)).

The master PACC will be located at STARSYS, Inc. headquarters on the East Coast (PACC East) and the redundant PACC will be located on the West Coast (PACC West).

PACC required performance is dependent on the overall system use factor. Therefore modular architecture has been chosen which provides easy performance level upgrade without interruption of service. The processing systems are built around two (2) layers of duplicated LAN using standard mini-computers acquired from a major OEM (IBM, DEC, HP, etc.), (see Figure VII.C.1(2)).

Ground segment general diagram

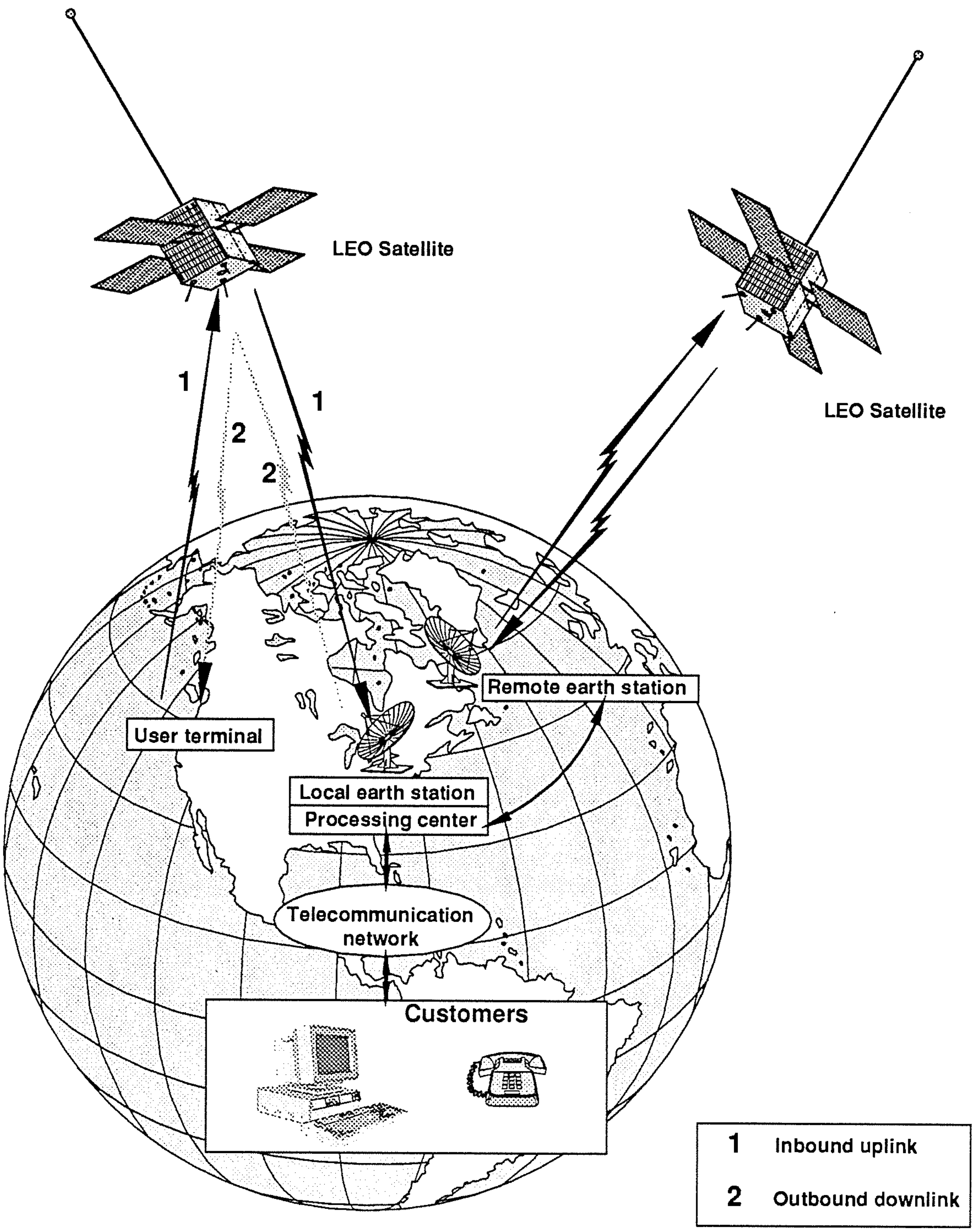
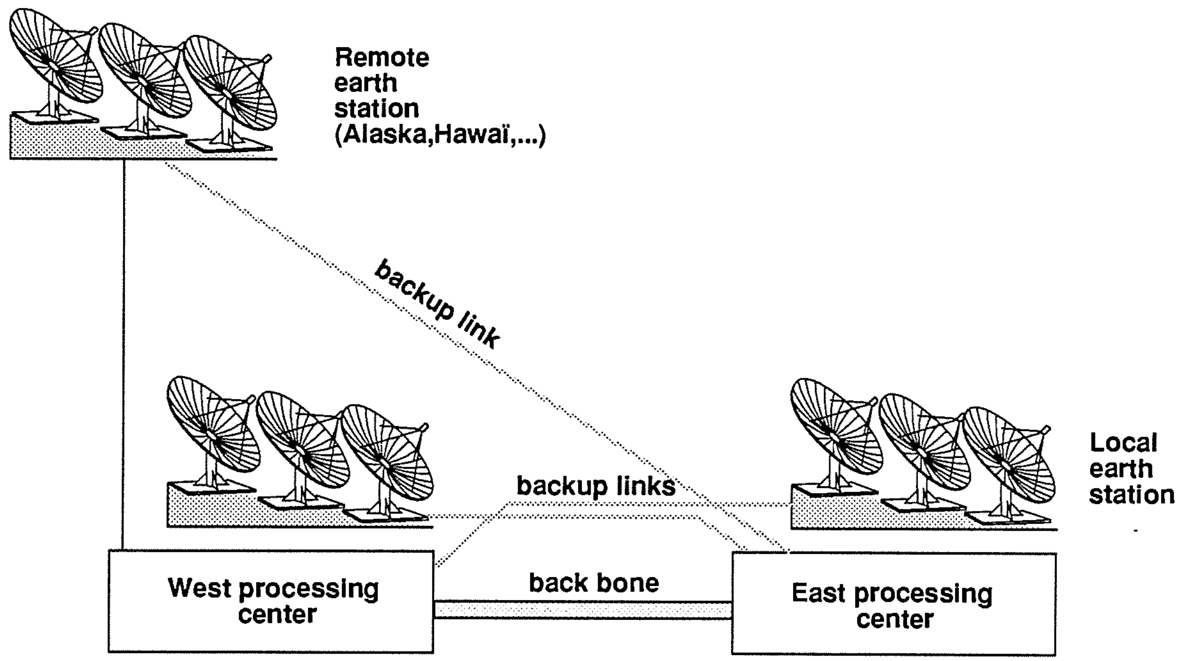


Figure VII.C.1(1)



Ground segment architecture

Figure VII.C.1(2)

The main functions of the PACCs, which include a CDA, are: communication, position processing, message handling, user interface, and system monitoring, and comprise the following subsystems:

1.1 PACC Subsystems

- **communication interface**: to communicate with the CDA stations to receive messages and raw data, and the ranging and Doppler measurements. This interface also manages the high capacity (n x 56 kbps) "back-bone" communications link between the two processing centers.

- **location subsystem**: to compute the user terminal location according to user terminal type and class of service. This subsystem comprises a satellite location determination module to process the messages from the Reference Calibration Platforms (RCPs - a group of precisely surveyed benchmark terminals arranged around the world), and a user terminal location module to process the user terminal messages.

- **message handling subsystem**: to route the messages through the system, to/from the CDAs, to/from the other PACC, to/from the telecommunication networks.

- **administrative subsystem**: to manage the administrative functions of the system:

  . terminal and user management,
  . user billing
  . user service.

- **user interface subsystem**: this subsystem starts as an interface with the telecommunication networks (X25, X400, ...) and houses value-added services such as:

  . 1-800 STARNET voice interface,
  . mail-box,
  . proximity service.

  The user interface shall extensively use the resources of modem telecommunication networks (ISDN, 800 numbers, etc.) to provide cost effective, reliable and user friendly operations. Service based interfaces (e.g., to emergency service) are also available as computer-to-computer connections.

- **monitoring subsystem**: comprising the following :

  . satellite control: satellite health monitoring,

  . CDA station control: station alarm monitoring and tracking strategy optimizations,

. system control: traffic and load observation,

. processing center control: center behavior control, automatic reconfiguration procedures.

2. Command and Data Acquisition Stations (CDAs)

The CDAs communicate with the STARNET satellites and provide:

- the OUTBOUND uplink to provide a timing synchronization for ranging, routing messages toward the user terminal, and for commanding the satellite subsystems for satellite health and safety purposes;

- the INBOUND downlink to receive messages and location information from the user terminals.

In addition, the CDAs will handle satellite housekeeping telemetry and telecommand.

Two (2) CDA stations will provide footprint coverage over the CONUS and will be co-located with PACC east and PACC west. See Figure VII.C.2-1. Two (2) additional CDA stations will be installed, one in Alaska, and another in Hawaii. These latter stations will provide coverage of North America (Canada and Alaska) and the Pacific Ocean, thus providing complete coverage of the U. S. See Figure VII.C.2-2.

These Figures, (with 5^{o} template), depict the limits within which a satellite can be received. The actual system coverage is much greater because each satellite communicates with all user terminals within its own footprint.

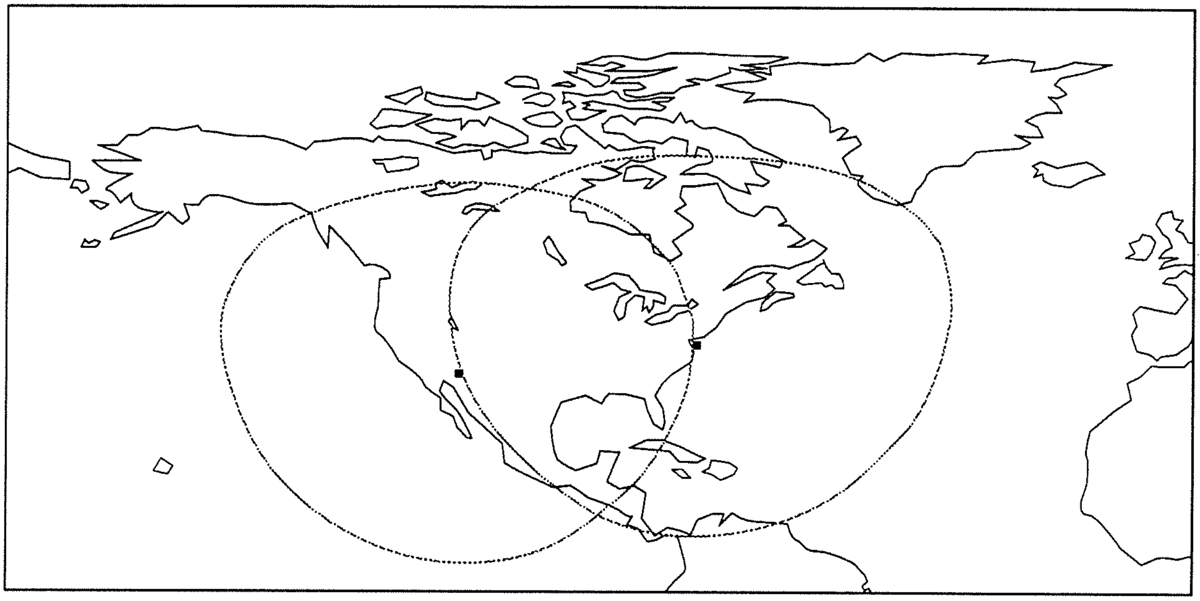


Figure VII.C.2-1

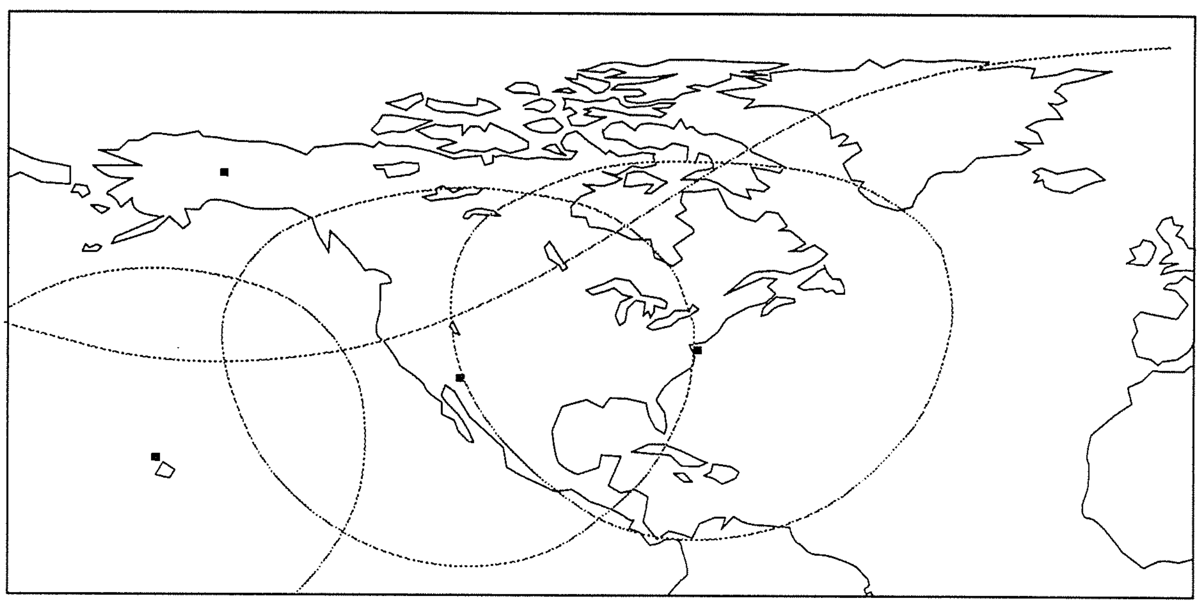


Figure VII.C.2-2