AEROSPACE REPORT NO.
ATR-76(7365)-1 VOL. III

DRA

Advanced Space System Concepts and Their Orbital Support Needs (1980-2000)

Volume III: Detailed Data - Part I: Catalog of Initiatives, Functional Options, and Future Environments and Goals

(A Study of the Commonality of Space Vehicle Applications to Future National Needs)

(UNCLASSIFIED VERSION)

Prepared by
I. BEKEY, H. L. MAYER, and M. G. WOLFE
Advanced Mission Analysis Directorate
Advanced Orbital Systems Division

April 1976

Prepared for
OFFICE OF SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASW 2727

Systems Engineering Operations

THE AEROSPACE CORPORATION

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FOREWORD

This report documents the results of Study 2.5, "Study of the Commonality of Space Vehicle Applications to Future National Needs," performed under NASA Contract NASW 2727, during Fiscal Years 1975 and 1976. Capt. R. F. Freitag and Mr. F. S. Roberts, Advanced Programs, Office of Space Flight, NASA Headquarters, provided technical direction during the course of the effort. The report is being issued in separate classified and unclassified versions.

This report is comprised of four separate volumes entitled:

Volume I	Executive Summary
Volume II	Final Report
Volume III	Detailed Data - Part I: Catalog of Initiatives, Functional Options; and Future Environments and Goals
Volume IV	Detailed Data - Part II: Program Plans and Common Support Needs

The first two volumes summarize the overall report. The third volume presents a catalog of the initiatives and functional system options; and thoughts on future environments and needs. The fourth volume matches the "initiatives" against the requirements and presents detailed data on alternate program plans for alternate future scenarios, from which likely supporting vehicle and technology needs are derived.

This volume contains the catalog of initiative system concepts; a data bank of time-phased functional system options; considerations of the future environments and their implications on national needs and space goals; relationship between the goals and the initiatives; and the methodology used for weights estimation.

ACKNOWLEDGMENTS

The study was performed for NASA under the direction of Mr. I. Bekey, Study Director and Assistant Group Director of the Advanced Mission Analysis Directorate.

The bulk of the innovative technological material was prepared by I. Bekey and Dr. H. Mayer jointly in a collaborative team effort. The material dealing with the future environments and goals was preparee primarily by Dr. H. Mayer. The programmatic material was prepared by Dr. M. Wolfe and I. Bekey jointly. The marshalling of other Aerospace Corporation resources including system weights estimation was performed by Dr. M. Wolfe. Cost estimation was aided by Mr. H. Campbell. The program evaluation algorithm and the extent of the spectrum of alternate world scenarios were provided by Dr. G. V. Nolde, consultant. Mrs Janet Antrim provided invaluable and patient support in copy preparation and manuscript typing. The dedicated efforts of all participants are hereby gratefully acknowledged.

CONTENTS

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SECTION 1

CATALOG OF INITIATIVE SYSTEM CONCEPTS

The next several pages present an index to the catalog of initiatives. A simple coding scheme is used to identify the initiatives. The first letter "M" or "C" designates whether it is Military or Civilian. The second letter, "O", "C", or "S", designates whether its main function is Observation, Communications, or Support. A number then represents the chronological file number of the initiatives within each of the above functions.

The initiatives appear in the data bank filed according to the above scheme.

INDEX TO INITIATIVES

CIVILIAN - OBSERVATION

CIVILIAN - COMMUNICATIONS

INDEX TO INITIATIVES (CONTINUED)

CIVILIAN – SUPPORT

INDEX TO MILITARY INITIATIVES

(The index as well as the descriptive material of the initiatives have been deleted for security classification reasons.)

The facing page is a sample format used in presenting the data on the initiatives in the catalog. Each initiative is described on one such format sheet. Each initiative has had sufficient preliminary analysis to grossly define the system concept, to estimate the satellite gross weights and sizes, and to define the major performance parameters of key space and ground elements. A pictorial is presented of the function to be performed.

A brief statement is made of the purpose of the initiative and of the reasons why such an initiative might be useful. The concept is very briefly described. The characteristics of the satellite are summarized in terms of gross weight, size, and raw power on orbit. The orbit characteristics are given. The number of satellites required to form an active constellation of the calculated performance are given. The category of technological, phenomenological, or hazard risk (low, medium, or high) is estimated. The time frame during which the earliest conception of each initiative could be acquired is estimated. The space only cost to the first operational capability including R&D, investment in the first operational units, and the required booster costs is estimated. The performance is described in terms of those numbers most relevant to the utility.

For each initiative concept, the building block requirements (such as Shuttle or Large Launch Vehicle, upper stage or Tug or SEPS or other orbital vehicle) are stated and any special requirements above and beyond today's technology, those sections are left blank.

- PURPOSE

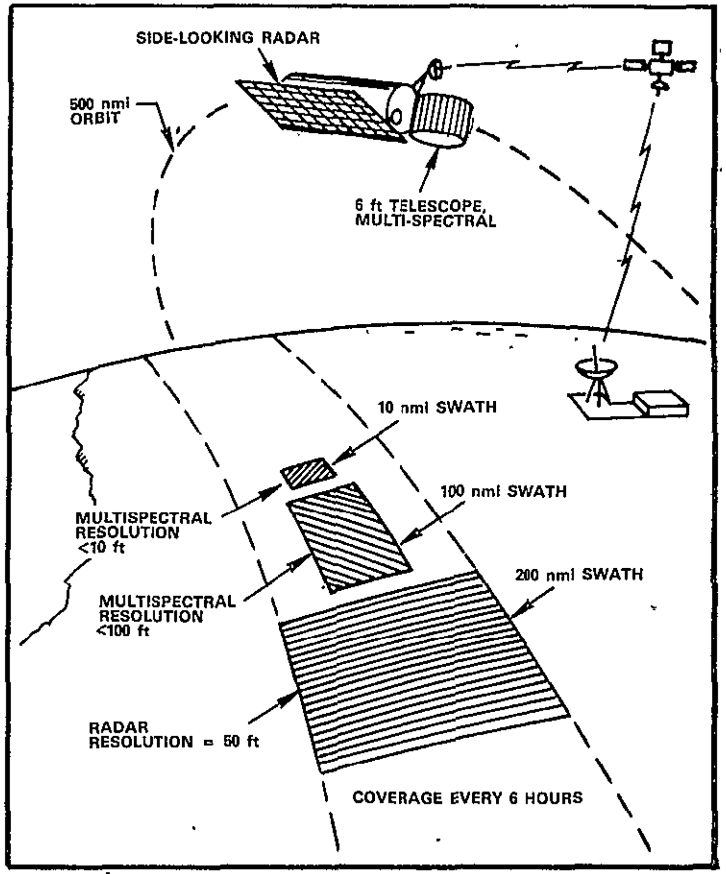
- RATIONALE

- CONCEPT DESCRIPTION

- CHARACTERISTICS
  - WEIGHT
  - SIZE
  - RAW POWER
  - ORBIT
  - CONSTELLATION SIZE
  - RISK CATEGORY
  - TIME FRAME
  - IOC COST
- PERFORMANCE

- BUILDING BLOCK REQUIREMENTS
  - TRANSPORTATION
  - ON-ORBIT OPERATIONS
  - SUBSYSTEMS
  - TECHNOLOGY
  - OTHER

ADVANCED RESOURCES/POLLUTION OBSERVATORY (CO-1)



- **PURPOSE**

  To provide high quality, multispectral earth resources and pollution data.

- **RATIONALE**

  Integrated ERTS-like system, real-time data distribution to worldwide users, active sensors needed.

- **CONCEPT DESCRIPTION**

  Active and passive sensors, large aperture, high, medium, and low resolution imaging obtained in multispectral region and radar. Data disseminated by laser link through relay satellite.

- **CHARACTERISTICS**

• **WEIGHT**	30,000 lb
• **SIZE**	10 x 60 ft
• **RAW POWER**	12 kW
• **ORBIT**	500 nmi sun synch.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space only)	350 M

- **PERFORMANCE**

  Multispectral resolutions varying from <10 to <100 ft obtained worldwide.

- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and tug
• **ON-ORBIT OPERATIONS**	Shuttle attached manipulator, servicing stages
• **SUBSYSTEMS**	Guidance and navigation; attitude control; transmitter
• **TECHNOLOGY**	Large radar antenna; high power tubes and modulator; LSI data processor
• **OTHER**	None

FIRE DETECTION (CO-2)

- **PURPOSE**

  To detect fires in remote regions, maintain surveillance of hot spots, fire perimeters.

- **RATIONALE**

  Fire damage can be minimized by early detection, and firefighting with knowledge of extent and progress.

- **CONCEPT DESCRIPTION**

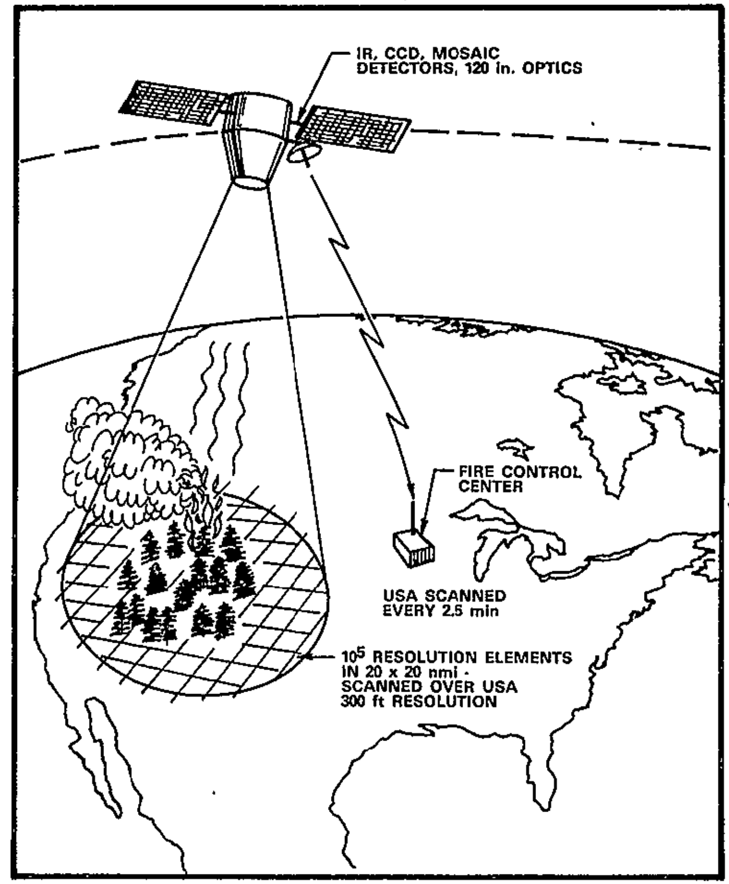
  Satellite with short and long wave infrared sensors detects fires at an early stage - transmits data to control center.

- **CHARACTERISTICS**

• **WEIGHT**	25,000 lb
• **SIZE**	15 x 60 ft
• **RAW POWER**	2 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space only)	230 M

- **PERFORMANCE**

  Detects fires as small as 10 x 10 ft. Location accuracy < 300 ft. Resolution = 300 ft - U. S. coverage every 2 1/2 minutes.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large tug
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit
• **SUBSYSTEMS**	Attitude control; sensor
• **TECHNOLOGY**	Large optical mirror; LSI data processor; CCD focal plane
• **OTHER**	None

WATER LEVEL AND FAULT MOVEMENT INDICATOR (CO-3)

- **PURPOSE**
  To make precision measurements in many places in rapid succession for aid in earthquake prediction, water resources establishment, disaster use, etc.

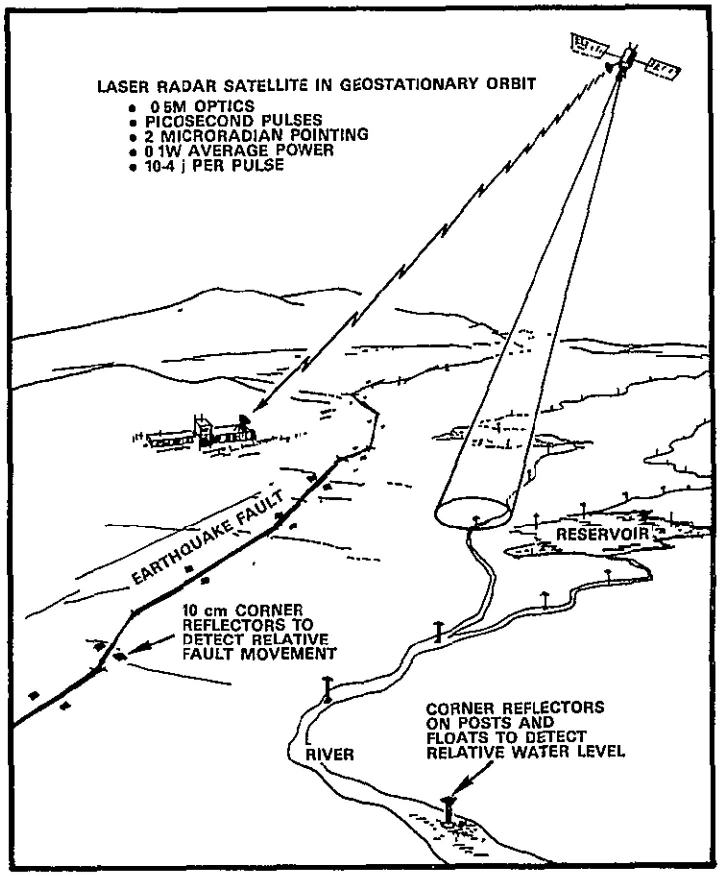
- **RATIONALE**
  Prediction of earthquakes, floods, droughts, and accurate water resources would be of great social and economic benefit.

- **CONCEPT DESCRIPTION**
  Picosecond (10^{-12} sec) pulsed laser radar in orbit obtains precision differential range measurements from corner reflectors implaced on both sides of faults, river banks and floats, etc.

- **CHARACTERISTICS**

• WEIGHT	800 lb
• SIZE	0.5 m optics
• RAW POWER	250 W
• ORBIT	Geostationary
• CONSTELLATION SIZE	1
• RISK CATEGORY	I (Low)
• TIME FRAME	1985
• IOC COST (SPACE ONLY)	50 M

- **PERFORMANCE**
  Relative range obtained to ± 0.3 millimeters at any number of points separated by 100 meters or more. 10^5 instrumented points can be measured every hour.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle, IUS/Tug
• ON-ORBIT OPERATIONS	Automated or manned servicing
• SUBSYSTEMS	Picosecond receiver, transmitter, 2 μr pointing
• TECHNOLOGY	Streak camera converter, mode locked laser and switch
• OTHER	

OCEAN RESOURCES AND DYNAMICS SYSTEM (CO-4)

- **PURPOSE**
  To locate schools of fish and to map ocean dynamic signatures.

- **RATIONALE**
  Fish protein resource yield needs to be maximized due to world protein shortage. Mapping instruments needed.

- **CONCEPT DESCRIPTION**
  Temperature and emissivity differences in surface water caused by schools of fish, currents, and plankton concentrations are detected by the differences in their self-emission in the long-wave infrared.

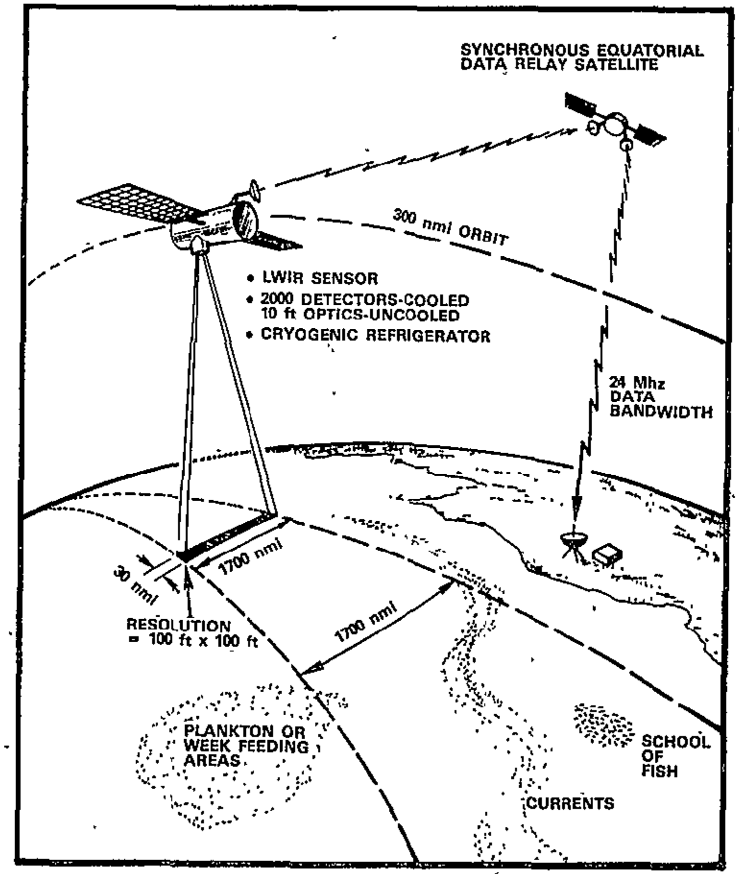
- **CHARACTERISTICS**

• WEIGHT	15,000 lb
• SIZE	10 x 60 ft
• RAW POWER	25 kW
• ORBIT	300 nmi polar
• CONSTELLATION SIZE	1
• RISK CATEGORY	I (Low)
• TIME FRAME	1985
• IOC COST (SPACE ONLY)	300 M

- **PERFORMANCE**
  100-ft resolution attained over all ocean surfaces every 12 hours. Sensitivity equivalent to 0.002 deg C achieved.

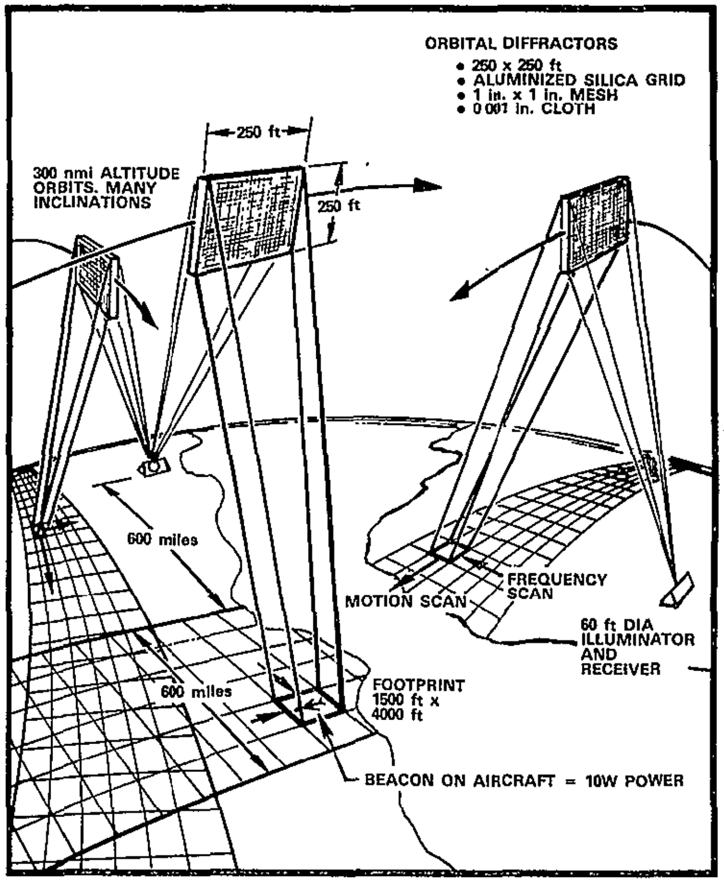
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle
• ON-ORBIT OPERATIONS	Shuttle attached manipulator
• SUBSYSTEMS	Thermal dissipation, sensor, cryogenic cooler
• TECHNOLOGY	Large LWIR sensor: cryogenic refrigerator; LSI data processor
• OTHER	None



MULTINATIONAL AIR-TRAFFIC CONTROL RADAR (CO-5)

- **PURPOSE**
  To extend radar coverage beyond the line-of-sight for Air Traffic Surveillance, and avail other countries of the same satellites.
- **RATIONALE**
  Radars are costly and many are required today due to line-of-sight limits.
- **CONCEPT DESCRIPTION**
  Orbital diffracting passive arrays allow large coverage from a few central radars. Scanning accomplished by orbital motion and frequency shift.



- **CHARACTERISTICS**

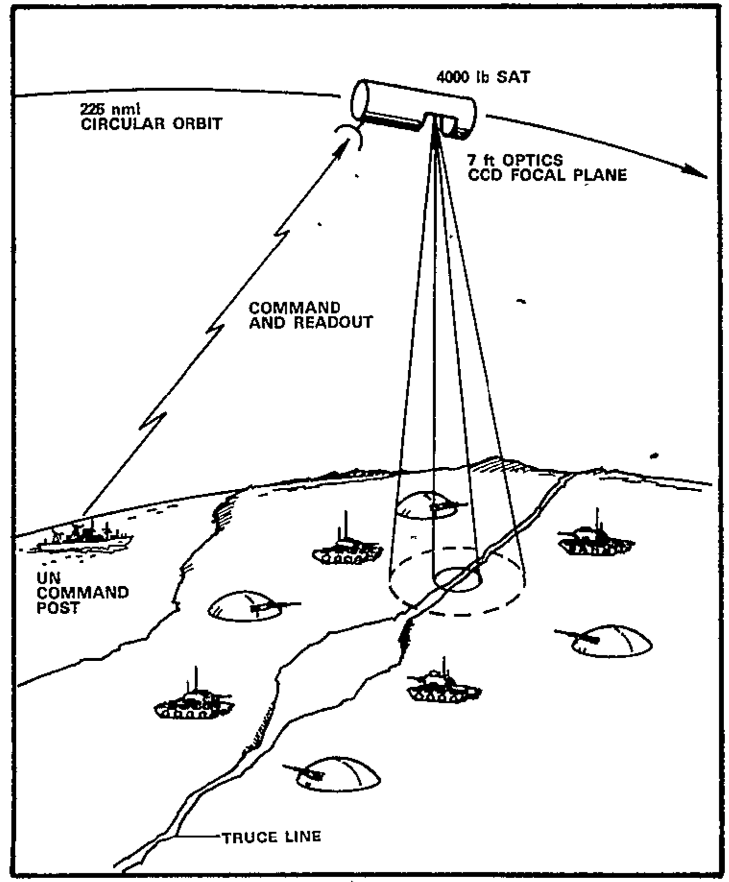
• **WEIGHT**	3,700 lb
• **SIZE**	250 x 250 ft
• **RAW POWER**	1 kW
• **ORBIT**	300 nmi, 35-50°
• **CONSTELLATION SIZE**	150
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space only)	330 M

- **PERFORMANCE**
  All aircraft equipped with 10 W beacons detected reliably for enroute control every 4 min. U.S.A. covered with three radars. Smaller countries need only 1 - 2 radars.
- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle
• **ON-ORBIT OPERATIONS**	Shuttle manipulator, automated or manual assembly/ servicing
• **SUBSYSTEMS**	Attitude control, structure
• **TECHNOLOGY**	Ion thruster, structural rigidity
• **OTHER**	None

U.N. TRUCE OBSERVATION SATELLITE (CO-6)

- **PURPOSE**
  Aid U.N. teams to monitor truce agreements, particularly border zones, and weapon system dispositions such as missile launchers.
- **RATIONALE**
  U.N. will have responsibility for truce monitoring, but will be denied on-site capability in some cases. Space systems are free from local control or interference.
- **CONCEPT DESCRIPTION**
  One low altitude satellite with visible light optics for daytime monitoring and infrared optics for night-time operation.



- **CHARACTERISTICS**

• WEIGHT	4,000 lb
• SIZE	15 x 60 ft
• RAW POWER	3 kW
• ORBIT	225 nmi near-polar
• CONSTELLATION SIZE	1
• RISK CATEGORY	I (Low)
• TIME FRAME	1985
• IOC COST (Space only)	90 M

- **PERFORMANCE**
  Ground resolution, <6 ft. (Visible) 120-ft I.R. Location accuracy, 300 ft. Truce area covered twice a day.
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle
• ON-ORBIT OPERATIONS	Shuttle attached manipulator
• SUBSYSTEMS	Focal plane
• TECHNOLOGY	Similar to weather satellites and ERTS; CCD focal plane
• OTHER	

NUCLEAR FUEL LOCATOR (CO-7)

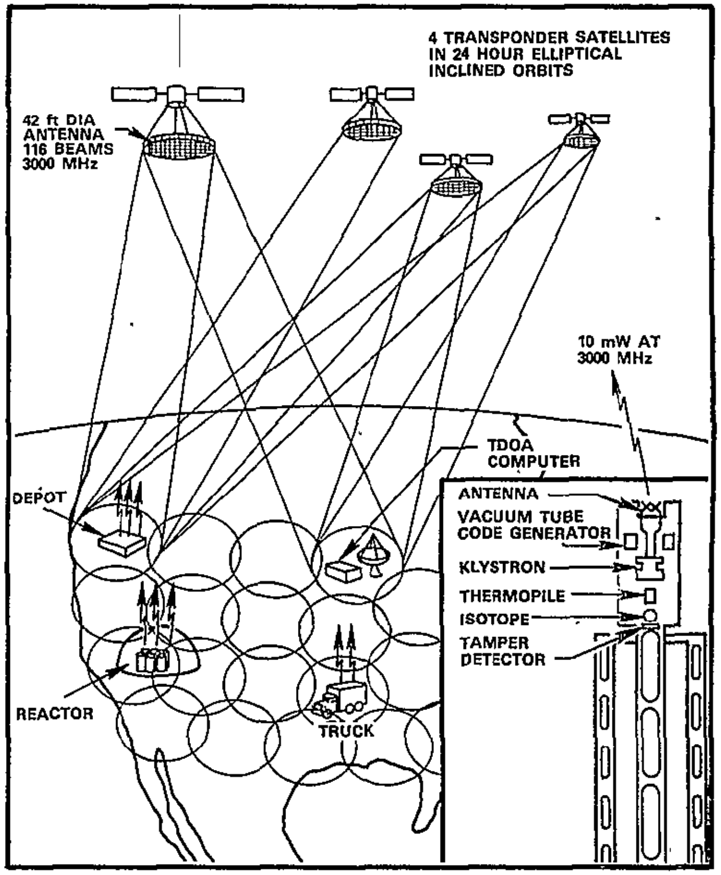
- **PURPOSE**
  To detect and locate all nuclear reactor fuel elements continuously wherever they are.

- **RATIONALE**
  Real-time monitoring of location of nuclear material needed to prevent proliferation of weapons and nuclear blackmail.

- **CONCEPT DESCRIPTION**
  Each assembly or container is tagged with a microwave generator in a tamper-indicating case. The uniquely coded signals are transponded by four satellites and the position computed by time-difference-of-arrival on the ground.

- **CHARACTERISTICS**

• WEIGHT	3000 lb
• SIZE	42 ft antenna
• RAW POWER	300 W
• ORBIT	Synch. Ellipt./Incl.
• CONSTELLATION SIZE	4
• RISK CATEGORY	I (Low)
• TIME FRAME	1985
• IOC COST (SPACE ONLY)	270 M



- **PERFORMANCE**
  Each fuel assembly identified and located to ±500 ft continuously, whether in a reactor building, in transit, or in storage; 10,000 assemblies tracked simultaneously.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and Tug
• ON-ORBIT OPERATIONS	Automated or manual service unit
• SUBSYSTEMS	Antenna, transponder
• TECHNOLOGY	Multibeam antenna - multi-channel transponder
• OTHER	LSI ground multi-channel cross-correlator receivers; high temperature and high radiation resistant vacuum tube transmitter and code generator; thermopile electrical generator; tamper alarm. Roof transponders.

BORDER SURVEILLANCE (CO-8)

- **PURPOSE**
  To detect overt or covert attempts at crossing a border.

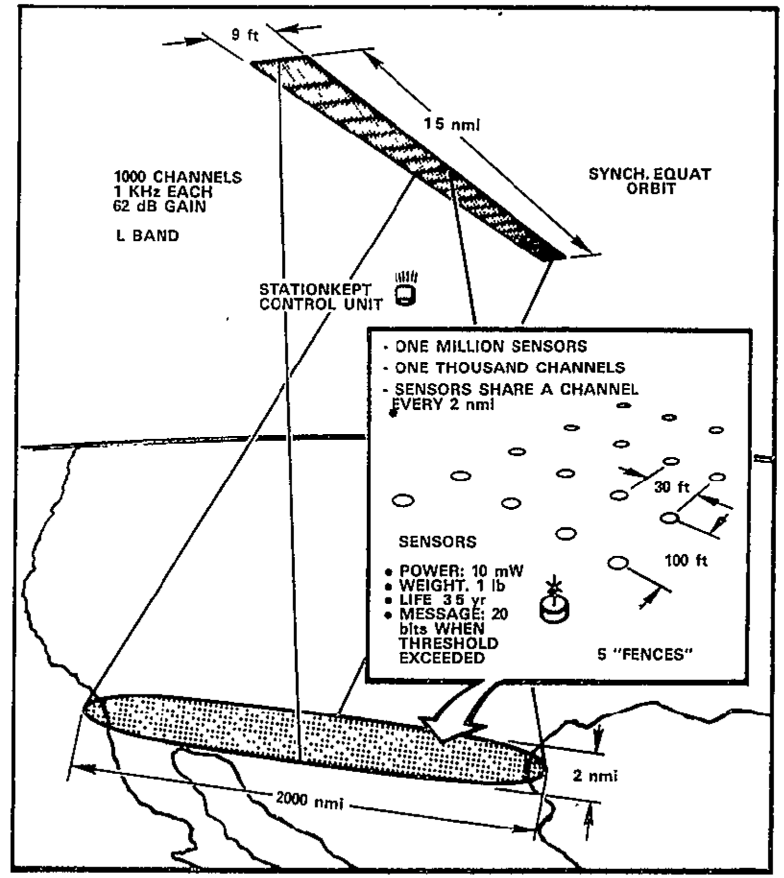
- **RATIONALE**
  Flow of illegal aliens and drug traffickers is a major problem. Detection is difficult along long, unpatrolled borders.

- **CONCEPT DESCRIPTION**
  Very many, very small seismic sensors are read out by a satellite with very large antenna. Penetration causes vibrations which are picked up and correlated at a central site.

- **CHARACTERISTICS**

• **WEIGHT**	8000 lb
• **SIZE**	9000 ft x 9 ft
• **RAW POWER**	20 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	II (Medium)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	170 M

- **PERFORMANCE**
  Virtually all moving objects detected. False alarms sorted by correlation between sensors and fences. Sensor life 3.5 years at one penetration attempt per sensor per month.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and tug
• **ON-ORBIT OPERATIONS**	Automated or manual assembly and servicing unit
• **SUBSYSTEMS**	Structure; attitude control; antenna
• **TECHNOLOGY**	Large passive microwave antenna - stationkeeping subsatellites; laser master measuring and control unit
• **OTHER**	Small, light, long-lived sensor units which are very cheap in mass production.

COASTAL ANTI-COLLISION PASSIVE RADAR (CO-9)

- **PURPOSE**
  Inexpensive and lightweight radar for all surface vessels - navigation; collision avoidance.

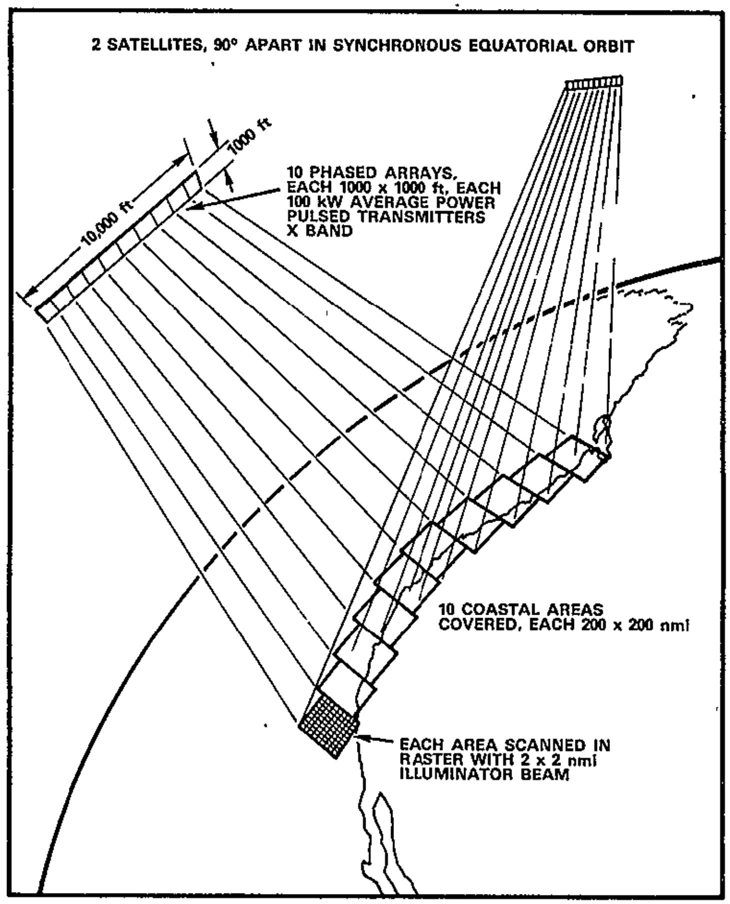
- **RATIONALE**
  Conventional radar too expensive and interference prone. Pleasure craft usually denied radar benefits.

- **CONCEPT DESCRIPTION**
  Illuminate seacoasts with scanning microwave beams from space. Scanning receiving antennas on boats obtain range and angle data on hazards.

- **CHARACTERISTICS**

• **WEIGHT**	2,000,000 lb
• **SIZE**	1,000 x 10,000 ft
• **RAW POWER**	3 MW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	2
• **RISK CATEGORY**	II (Medium)
• **TIME FRAME**	1995
• **IOC COST**	10 B

- **PERFORMANCE**
  Relative location of all objects >100 m^2 within 12 nmi range. 100 x 300 ft accuracy in 50^{o} sector. 3 x 0.5 ft antenna in vessel. Unlimited number of users.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	LLV and large tug or large SEPS
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit; assembly in orbit
• **SUBSYSTEMS**	Structures; attitude control; antenna; power
• **TECHNOLOGY**	Large adaptive microwave antenna; high power transmitters; prime power source.
• **OTHER**	

ASTRONOMICAL SUPER TELESCOPE (CO-10)

- **PURPOSE**
  To extend knowledge of universe by examination of most distant objects.

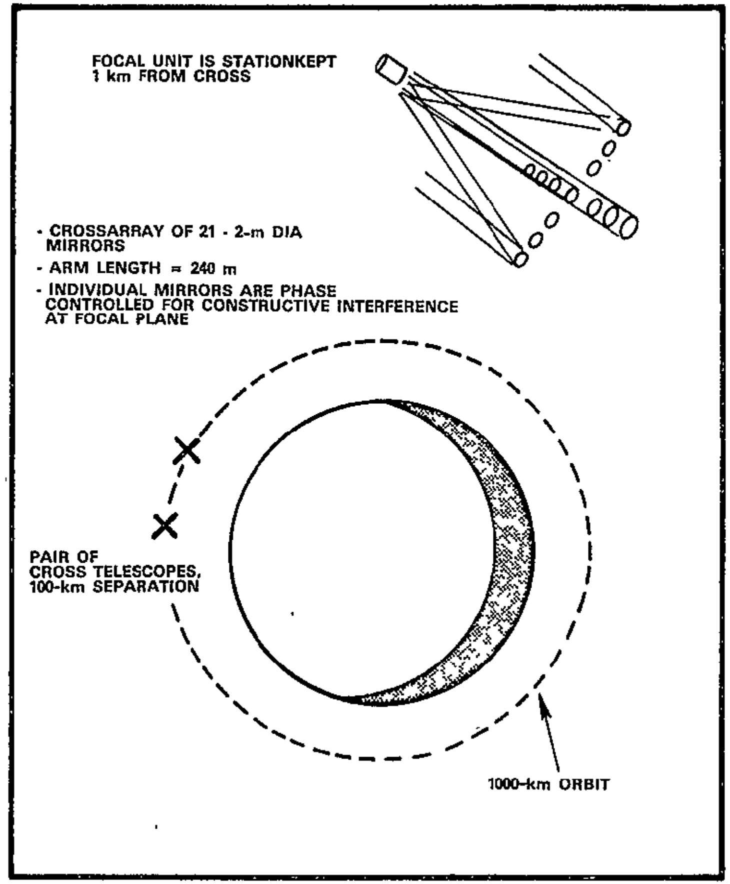
- **RATIONALE**
  Largest earth telescopes have insufficient resolution. Need even more than LST will provide.

- **CONCEPT DESCRIPTION**
  A cross-array of visible light and 100 μm mirrors is phase controlled at mirrors or near focal plane for constructive interference. Laser link to other cross-array.

- **CHARACTERISTICS**

• **WEIGHT**	40,000 lb
• **SIZE**	800 ft cross
• **RAW POWER**	10 kW
• **ORBIT**	300 nmi circular
• **CONSTELLATION SIZE**	2-100 km apart
• **RISK CATEGORY**	IV (High)
• **TIME FRAME**	2000
• **IOC COST** (Space only)	430 M

- **PERFORMANCE**
  Direct parallax measurements to 6500 light years with one cross. Resolution of one cross = 3×10^{-9} radians. Resolution of 2 crosses = 10^{-11} radians.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle
• **ON-ORBIT OPERATIONS**	Automated or manual service unit, manned assembly
• **SUBSYSTEMS**	Mirrors, stationkeeping, structure, sensor, phase control mechanism
• **TECHNOLOGY**	Adaptive focal plane, mirrors, stationkeeping sensors
• **OTHER**	

ATMOSPHERIC TEMPERATURE PROFILE SOUNDER (CO-11)

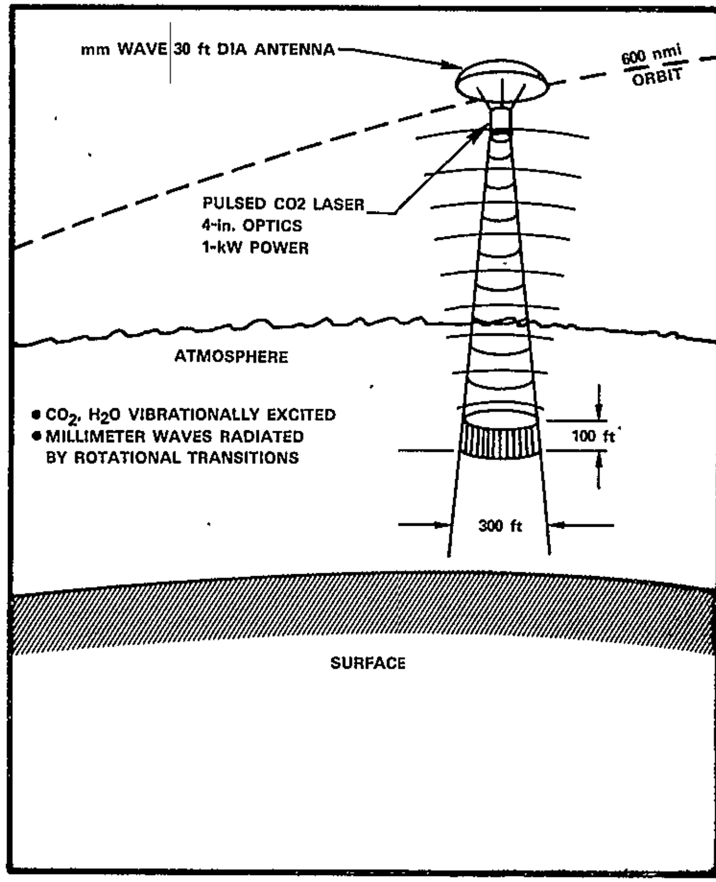
- **PURPOSE**
  To measure actual profiles of temperature in the atmosphere.

- **RATIONALE**
  Weather prediction requires knowledge of temperature profiles, as well as other phenomena.

- **CONCEPT DESCRIPTION**
  Pulsed laser vibrationally excites CO_2 or H_2O molecules. Subsequent rotational transitions in the millimeter wave spectrum show temperature dependence which is measured by ratio of energy in several lines.

- **CHARACTERISTICS**

• WEIGHT	4000 lb
• SIZE	30-ft dia antenna
• RAW POWER	5 kW
• ORBIT	600-nmi polar
• CONSTELLATION SIZE	4
• RISK CATEGORY	III (Medium)
• TIME FRAME	1990
• IOC COST (SPACE ONLY)	250 M

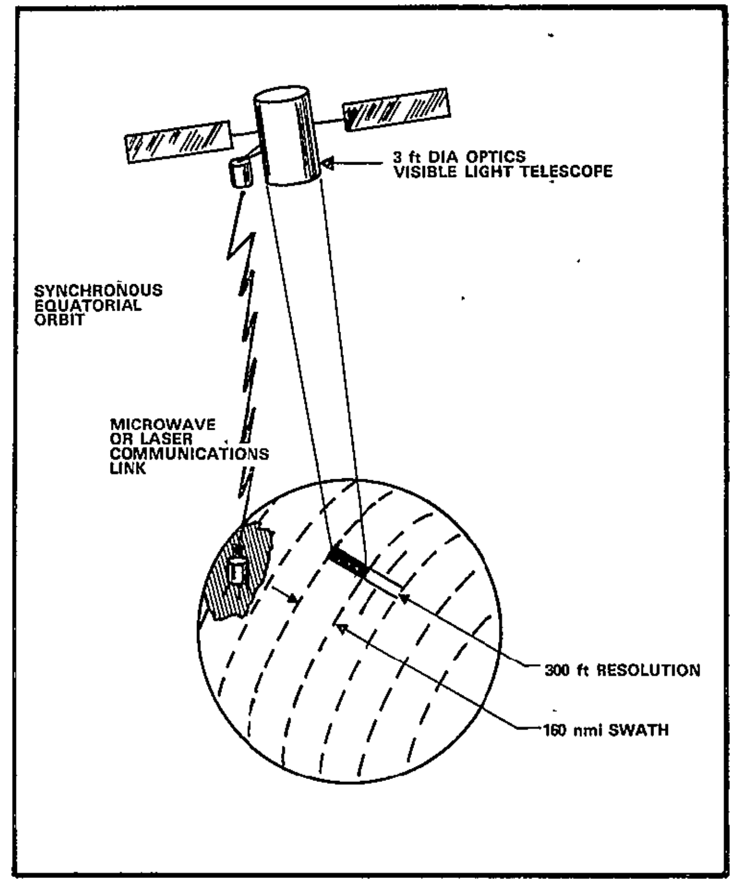


- **PERFORMANCE**
  Entire atmosphere measured, with resolution of 300 ft horizontally and 100 ft vertically, every four hours. Emission lines and signal strength imprecisely defined at present.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug/IUS
• ON-ORBIT OPERATIONS	Automated service unit/Shuttle-attached manipulator
• SUBSYSTEMS	Antenna, laser, attitude control
• TECHNOLOGY	Laser, power dissipation, antenna, pointing, sensitive heterodyne receiver
• OTHER	

SYNCHRONOUS METEOROLOGICAL SATELLITE (CO-12)



- **PURPOSE**
  To collect worldwide atmospheric data for global weather prediction.
- **RATIONALE**
  High resolution and frequent coverage of globe are needed for forecasts.
- **CONCEPT DESCRIPTION**
  Optical sensor with 1 meter mirror collects visible light data on gross meteorological features. Same instrument makes spectrum measurements for detailed information on atmosphere.
- **CHARACTERISTICS**

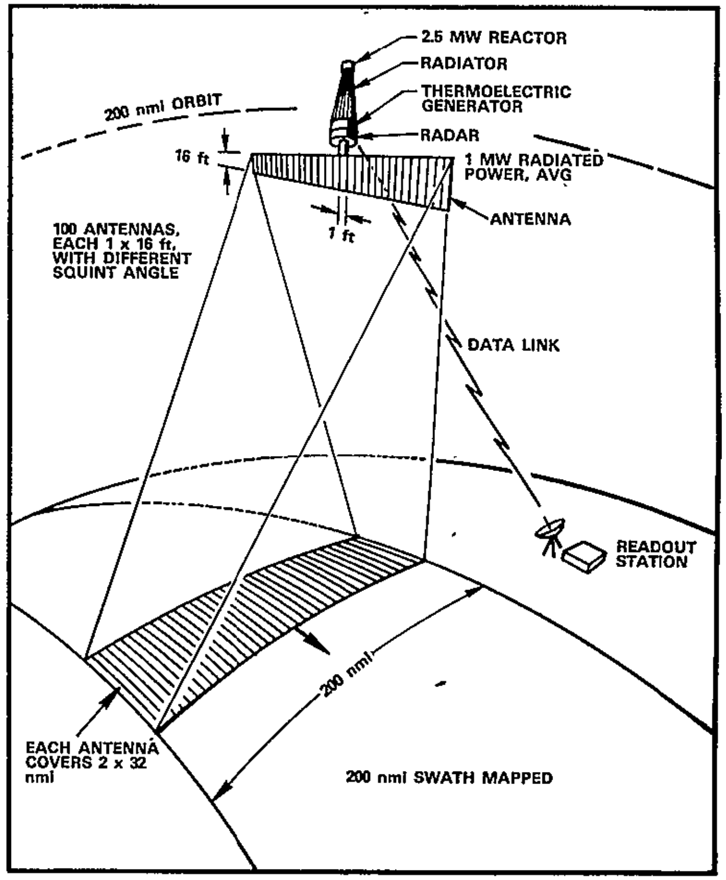
• **WEIGHT**	3,000 lb
• **SIZE**	5 x 30 ft
• **RAW POWER**	1 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	3
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space only)	190 M

- **PERFORMANCE**
  Ground resolution 300-ft dia. Scan rate: earth coverage in 20 sec for clouds, etc. Detailed measurements of spectrum every 200 sec.
- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and tug
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit
• **SUBSYSTEMS**	Laser for communications
• **TECHNOLOGY**	Laser communications link. LSI computer
• **OTHER**	Weather prediction algorithm

HIGH RESOLUTION EARTH MAPPING RADAR (CO-13)

- **PURPOSE**
  To provide maps of the surface with high resolution through cloud cover.
- **RATIONALE**
  Resources, pollution, crop, water, and other observations may be aided by high resolution and frequent coverage regardless of weather.
- **CONCEPT DESCRIPTION**
  Synthetic array radar of very high power provides high resolution. On-board image processing allows microwave data link for all weather capability.
- **CHARACTERISTICS**
  - **WEIGHT** 110,000 lb
  - **SIZE** 16 x 100 ft
  - **RAW POWER** 2.5 MW
  - **ORBIT** 200 nmi polar
  - **CONSTELLATION SIZE** 1
  - **RISK CATEGORY** II (Medium)
  - **TIME FRAME** 1990
  - **IOC COST** (Space only) 500 M
- **PERFORMANCE**
  200 nmi ground swath mapped to less than a few feet resolution once a day. U. S. covered every six days.



- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** Shuttle
  - **ON-ORBIT OPERATIONS** Shuttle manipulator; servicing
  - **SUBSYSTEMS** Thermal, nuclear, power generator, radar
  - **TECHNOLOGY** High power transmitter; automated image processor, reactor, shielding
  - **OTHER** None

INTERPLANETARY T.V. LINK (CO-14)

- **PURPOSE**

  To provide for color T.V., live reception over planetary ranges.

- **RATIONALE**

  Complex missions and information needs will require live T.V. communications.

- **CONCEPT DESCRIPTION**

  Large reflector in synchronous orbit is used to detect laser energy from planetary probe, and modulates microwave transmitter. Signal detected by earth tracking station.

- **CHARACTERISTICS**

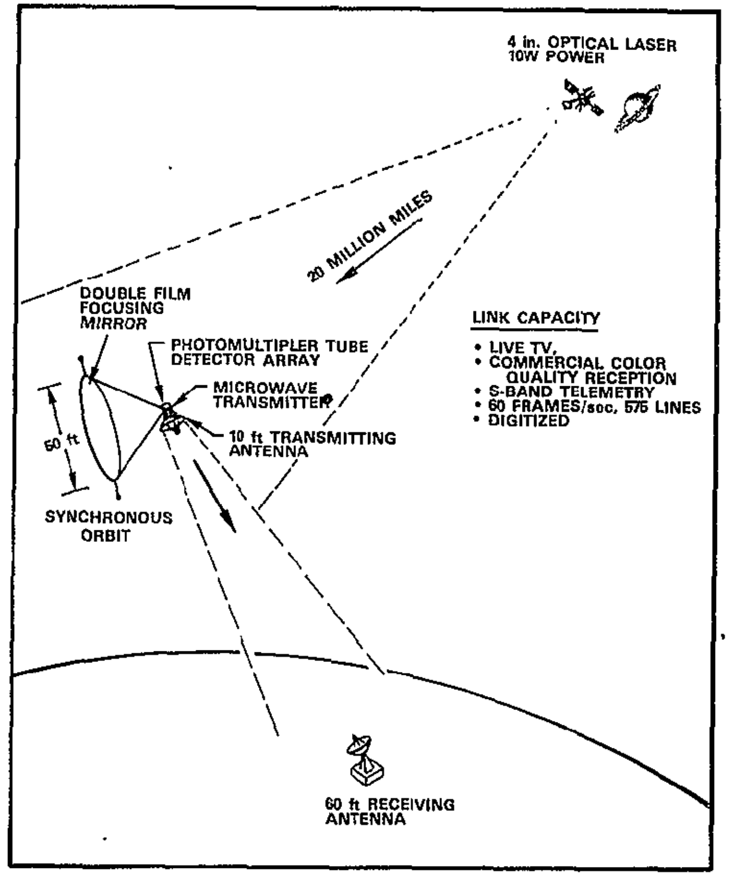
• **WEIGHT**	1,000 lb
• **SIZE**	50-ft dia
• **RAW POWER**	250 W
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space Only)	40 M

- **PERFORMANCE**

  Live - 60 frames/second color T.V., commercial image quality (or equivalent) transmitted over 20 million miles to 60-ft ground antennas. 4 in. laser and 10W suffice in transmitter.

- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle, IUS/tug
• **ON-ORBIT OPERATIONS**	Automated servicing
• **SUBSYSTEMS**	Thin film mirror
• **TECHNOLOGY**	Thin film self-supporting structure
• **OTHER**	



GLOBAL SEARCH + RESCUE LOCATOR (CC-1)

- **PURPOSE**
  To locate emergency transmitters worldwide; to allow small, lightweight transmitters.

- **RATIONALE**

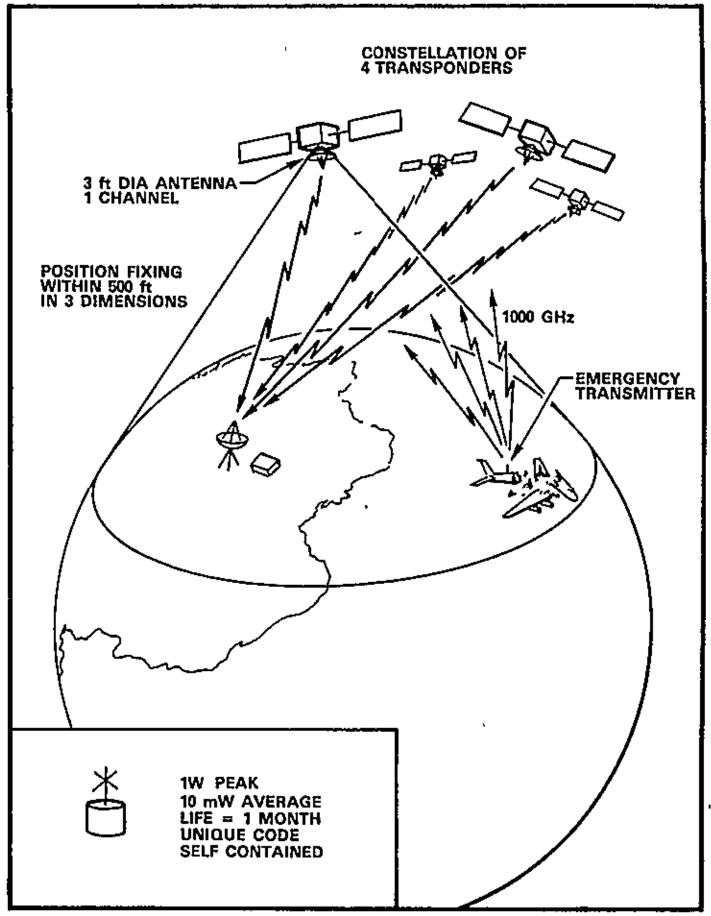
  Search for rescue is expensive and not always successful.

- **CONCEPT DESCRIPTION**
  Coded, small transmitter in emergency package carried by traveling boats, aircraft. Signals received and transponded by satellites, and location computed by TDOA techniques.

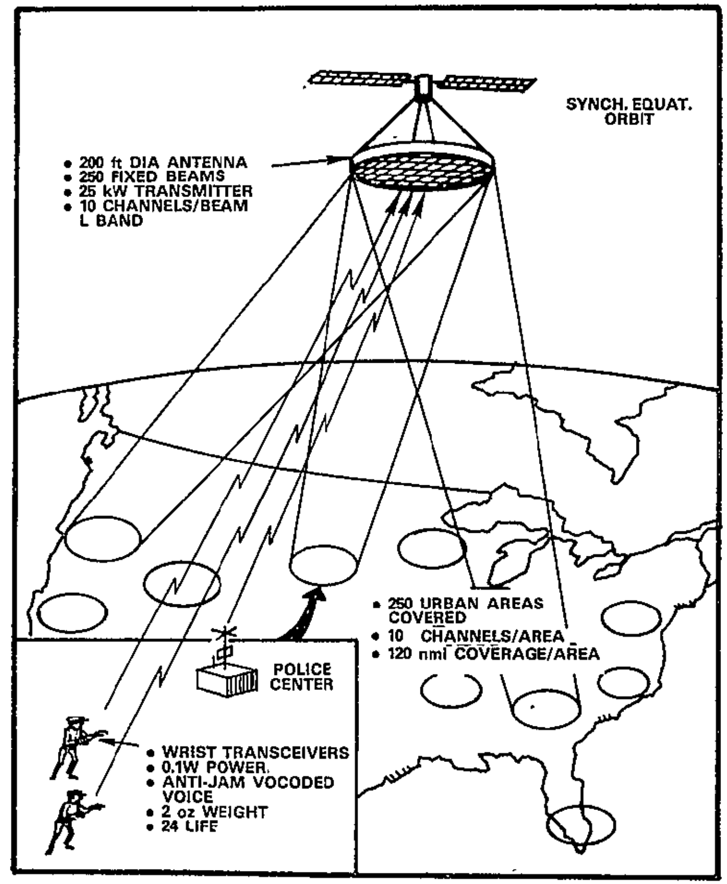
- **CHARACTERISTICS**
  - **WEIGHT** 1500 lb
  - **SIZE** 5 x 20 ft
  - **RAW POWER** 1 kW
  - **ORBIT** Near-Synch., or Med. Alt.
  - **CONSTELLATION SIZE** 20
  - **RISK CATEGORY** I (Low)
  - **TIME FRAME** 1985
  - **IOC COST** (Space only) 350 M

- **PERFORMANCE**
  Location of up to 1000 simultaneous emergency transmitters to 500 ft in three coordinates, anywhere, worldwide.

- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** Expendable or shuttle and tug
  - **ON-ORBIT OPERATIONS** Automated servicing unit
  - **SUBSYSTEMS** No unusual requirements
  - **TECHNOLOGY** No unusual requirements
  - **OTHER** None



URBAN/POLICE WRIST RADIO (CC-2)



- **PURPOSE**
  To give real-time, secure, anti-jam, high coverage, wide area personal communications to each policeman.

- **RATIONALE**
  Portable/personal sets needed to increase police mobility/safety. Jamming/eavesdropping will become routine.
- **CONCEPT DESCRIPTION**
  Wrist 2-way transceiver and channelized Comsat give instant 2-way communications to patrolmen. Multibeam antenna, anti-jam processing, and pseudo-random coding make jamming difficult.
- **CHARACTERISTICS**

• **WEIGHT**	18,000 lb
• **SIZE**	200-ft dia antenna
• **RAW POWER**	75 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	1 (Low)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	390 M

- **PERFORMANCE**
  10 Channels/city area, 250 areas simultaneously. Resists 1 kW uplink jammer and 40 kW downlink jammer two miles distant.

- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large tug or SEP'S
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit; assembly on orbit
• **SUBSYSTEMS**	Attitude control; antenna; processor
• **TECHNOLOGY**	Large multibeam antenna; multi-channel transponder; LSI processor; multi-access techniques
• **OTHER**	Wrist transceiver, LSI technology

DISASTER COMMUNICATIONS SET (CC-3)

- **PURPOSE**

  To provide communications, command, and control to disaster area emergency personnel.

- **RATIONALE**

  Lack of communications hampers quick and effective handling of emergencies.

- **CONCEPT DESCRIPTION**

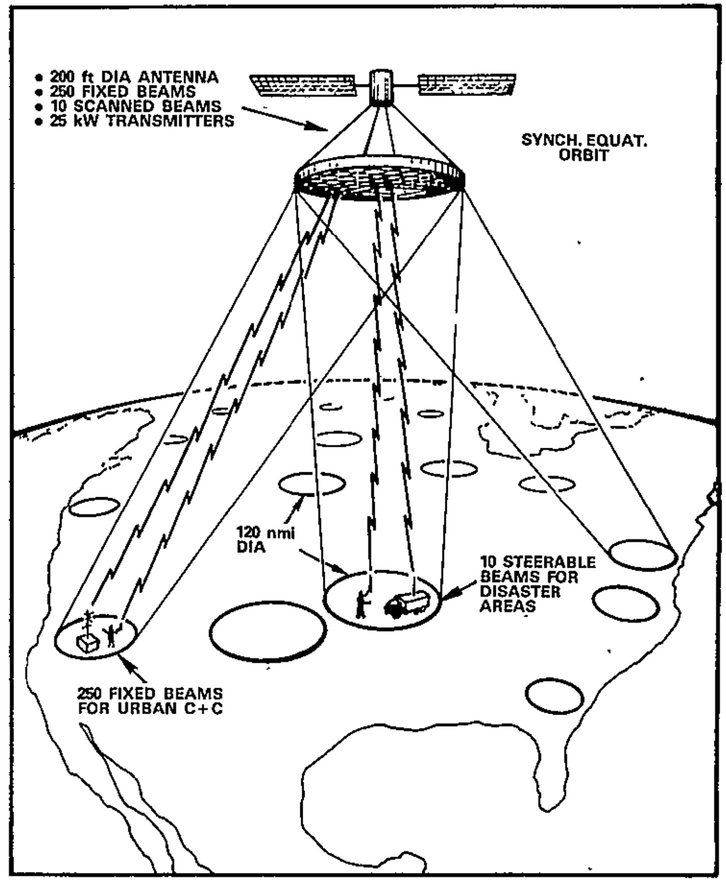
  Wrist 2-way transceivers connected to each other and to control centers through multi-channel Comsat. Anti-jam.

- **CHARACTERISTICS**

• WEIGHT	18,000 lb
• SIZE	200-ft dia antenna
• RAW POWER	75 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• RISK CATEGORY	1 (Low)
• TIME FRAME	1990
• IOC COST	390 M

- **PERFORMANCE**

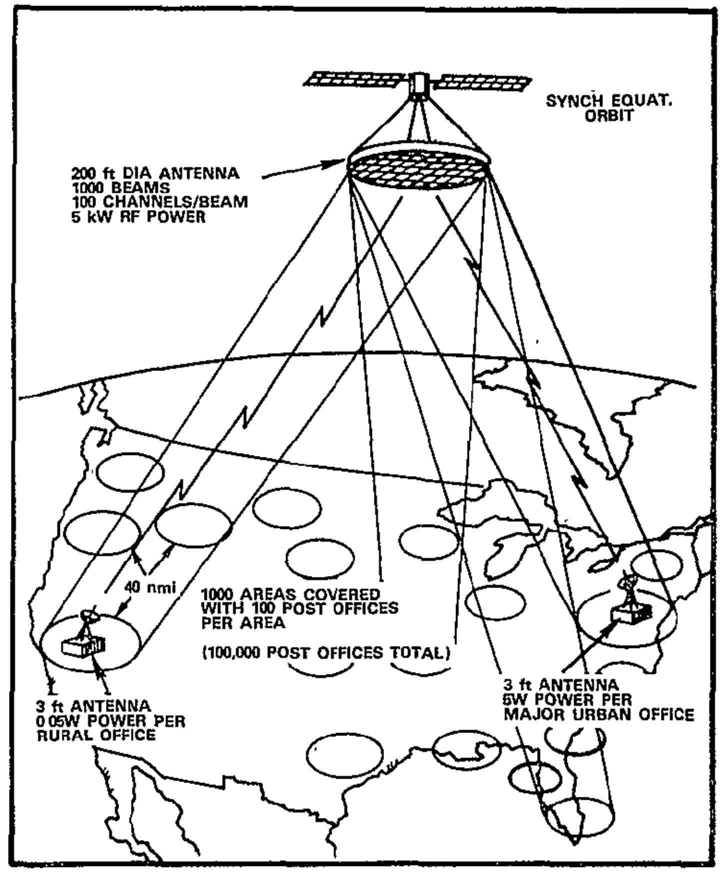
  Provides 10 disaster areas and 250 urban centers with 10 channels of voice communications each. Secure, anti-jam coded.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug or SEPS
• ON-ORBIT OPERATIONS	Automated or manual servicing unit; assembly on orbit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor; multi-access techniques
• OTHER	None

ELECTRONIC MAIL TRANSMISSION (CC-4)



- **PURPOSE**

  To speed up delivery and lower costs of most mail.
  To service thinly populated areas.

- **RATIONALE**

  Delivery of physical letters is slow and needless in most cases when locally reproduced facsimile could do.

- **CONCEPT DESCRIPTION**

  Page readers and facsimile printers at each post office read, transmit, receive, and reproduce mail. Satellite acts as multi-channel repeater.

- **CHARACTERISTICS**

• **WEIGHT**	20,000 lb
• **SIZE**	200-ft dia antenna
• **RAW POWER**	15 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	430 M

- **PERFORMANCE**

  Transmits facsimile at 10 pages (8 1/2 x 11") per second per post office. Up to 100,000 post offices serviced in up to 50% of area of U. S. A. Total service = 100 billion pages/day.

- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large tug or SEPS
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit; assembly on orbit
• **SUBSYSTEMS**	Attitude control; antenna; processor
• **TECHNOLOGY**	Large multibeam antenna; multi-channel transponder; LSI processor; multiple-access techniques
• **OTHER**	None

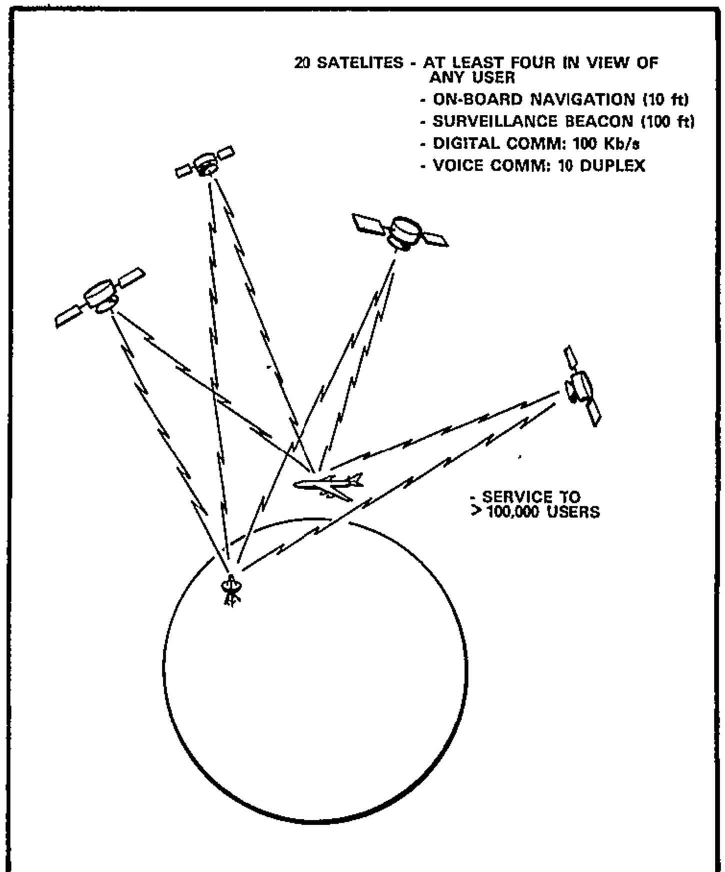
TRANSPORTATION SERVICES SATELLITES (CC-5)

- **PURPOSE**
  Simultaneously satisfy traffic control, air surveillance, navigation, position fixing, command/control for multiplicity of uses.
- **RATIONALE**
  Similar and overlapping requirements by many agencies for precision navigation enable one comprehensive system to meet all needs for all users.
- **CONCEPT DESCRIPTION**
  Comsat transponders are used, with four in view of user at different angles/ranges, to provide TDOA position fixing and 2-way communications.
- **CHARACTERISTICS**

• WEIGHT	1400 lb
• SIZE	6 x 8 ft
• RAW POWER	600 W
• ORBIT	8000 nmi polar
• CONSTELLATION SIZE	20
• RISK CATEGORY	I (Low)
• TIME FRAME	1985
• IOC COST (Space only)	350 M

- **PERFORMANCE**
  100,000 users serviced; position to 30 ft, surveillance of beacon to 100 ft, digital communications of 100 kb/sec.
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Expendable or shuttle and tug
• ON-ORBIT OPERATIONS	Automated servicing unit
• SUBSYSTEMS	No unusual requirements
• TECHNOLOGY	No unusual requirements
• OTHER	None

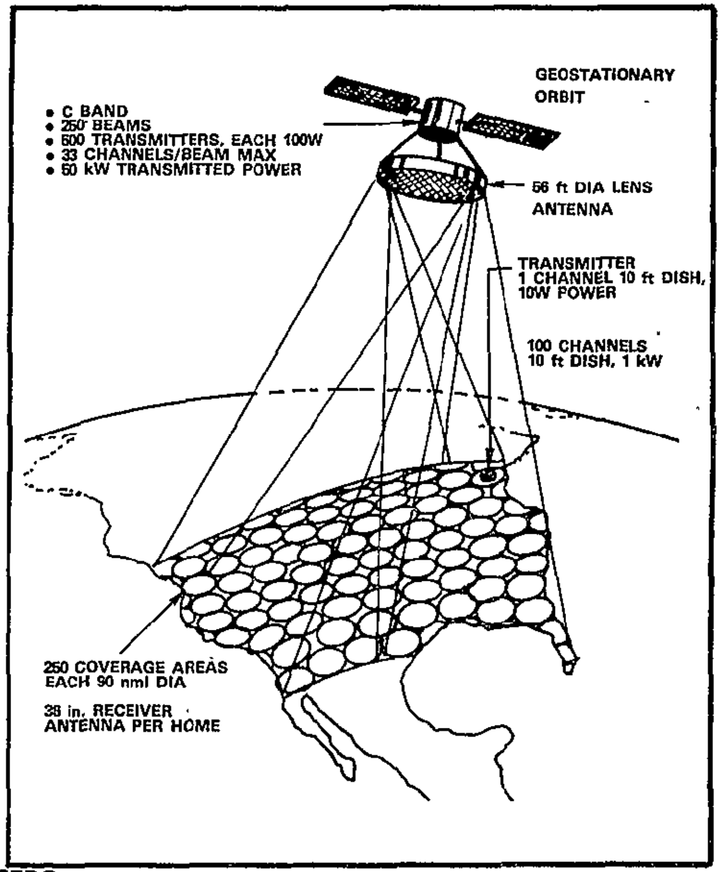


ADVANCED T.V. BROADCAST (CC-6)

- **PURPOSE**
  To make T.V. available to all locations in U.S., with small receiver antennas.

- **RATIONALE**
  Mountainous, rural, and remote areas currently have poor or no service due to line-of-sight transmissions.

- **CONCEPT DESCRIPTION**
  Powerful satellite in geostationary orbit makes reception possible in all U.S. areas with very small antennas.



- **CHARACTERISTICS**

• **WEIGHT**	14,000 lb
• **SIZE**	56-ft antenna
• **RAW POWER**	150 kW
• **ORBIT**	Geosynchronous
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	460 M

- **PERFORMANCE**
  512 color T.V. channels broadcast to U.S. land area, covered in 250 beams, each with 90-mi footprint. Local stations can distribute program anywhere.

- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large tug or SEPS
• **ON-ORBIT OPERATIONS**	Automated or manned servicing
• **SUBSYSTEMS**	100 W output tube, 60-ft multibeam antenna
• **TECHNOLOGY**	Processor/filters
• **OTHER**	None

VOTING/POLLING WRIST SET (CC-7)

- **PURPOSE**

  To provide direct access to entire population for voting or polling purposes.

- **RATIONALE**

  Voting and polling are time-consuming processes, subject to many errors due to small sample size.

- **CONCEPT DESCRIPTION**

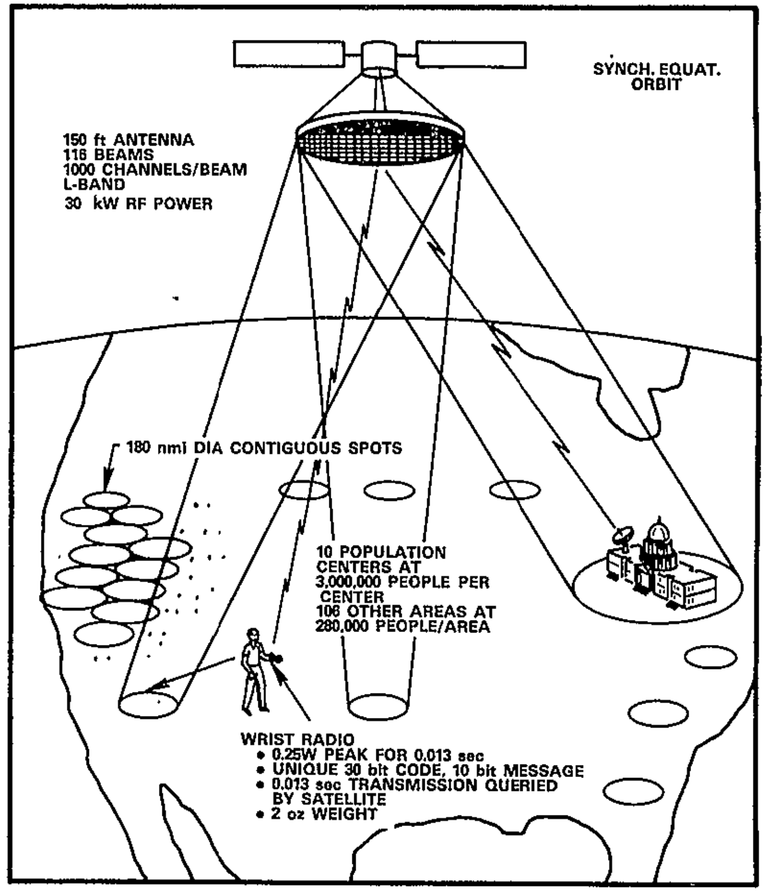
  Multi-channel satellite queries wrist radios, and relays responses to Washington from individual voters. Unique voter pseudo-random codes.

- **CHARACTERISTICS**

• WEIGHT	13,000 lb
• SIZE	150-ft dia antenna
• RAW POWER	90 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• RISK CATEGORY	1 (Low)
• TIME FRAME	1990
• IOC COST (Space only)	300 M

- **PERFORMANCE**

  100,000,000 people polled/vote in one hour. Any 10-bit message relayed automatically upon query by satellite.



- **BUILDING BLOCK REQUIREMENTS**

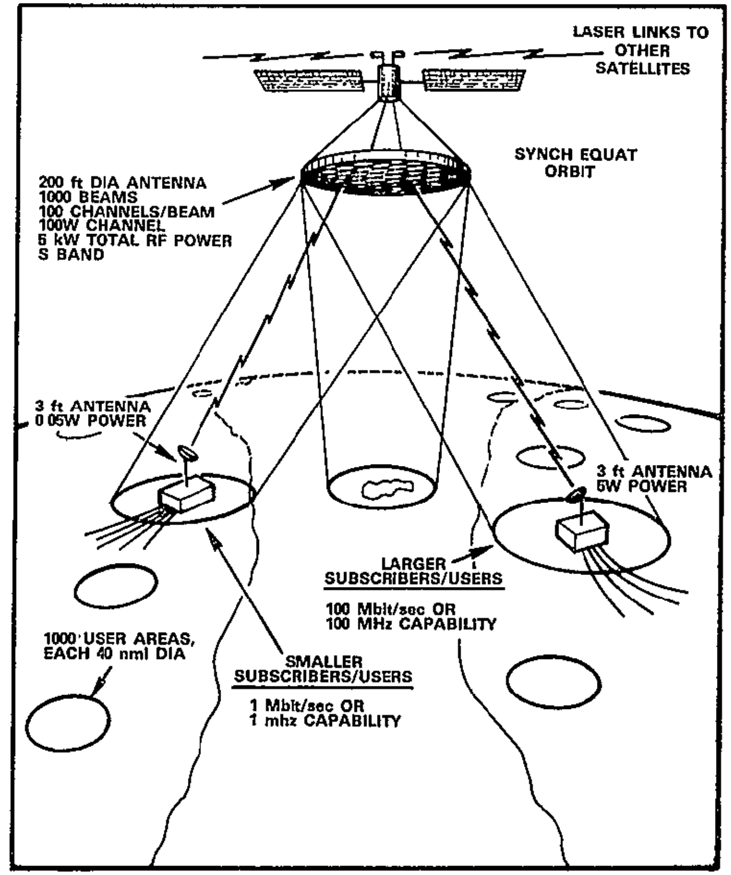
• TRANSPORTATION	Shuttle and tandem tug
• ON-ORBIT OPERATIONS	Automated or manual servicing unit; assembly on orbit
• SUBSYSTEMS	Attitude control; antenna; processor
• TECHNOLOGY	Large multibeam antenna; multi-channel transponder; LSI processor; multiple-access techniques
• OTHER	LSI wrist transceiver

NATIONAL INFORMATION SERVICES (CC-8)

- **PURPOSE**
  To provide a National or Intelsat adjunct network with capability to serve small-antenna users.
- **RATIONALE**
  Current satellites require very large antennas and therefore have few entry points - not suited for "disadvantaged" users.
- **CONCEPT DESCRIPTION**
  Large multibeam antenna satellites link facsimile, voice, data, and teletype terminals with low power and small antennas. Satellite is a multi-channel processing repeater.
- **CHARACTERISTICS**

• **WEIGHT**	20,000 lb
• **SIZE**	200-ft dia antenna
• **RAW POWER**	15 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	4
• **RISK CATEGORY**	1 (Low)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	1.1 B

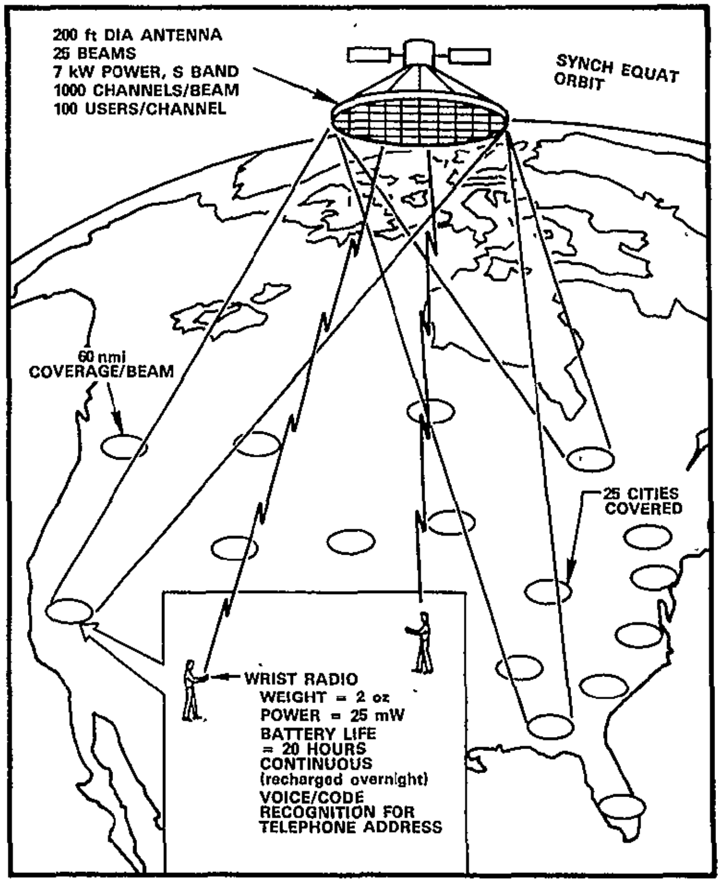
- **PERFORMANCE**
  400,000 channels of 1 Mbit/sec or 1 MHz capability serviced in 4000 areas worldwide, with 0.05-W transmitters and 3-ft antennas at user terminals.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large tug or SEPS
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit; assembly on orbit
• **SUBSYSTEMS**	Attitude control; antenna; processor
• **TECHNOLOGY**	Large multibeam antenna; multi-channel transponder; LSI processor; multiple-access techniques
• **OTHER**	

PERSONAL COMMUNICATIONS WRIST RADIO (CC-9)



- **PURPOSE**
  To allow citizens to communicate through exchanges by voice, from anywhere.

- **RATIONALE**
  Mobile telephones are desirable, but should be wrist worn. Uses include emergency, recreation, business, rescue, etc.

- **CONCEPT DESCRIPTION**
  Multichannel switching satellite and wrist transmitter-receivers connect people anywhere to each other directly or to telephone networks. Analog or vocoded voice used.

- **CHARACTERISTICS**

• **WEIGHT**	16,000 lb
• **SIZE**	200 ft dia antenna
• **RAW POWER**	21 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1990
• **IOC COST** (SPACE ONLY)	300M

- **PERFORMANCE**
  25,000 simultaneous voice channels, each shared by up to 100 users: 2.5 million people communicate by normal voice.

- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large/tandem tug or SEPS
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit; assembly on orbit
• **SUBSYSTEMS**	Attitude control; antenna; processor; repeater
• **TECHNOLOGY**	Large multibeam antenna; multi-channel repeater; LSI processor, multiple-access techniques
• **OTHER**	Wrist transceiver, LSI technology

DIPLOMATIC/U.N. HOTLINES (CC-10)

- **PURPOSE**

  To provide rapid, reliable, secure communications between heads of state (or embassies).

- **RATIONALE**

  Good, rapid communications needed to reduce dangers of escalation in international situations.

- **CONCEPT DESCRIPTION**

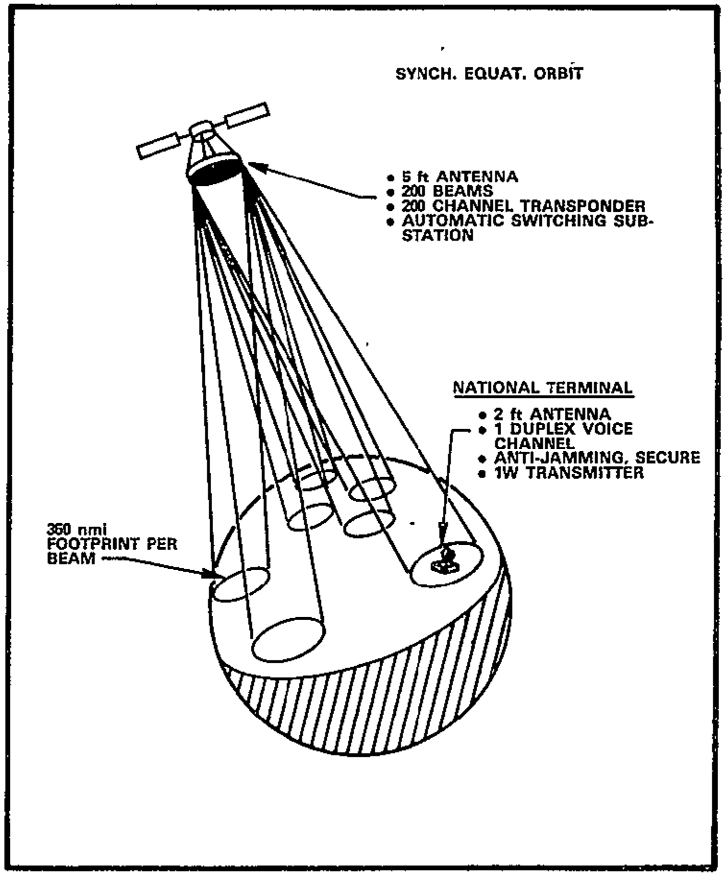
  Multibeam antenna Comsat crosslinks any or all terminals, one per country. Satellite processing is autonomous and not subject to capture.

- **CHARACTERISTICS**

• **WEIGHT**	3000 lb
• **SIZE**	5 x 20 ft
• **RAW POWER**	1 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	3
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space only)	330 M

- **PERFORMANCE**

  One full duplex voice channel per country, secure, 200 countries accommodated. Automatic switching in satellite; or multiple access user-controlled.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and IUS/tug
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit
• **SUBSYSTEMS**	Attitude control; antenna; processor and switch
• **TECHNOLOGY**	Multibeam antenna; multi-channel transponder; LSI processor and automatic switch; multiple-access techniques
• **OTHER**	None

3-D HOLOGRAPHIC TELECONFERENCING (CC-11)

- **PURPOSE**

  To greatly reduce the need to travel for most government or private industry business conferences without significant loss in ability to transact business.

- **RATIONALE**

  Travel for conferences is costly, time consuming, and inefficient.

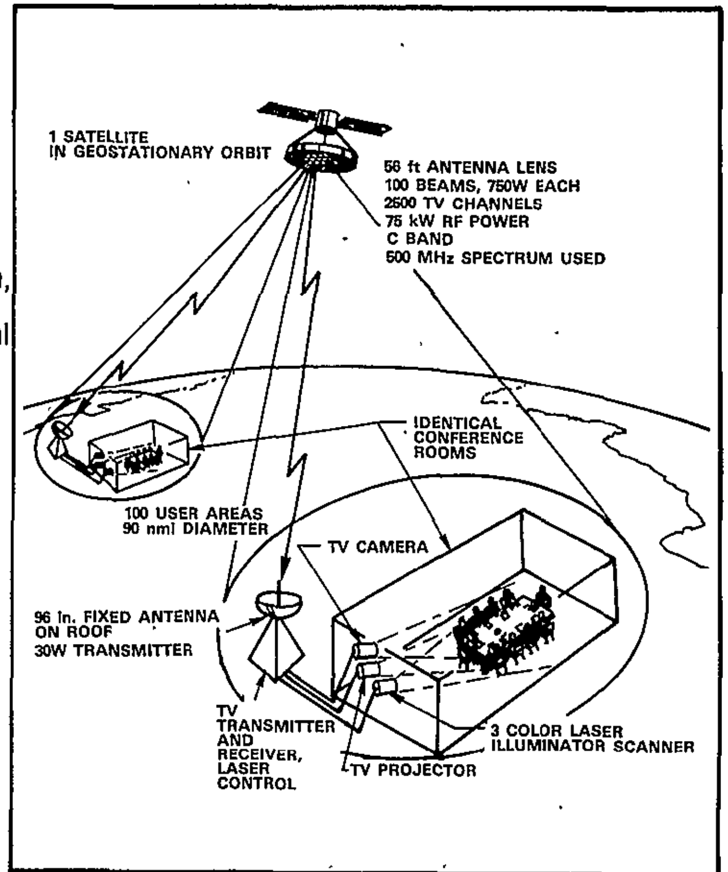
- **CONCEPT DESCRIPTION**

  Identical conference rooms are fitted with a T.V. camera, T.V. projector, and laser illuminator and stereo sound system. Resulting holograms produce three-dimensional images that can walk, talk, and present data.

- **CHARACTERISTICS**
  - **WEIGHT** 15,000 lb
  - **SIZE** 56-ft antenna
  - **RAW POWER** 220 kW
  - **ORBIT** Geostationary
  - **CONSTELLATION SIZE** 1
  - **RISK CATEGORY** III (Medium)
  - **TIME FRAME** 1990
  - **IOC COST** (Space only) 500 M

- **PERFORMANCE**

  1,250 identical conference rooms in 100 urban areas interconnected simultaneously with 3-D color holographic images and stereo sound.



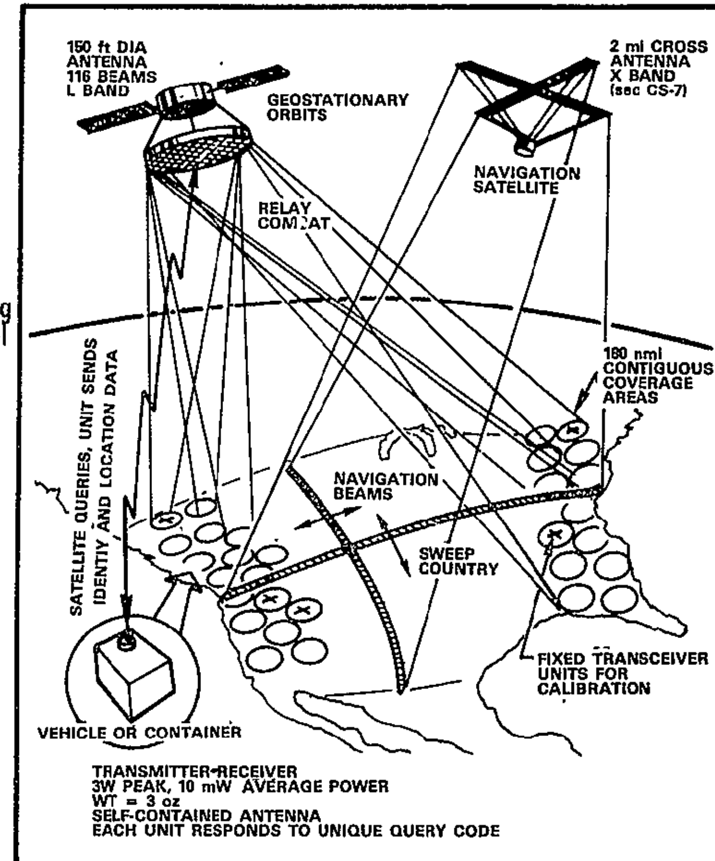
- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** Shuttle, large/tandem tug or SEPS
  - **ON-ORBIT OPERATIONS** Automated or manual assembly and servicing
  - **SUBSYSTEMS** Large multibeam antennas, processors, high power transmitter
  - **TECHNOLOGY** High power transmitters - LSI processors, prime power source
  - **OTHER** User equipment, holographic quality, image motion compensation

VEHICLE / PACKAGE LOCATOR (CC-12)

- **PURPOSE**
  To locate vehicles or articles in shipment continuously anywhere in U. S. A.
- **RATIONALE**
  To aid in prevention of theft or hijacking, increase efficiency, and minimize error in shipments
- **CONCEPT DESCRIPTION**
  A small transceiver is attached to (or enclosed in) each unit to be tracked. The unit determines its location using crossed antenna NAVSAT, and relays the data to a control center via a special Comsat when queried.
- **CHARACTERISTICS**

• **WEIGHT**	20,000 lb (Total)
• **SIZE**	2-mi antenna
• **RAW POWER**	23 kW
• **ORBIT**	Geostationary
• **CONSTELLATION SIZE**	2
• **RISK CATEGORY**	II (Medium)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	400 M

- **PERFORMANCE**
  Up to one billion vehicles or containers can be located ± 300 ft every hour anywhere in U. S. A. Location package could cost less than $10, weigh 3 ounces.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large/tandem tug or SEPS
• **ON-ORBIT OPERATIONS**	Automated or manned assembly and servicing
• **SUBSYSTEMS**	Antenna attitude control, laser radar, channelizer/processor, stationkept antenna
• **TECHNOLOGY**	Phase control, LSI processor, multiple access technique, stationkept sub-units
• **OTHER**	Cheap - LSI - container - transponder

ENERGY GENERATION - SOLAR/MICROWAVE (CS-1)

- **PURPOSE**
  To provide abundant electrical power with little pollution.

- **RATIONALE**

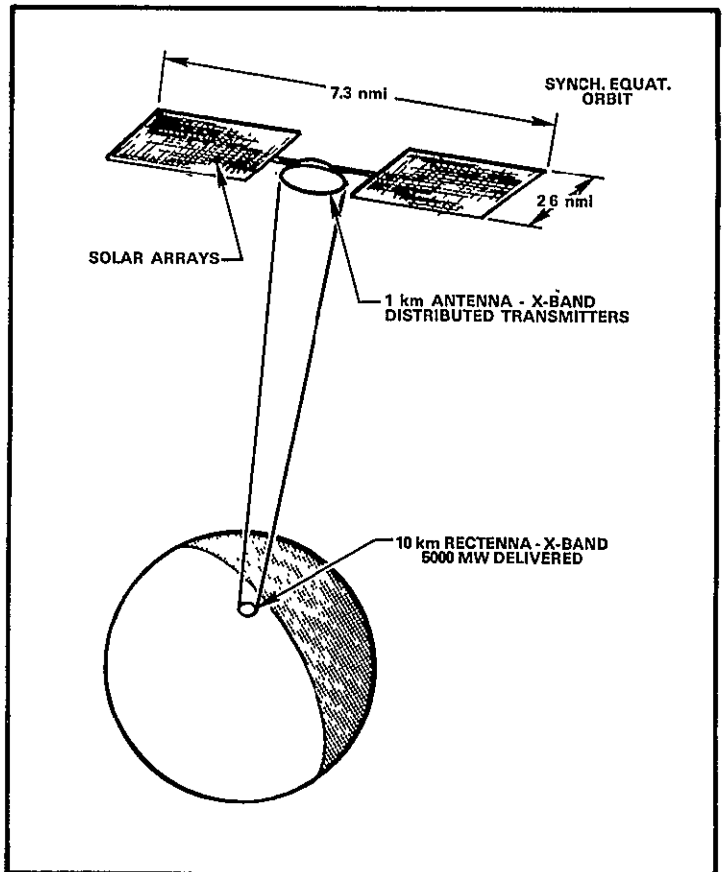
  More and clean energy needed.

- **CONCEPT DESCRIPTION**
  Solar energy is collected, converted to microwave energy, and transmitted to earth, where it is rectified to DC by a rectenna.

- **CHARACTERISTICS**

• **WEIGHT**	40,000,000 lb
• **SIZE**	7.3 x 2.6 nmi
• **RAW POWER**	10,000 MW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	IV (High)
• **TIME FRAME**	2000
• **IOC COST** (Space only)	61 B

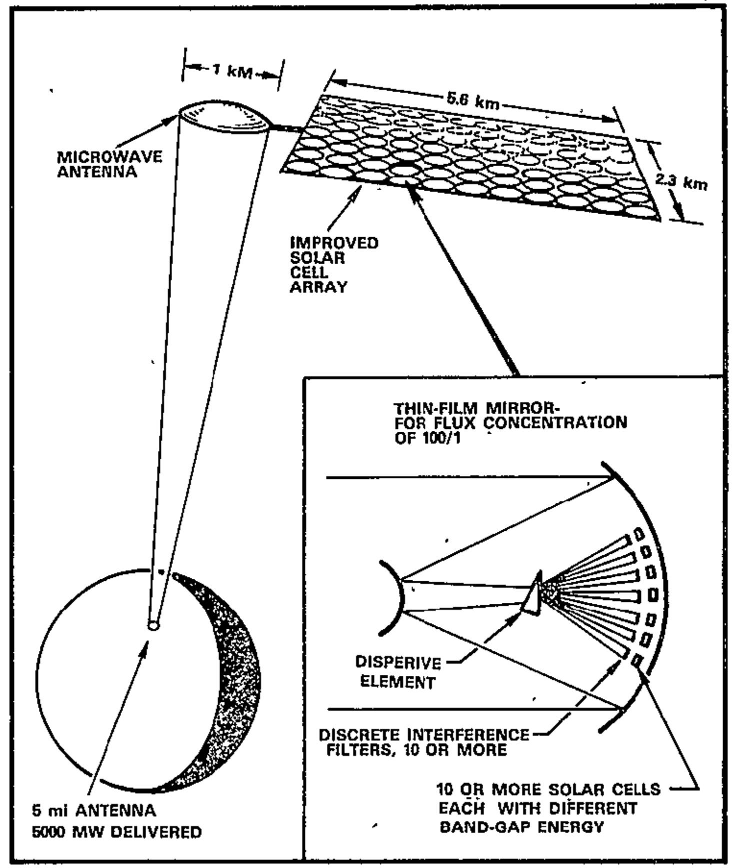
- **PERFORMANCE**
  5,000 megawatts supplied to 10 km collector, with less than 500 MW lost as heat to the environment, at a cost of ≈ $1,500 per kW.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	LLV and large tug and large SEPS
• **ON-ORBIT OPERATIONS**	Manned servicing unit; assemble in orbit
• **SUBSYSTEMS**	Attitude control; structures, power antenna
• **TECHNOLOGY**	Large economical solar arrays; large active microwave antenna; high power tubes; feeding and cross-connects
• **OTHER**	Rectenna on ground

HIGH EFFICIENCY SOLAR ENERGY GENERATION (CS-2)



- **PURPOSE**

  To increase the efficiency and decrease the cost of solar power delivery from space.

- **RATIONALE**

  Solar power satellites will be large, heavy, and expensive.

- **CONCEPT DESCRIPTION**

  Efficiency and cost of solar-voltaic conversion can be greatly increased by using multiple cells, each tailored to the photon energy in a restricted spectrum; and by using high ratio solar flux concentration.

- **CHARACTERISTICS**

• WEIGHT	8,000,000 lb
• SIZE	5.6 x 2.3 km
• RAW POWER	10,000 MW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• RISK CATEGORY	IV (High)
• TIME FRAME	2000
• IOC COST	TBD

- **PERFORMANCE**

  Same power delivered with one fifth the weight in orbit compared to the current solar power satellite concept (CS-1) and probable but undetermined cost reduction.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	LLV and large tug and large SEPS
• ON-ORBIT OPERATIONS	Manned servicing unit; assemble in orbit
• SUBSYSTEMS	Attitude control; structures; power antenna
• TECHNOLOGY	Large economical solar arrays; large active microwave antenna; high power tubes; lightweight concentrator; thermal design
• OTHER	Rectenna on ground

ENERGY GENERATION - NUCLEAR/MICROWAVE (CS-3)

- **PURPOSE**

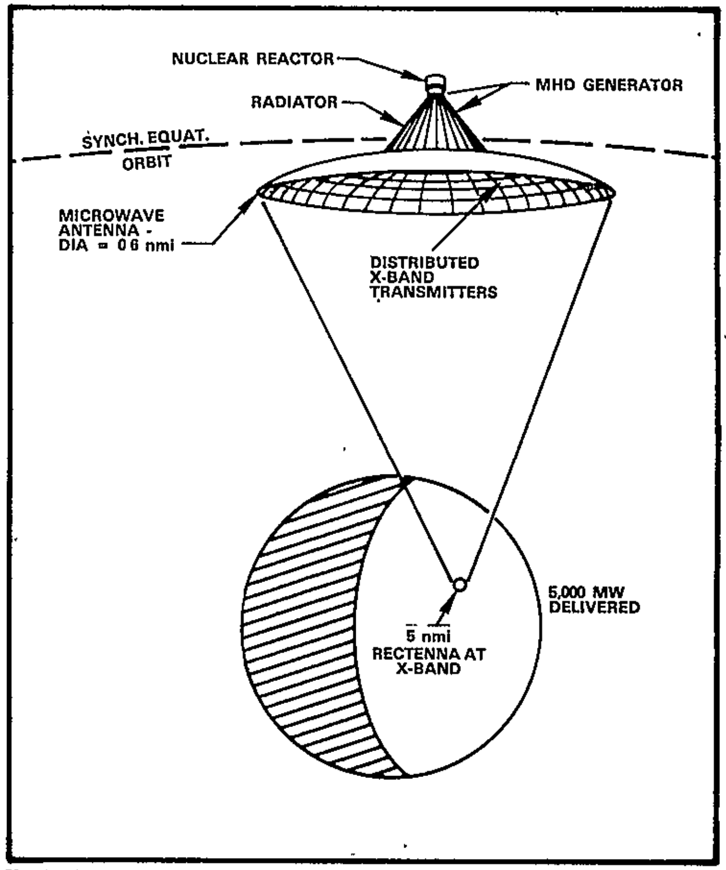
  To generate and deliver electrical energy without pollution or hazard.

- **RATIONALE**

  Power is needed which requires no radioactive material on earth, produces no atmospheric heating, and no resource consumption.

- **CONCEPT DESCRIPTION**

  A breeder reactor, MHD power generator, microwave transmitter, and microwave antenna are used to beam energy to a ground receiver. Fuel breeding supplies fuel.



- **CHARACTERISTICS**
  - **WEIGHT** TBD
  - **SIZE** 3,600-ft dia
  - **RAW POWER** 10,000 MW
  - **ORBIT** Synch. Equat.
  - **CONSTELLATION SIZE** 1
  - **RISK CATEGORY** IV (High)
  - **TIME FRAME** 2000
  - **IOC COST** (Space only) TBD

- **PERFORMANCE**

  5,000 Megawatts delivered power continuously - with sufficient fuel breeding for a life of at least 1000 years.

- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** LLV and large tug and large SEPS
  - **ON-ORBIT OPERATIONS** Manned service unit, automated servicing unit; assemble in orbit
  - **SUBSYSTEMS** Structure; attitude control; antenna; reactor; power unit
  - **TECHNOLOGY** Large active microwave antenna; large reactor; heat radiator; MHD power generator; pointing and tracking sensor
  - **OTHER** Rectenna on ground, safety

NUCLEAR WASTE DISPOSAL (CS-4)

- **PURPOSE**
  To permanently dispose of nuclear wastes without environmental damage.

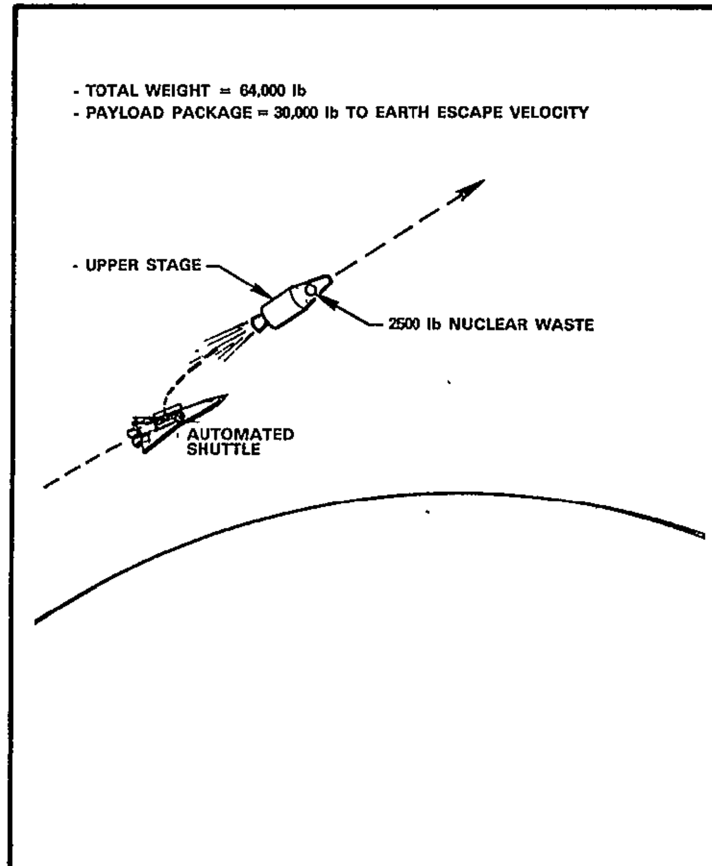
- **RATIONALE**
  Wholesale use of nuclear generating plants for electric power will result in large amounts of highly toxic and long lived radioactive wastes.

- **CONCEPT DESCRIPTION**
  Wastes are packaged in containers with shielding and cooling, and put into earth escape trajectories by shuttle and velocity stages.

- **CHARACTERISTICS**

• WEIGHT	64,000 lb
• SIZE	15 x 60 ft
• RAW POWER	---
• ORBIT	Escape
• CONSTELLATION SIZE	---
• RISK CATEGORY	II (Medium)
• TIME FRAME	1990 - 2000
• IOC COST (SPACE ONLY)	430 M

- **PERFORMANCE**
  2500 lb of waste per flight at $15 million per flight ($6000/lb). Cost increase to electrical consumer = 2%.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Automated shuttle and large tug
• ON-ORBIT OPERATIONS	Safety/abort - backup systems
• SUBSYSTEMS	Shielding/encapsulation; abort systems
• TECHNOLOGY	Thermal control; structural package integrity; recovery techniques
• OTHER	

AIRCRAFT LASER BEAM POWERING (CS-5)

- **PURPOSE**

  To provide an alternative to oil as a source of energy for powering commercial transports.

- **RATIONALE**

  Oil is a limited resource, becoming more expensive rapidly.

- **CONCEPT DESCRIPTION**

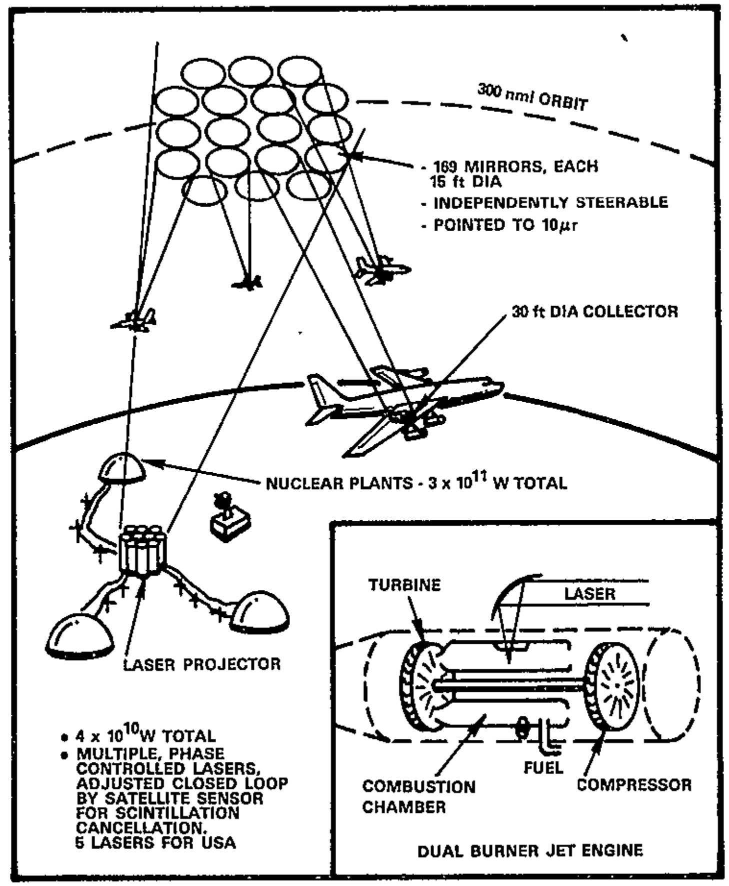
  Jet turbines are operated by heating air with laser beams projected to each aircraft by multi-mirror satellites. Laser on ground powered by nuclear reactors provides energy.

- **CHARACTERISTICS**

• **WEIGHT**	2,000,000 lb
• **SIZE**	169 mirrors, each 15-ft dia
• **RAW POWER**	---
• **ORBIT**	300 nmi, 45^0 incl.
• **CONSTELLATION SIZE**	200
• **RISK CATEGORY**	IV (High)
• **TIME FRAME**	2000+
• **IOC COST** (Space only)	87 B

- **PERFORMANCE**

  2000 large jet aircraft powered continuously (30% duty cycle) at 10-50 MW/aircraft. Break-even with oil operations at 50¢/gal.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	LLV and large SEPS
• **ON-ORBIT OPERATIONS**	Manned or automated servicing unit; orbital assembly
• **SUBSYSTEMS**	Attitude control; mirrors; processors; crosslink; thermal control
• **TECHNOLOGY**	Large high temp mirrors; radiators; pointing and tracking sensors; LSI processor
• **OTHER**	Ground high energy laser; atmospheric scintillation correction. Safety

NIGHT ILLUMINATOR (CS-6)

- **PURPOSE**
  To provide night lighting without earth-based energy, pollution, street lights, cables, trenches, etc.

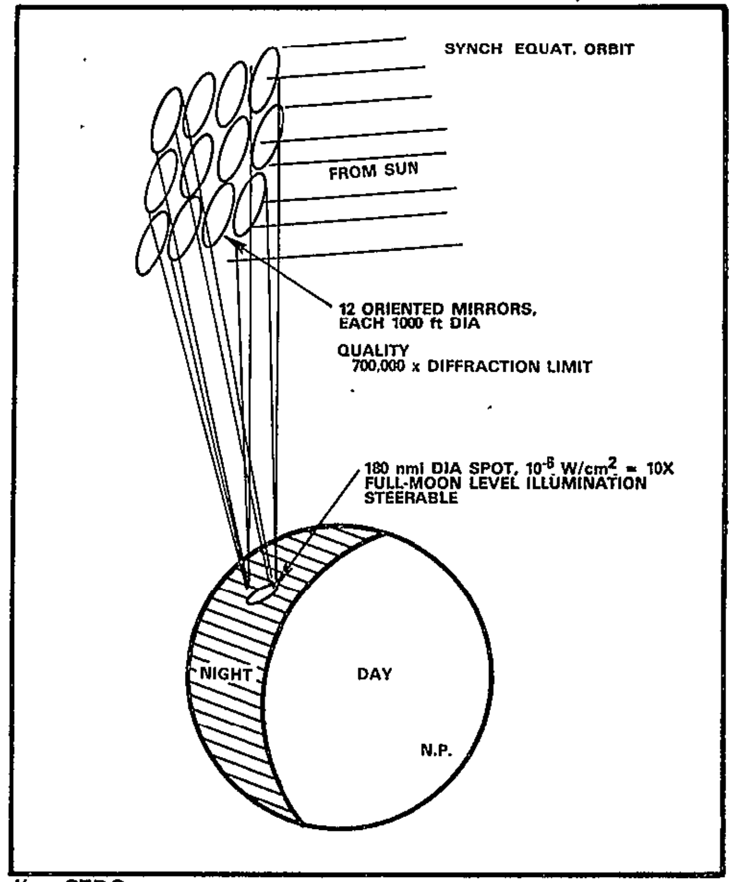
- **RATIONALE**
  Alternative energy sources are needed.

- **CONCEPT DESCRIPTION**
  Large area reflectors in space reflect the image of the sun onto the earth. Multiple satellites used to minimize construction difficulties.

- **CHARACTERISTICS**

• **WEIGHT**	100,000 lb
• **SIZE**	12 mirrors each 1,000-ft dia
• **RAW POWER**	1.2 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	II (Medium)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	160 M

- **PERFORMANCE**
  Ten times full-moon level illumination at night provided to area 180 nmi dia (no clouds). Full moon level provided through moderate clouds.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large tug and/or SEPS
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit
• **SUBSYSTEMS**	Attitude control; mirrors, structure
• **TECHNOLOGY**	Large reflector; pointing; stationkeeping master control
• **OTHER**	None

PERSONAL NAVIGATION WRIST SET (CS-7)

- **PURPOSE**
  To provide accurate relative position location with very inexpensive user equipment.

- **RATIONALE**
  Navigation system costs are dominated by user equipment costs.

- **CONCEPT DESCRIPTION**
  Narrow beams are swept over the U. S. by large phased arrays in space. Very simple receivers measure time elapsed between pulses received and display distances (N-S, E-W) to fixed point.

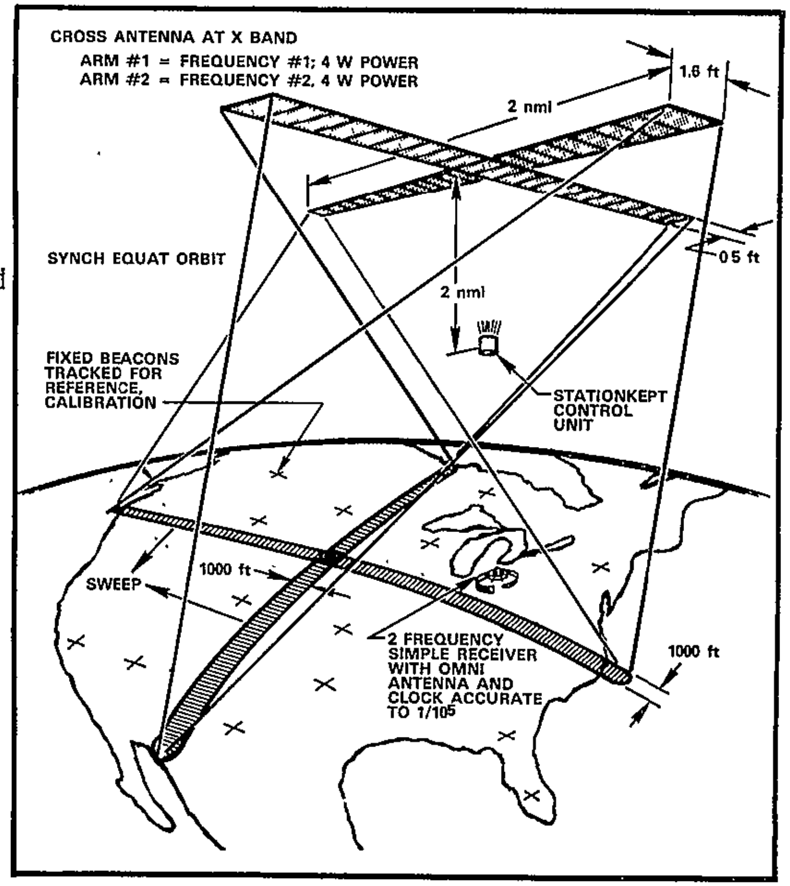
- **CHARACTERISTICS**

• WEIGHT	3000 lb
• SIZE	2 nmi cross
• RAW POWER	2 kW
• ORBIT	Sync. Equat.
• CONSTELLATION SIZE	1
• RISK CATEGORY	II (Medium)
• TIME FRAME	1990
• IOC COST (SPACE ONLY)	100 M

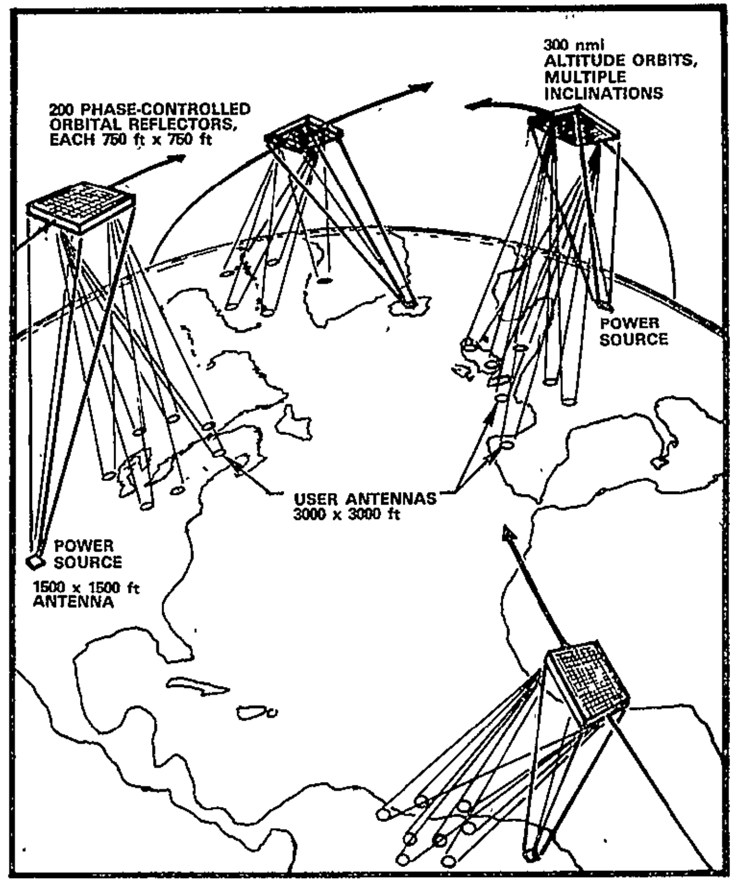
- **PERFORMANCE**
  - User position located to 300 ft every 10 sec relative to a fixed location < 100 nmi away.
  - User receiver can cost less than $10 in mass production.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and Tug
• ON-ORBIT OPERATIONS	Manned or automated assembly and servicing units
• SUBSYSTEMS	Antenna with independently stationkept subunits.
• TECHNOLOGY	Ion thruster, adaptive RF phase control, laser master measuring unit
• OTHER	LSI receivers



MULTINATIONAL ENERGY DISTRIBUTION (CS-8)



- **PURPOSE**
  To distribute energy to small-city users without transmission lines, and serve many nations simultaneously.
- **RATIONALE**
  Transmission lines are fixed, have an environmental impact, and limited capacity to feed growing communities or developing nations without large networks or large losses
- **CONCEPT DESCRIPTION**
  Phase-controlled array reflectors in low orbit sequentially relay remote source power to 100 user antennas per satellite. Power is rectified at substation receiving arrays and filtered.
- **CHARACTERISTICS**

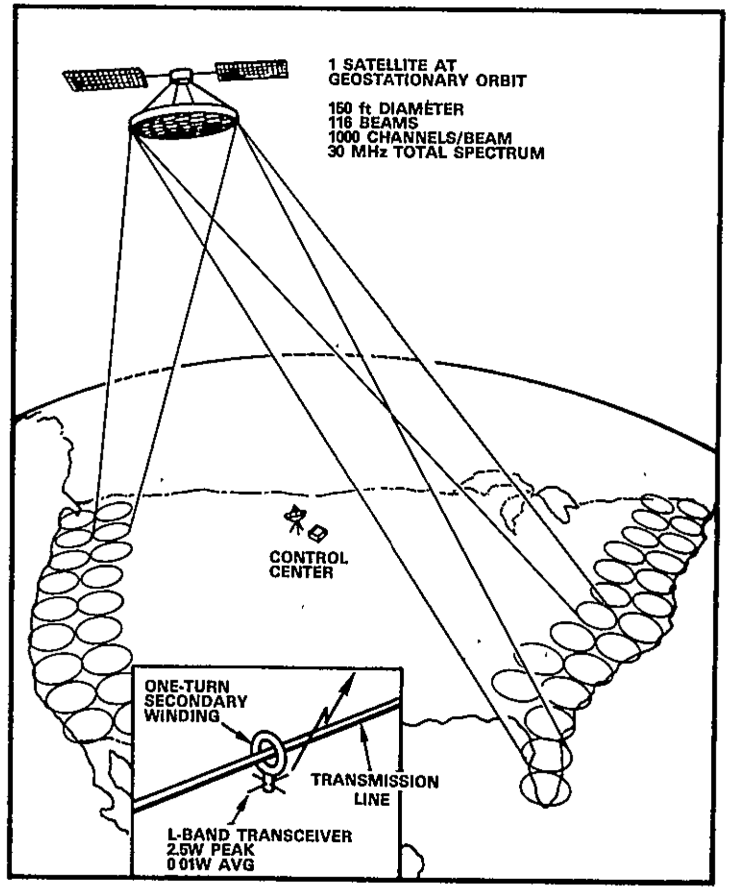
• **WEIGHT**	34,000 lb
• **SIZE**	750 x 750 ft
• **RAW POWER**	20 kW
• **ORBIT**	300 nmi several incl.
• **CONSTELLATION SIZE**	200
• **RISK CATEGORY**	IV (High)
• **TIME FRAME**	2000
• **IOC COST** (Space only)	5.8 B

- **PERFORMANCE**
  1000 user areas in U. S. A. powered with 100 MW each in rapid (1/120 sec) sequence from 10 power station source antennas. Scanning loss < 1%; overall efficiency >55% 3000-ft square receiver with 1.7 nmi square guard fence suffices for user.
- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle
• **ON-ORBIT OPERATIONS**	Shuttle attached manipulator; manual or automated servicing unit
• **SUBSYSTEMS**	Attitude control, stationkeeping units, phase control, figure control
• **TECHNOLOGY**	Ion thrusters, phase control, measurement and control lidar, LSI processor
• **OTHER**	

ENERGY MONITOR (CS-9)

- **PURPOSE**
  To measure energy flow at a very large number of points on distribution network.
- **RATIONALE**
  Power programming and fine-tuning requires knowledge of energy status on network.
- **CONCEPT DESCRIPTION**
  Small L-band transmitters send instantaneous current, voltage, or power readings on network when queried sequentially by multi-channel/processing communications repeater.
- **CHARACTERISTICS**
  - **WEIGHT** 10,000 lb
  - **SIZE** 150-ft dia
  - **RAW POWER** 23 kW
  - **ORBIT** Geostationary
  - **CONSTELLATION SIZE** 1
  - **RISK CATEGORY** I (Low)
  - **TIME FRAME** 1990
  - **IOC COST** (Space only) 300 M
- **PERFORMANCE**
  Up to one billion points on energy generation and distribution network measured every hour.
- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** Shuttle and IUS/tug
  - **ON-ORBIT OPERATIONS** Automated or manual servicing, assembly
  - **SUBSYSTEMS** Attitude control, antenna, processor
  - **TECHNOLOGY** Multi-channel transponder, LSI processor
  - **OTHER**



VEHICULAR SPEED LIMIT CONTROL (CS-10)

- **PURPOSE**
  To establish positive vehicle speed control zones in cities by radio control of vehicle engine governors.

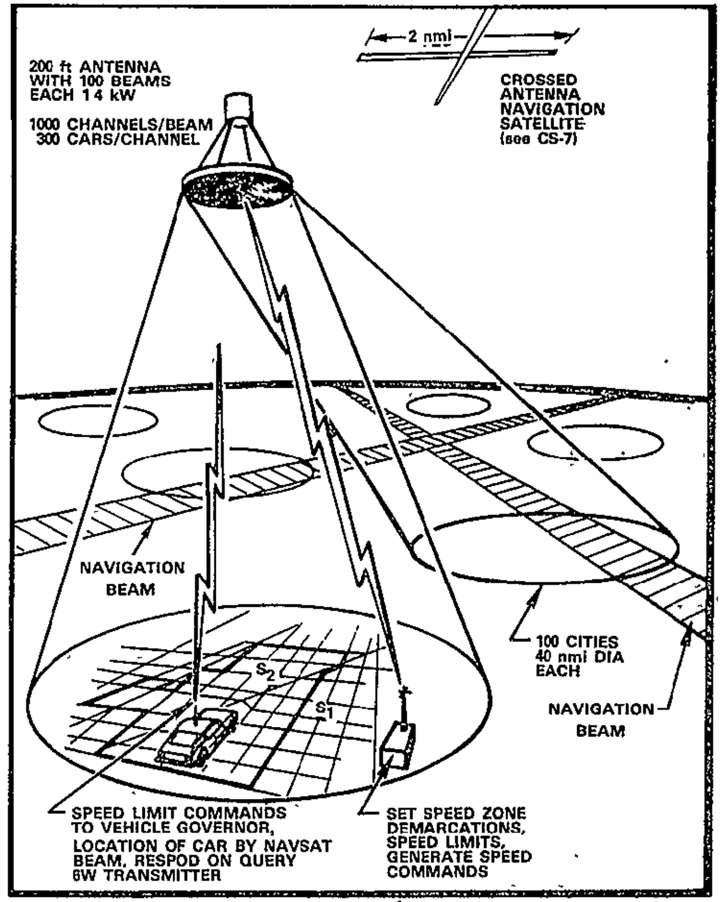
- **RATIONALE**
  Excessive speed is a major contributor to traffic accidents and injuries. With positive control, speeding is impossible.

- **CONCEPT DESCRIPTION** - Each vehicle has a small transceiver and a command receiver connected to a commandable speed governor. Each vehicle determines its location using crossed antenna NAVSAT. Speed commands are generated by computer on the ground.

- **CHARACTERISTICS**

• **WEIGHT**	22,000 lb
• **SIZE**	200-ft dia antenna
• **RAW POWER**	430 kW
• **ORBIT**	Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	II (Medium)
• **TIME FRAME**	1990
• **IOC COST** (Space only)	470 M

- **PERFORMANCE**
  Vehicle speed controlled to ± 1 mph. Provision for one million cars in each of 100 cities (100 million total vehicles). Speed zones changed by program change.



- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and large tug or SEPS
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit; assemble in orbit
• **SUBSYSTEMS**	Attitude control; antenna; RF power DC power, channelized transponder
• **TECHNOLOGY**	Large multibeam antenna; power tubes; channelization techniques; large-scale multiple access
• **OTHER**	

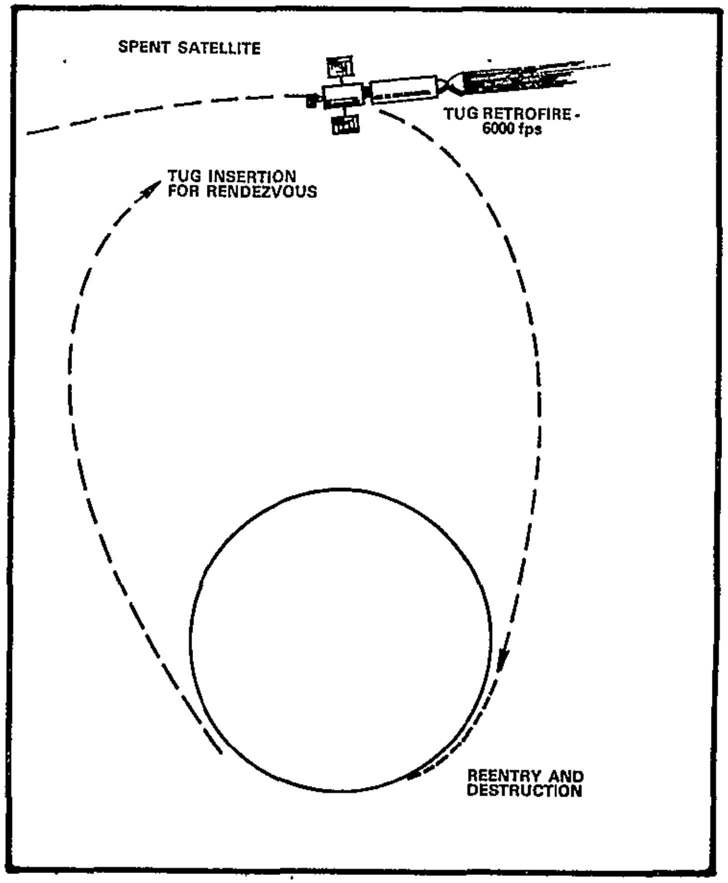
SPACE DEBRIS SWEEPER (CS-11)

- **PURPOSE**
  To remove expended satellites and debris from synchronous equatorial corridor where they pose a long-term collision threat.
- **RATIONALE**
  Synchronous equatorial corridor is becoming very crowded and could be dangerous in future.
- **CONCEPT DESCRIPTION**
  Use tug to impart ΔV to debris to drop its perigee to < 100 nmi. Debris will reenter within weeks. One orbit later, tug re-injects itself into SE orbit. Tug resupplied by shuttle.
- **CHARACTERISTICS**

• **WEIGHT**	500,000-lb propellant
• **SIZE**	Tug
• **RAW POWER**	--
• **ORBIT**	Up to Synch. Equat.
• **CONSTELLATION SIZE**	1
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space only)	0.5 M

- **PERFORMANCE**
  500,000 lb of propellant will deorbit 100 satellites of 5,000 lb each.
- **BUILDING BLOCK REQUIREMENTS**

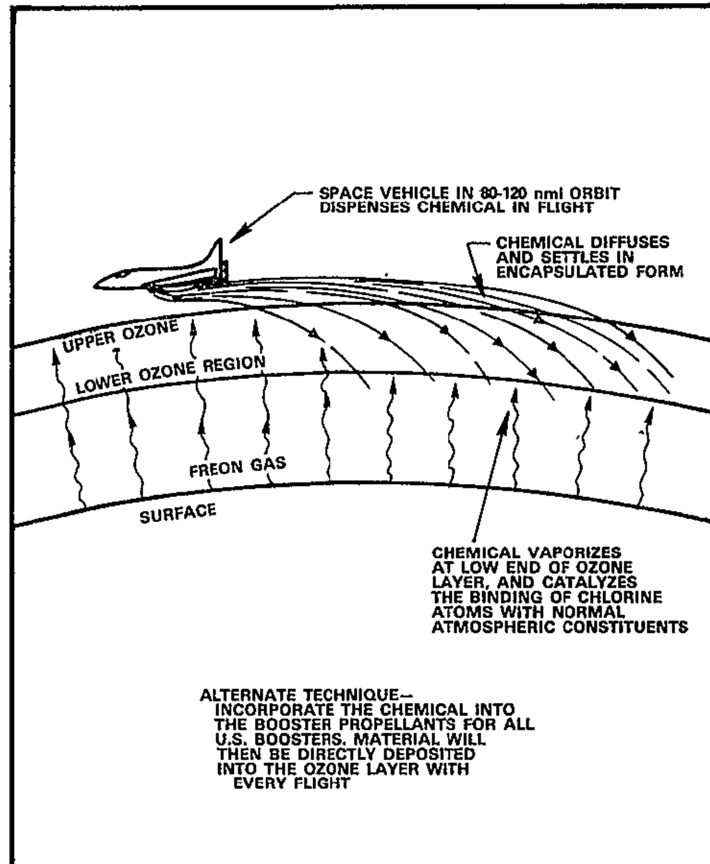
• **TRANSPORTATION**	Shuttle and tug
• **ON-ORBIT OPERATIONS**	No unusual requirements
• **SUBSYSTEMS**	No unusual requirements
• **TECHNOLOGY**	No unusual requirements
• **OTHER**	None



OZONE LAYER REPLENISHMENT/PROTECTION (CS-12)

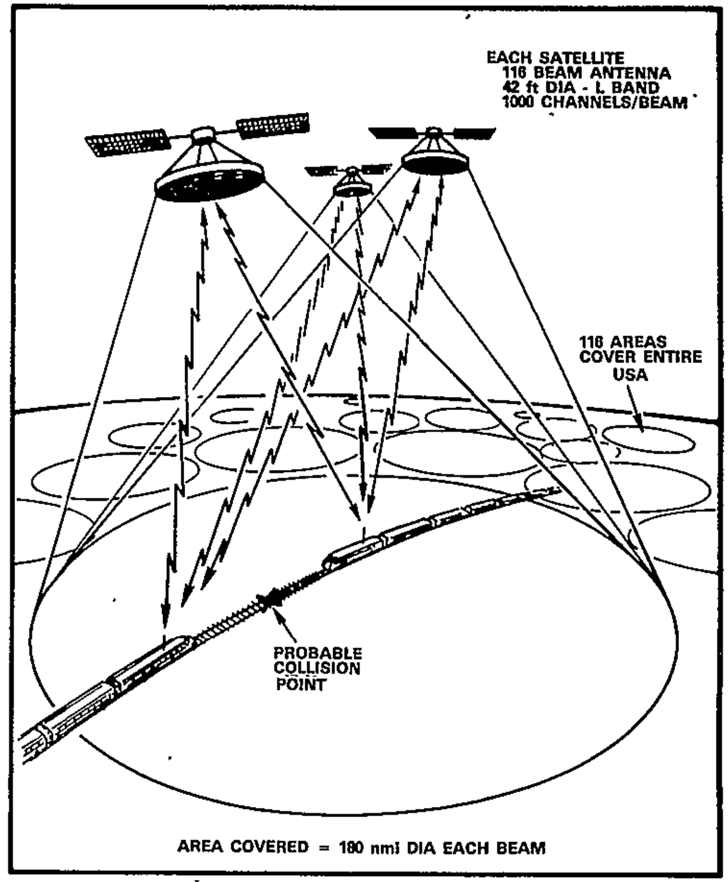
- **PURPOSE**
  To reduce the depletion of the ozone layer from "freon" compounds.

- **RATIONALE**
  The ozone concentration in the layer is decreasing dangerously due to freons released by spray cans and refrigerators.
- **CONCEPT DESCRIPTION**
  Space shuttle or heavy lift booster dispenses a chemical which settles and catalyzes the binding of free chlorine atoms produced by the freon, preventing the chlorine from destroying ozone.
- **CHARACTERISTICS**
  - **WEIGHT** 50,000,000 lb
  - **SIZE** ---
  - **RAW POWER** ---
  - **ORBIT** 80-120 nmi polar
  - **CONSTELLATION SIZE** 1
  - **RISK CATEGORY** IV (High)
  - **TIME FRAME** 1995
  - **IOC COST** (Space only) 750 M
- **PERFORMANCE**
  Ozone layer replenished, protected for five years by dispensing of 25,000 tons of chemical in the northern hemisphere.



- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** LLV
  - **ON-ORBIT OPERATIONS** No unusual requirements
  - **SUBSYSTEMS** Reentry package for dispensing at the proper altitude
  - **TECHNOLOGY** No unusual requirements
  - **OTHER** Phenomenology of ozone layer depletion; synthesis of solely-chlorine-active catalyst. Environment side-effects.

RAIL ANTI-COLLISION SYSTEM (CS-13)



- **PURPOSE**
  To prevent train collisions.

- **RATIONALE**
  Life, property, and productivity losses due to train collisions are large. Prevention is desirable.

- **CONCEPT DESCRIPTION**
  Each train has a small beacon and command receiver. Location of each train is continuously computed on the ground using TDOA, and upon detection of collision course, alerting buzzer in train is sounded or train stopped.

- **CHARACTERISTICS**

• **WEIGHT**	3000 lb
• **SIZE**	42-ft dia antenna
• **RAW POWER**	500 W
• **ORBIT**	Synch. Equat. + Incl.
• **CONSTELLATION SIZE**	3
• **RISK CATEGORY**	I (Low)
• **TIME FRAME**	1985
• **IOC COST** (Space only)	240 M

- **PERFORMANCE**
  Alert sounded in a train within 0.5 sec of establishment of collision trajectory. Provision for 10,000 trains simultaneously.

- **BUILDING BLOCK REQUIREMENTS**

• **TRANSPORTATION**	Shuttle and tug
• **ON-ORBIT OPERATIONS**	Automated or manual servicing unit
• **SUBSYSTEMS**	Attitude control, large antennas, channelized transponders, power, computation speed
• **TECHNOLOGY**	Fast algorithms, power tubes, antennas, multiple access techniques
• **OTHER**	

BURGLAR ALARM/INTRUSION DETECTION (CS-14)

- **PURPOSE**
  To detect burglars/intruders in government and industrial buildings, facilities, or homes.

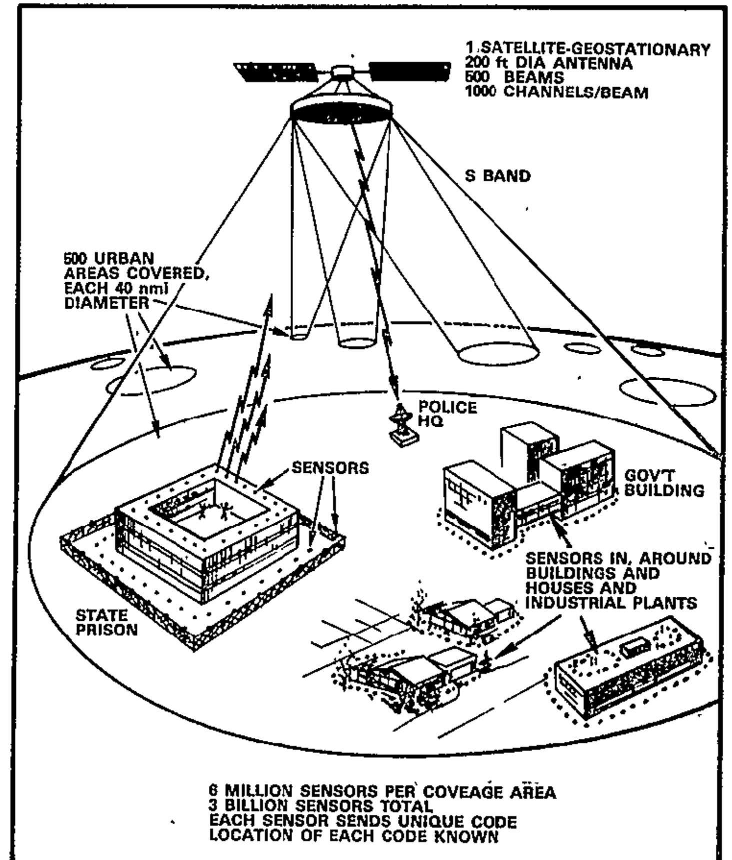
- **RATIONALE**
  Effective widespread burglar alarm system could reduce this enormous loss of property, productivity, and life.

- **CONCEPT DESCRIPTION**
  Very many, very tiny seismic or discrete sensors transmit when actuated. Signals picked up by single large antenna satellite for all U.S.A. and relayed to police command post nearest to area being burgled.

- **CHARACTERISTICS**

• WEIGHT	16,000 lb
• SIZE	200-ft dia antenna
• RAW POWER	1 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• RISK CATEGORY	I (Low)
• TIME FRAME	1990
• IOC COST (Space only)	350 M

- **PERFORMANCE**
  Up to six million intrusions detected every second in each of 500 urban areas, 3 billion intrusions per second total. Police alerted within 0.25 sec of entry.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug or SEPS
• ON-ORBIT OPERATIONS	Automated or manual servicing, assembly in orbit
• SUBSYSTEMS	Transponder, antenna, attitude control
• TECHNOLOGY	Multiple access technique, software, antenna switching
• OTHER	Cheap sensors

POWER RELAY SATELLITE (CS-15)

- **PURPOSE**
  To provide for transmission of electrical power from remote regions, minimizing environmental impact.

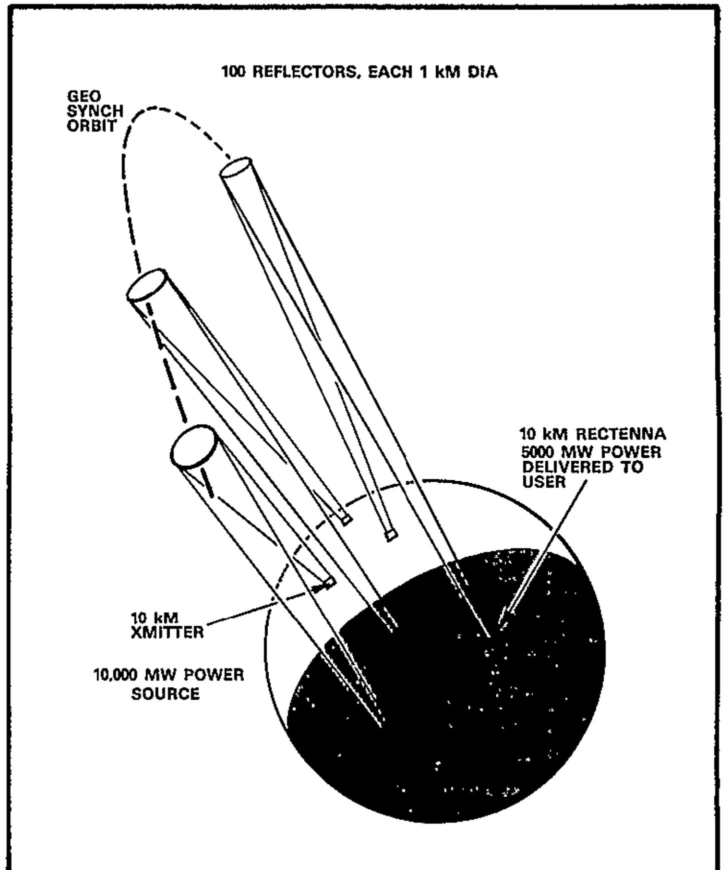
- **RATIONALE**
  Power should be generated in remote regions. Sunny side of Earth can supply power to night side.

- **CONCEPT DESCRIPTION**
  Source power is converted to a microwave beam, bounced off an orbiting reflector, and reconverted to DC at receiving antenna on ground.

- **CHARACTERISTICS**

• WEIGHT	600,000 lb
• SIZE	0.5-nmi dia
• RAW POWER	---
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	100
• RISK CATEGORY	IV (High)
• TIME FRAME	1995
• IOC COST (Space only)	36 B

- **PERFORMANCE**
  5,000 megawatts delivered to each of 100 user areas. 53 percent overall DC-DC efficiency attained. Total energy is about 10 percent of U.S. consumption.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	LLV and large tug or large SEPS
• ON-ORBIT OPERATIONS	Manned/automated servicing, assemble in orbit
• SUBSYSTEMS	Attitude control; structures, phase front control
• TECHNOLOGY	High efficiency, large, passive steerable phase front antenna; Ion thrusters
• OTHER	Ground-based elements

NEAR-TERM NAVIGATION CONCEPT (CS-16)

- **PURPOSE**

  To provide reasonably accurate relative position location in the near term with very inexpensive user equipment.

- **RATIONALE**

  Navigation system costs are dominated by user equipment costs. Wide popular need.

- **CONCEPT DESCRIPTION**

  Narrow beams are swept over the U.S. by phased arrays in space. Very simple receivers measure time elapsed between pulses received and display distances (N-S, E-W) to fixed points.

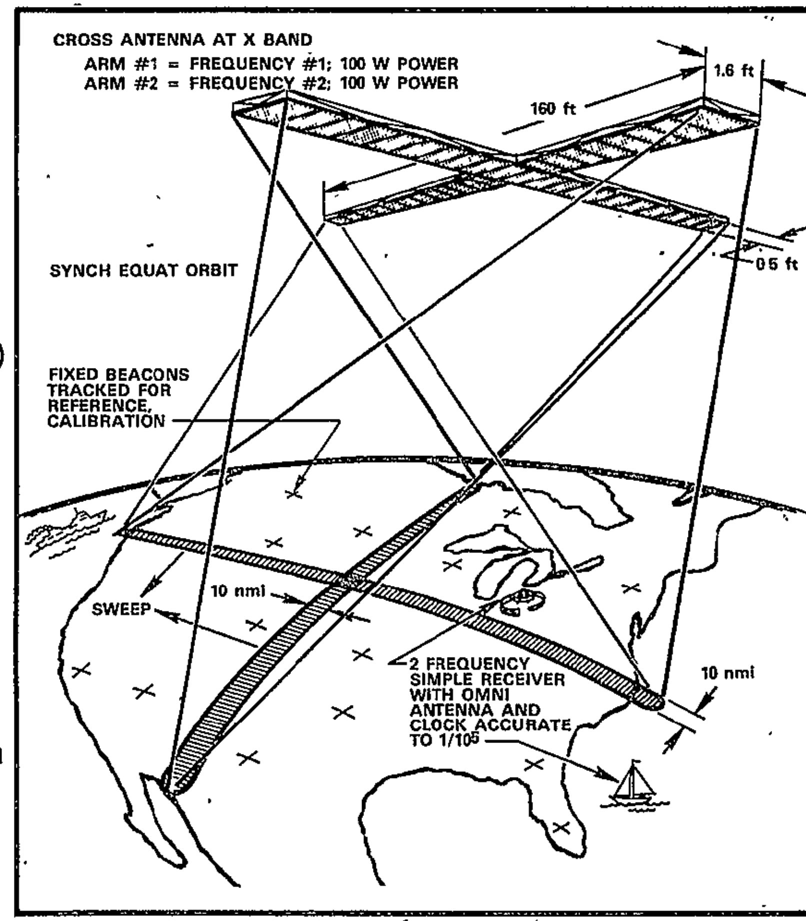
- **CHARACTERISTICS**
  - **WEIGHT** 1,600 lb
  - **SIZE** 160 ft cross
  - **RAW POWER** 1 kW
  - **ORBIT** Sync. Equat.
  - **CONSTELLATION SIZE** 1
  - **RISK CATEGORY** I (Low)
  - **TIME FRAME** 1980
  - **IOC COST** 90 M

- **PERFORMANCE**

  -User position located to 1/2 nmi every 10 sec anywhere in USA and 200 nmi beyond coastlines.

  -User receiver can cost less than $10 in mass production.

- **BUILDING BLOCK REQUIREMENTS**
  - **TRANSPORTATION** Shuttle and IUS
  - **ON-ORBIT OPERATIONS** Manned or automated assembly and servicing units
  - **SUBSYSTEMS** Antenna, attitude control
  - **TECHNOLOGY** ---
  - **OTHER** LSI receivers



F-0147

A number of initiative ideas were collected which did not survive the initial screening as ideas that should be carried through to even the back-of-the-envelope analysis stage. Some of these were put into this category beacuse the phenomenology is not well enough understood to define a program, even though the desirability of such an initiative might be evident. Others were included because even though the phenomenology might be understood, the technology requirements were either outlandish (even compared to some of the far-term and extremely ambitious initiatives which survived) or the function performed was not felt to be useful.

WORTHY CIVILIAN INITIATIVE IDEAS NOT DEFINED

- Radioactive Cloud Location Monitoring
- Laser-Propelled Rockets
- All-Weather FAR-IR Observation or Communications
- Space Plasma Mixing of RF or Laser Beams

CIVILIAN INITIATIVE IDEAS REJECTED

- Federal Office Monitoring
- Surveying Marker Aid
- Airport Fog Dispersal
- Direct Weather Modification
- Searchlight From Space

The catalog of initiatives represents opportunities for acquiring space system concepts. An attempt is made in the next three illustrative sheets to identify the civilian initiatives by the gross time period in which they might be acquired, divided into the 1980-1990 and 1990-2000+ time periods. Acquisition of many of the concepts would be preceded by test and demonstration projects of reduced scope. The operational dates are estimated based on availability of key technology and such a phased development and test program.

CIVILIAN OBSERVATION INITIATIVES

1980-1990 TIME PERIOD	1900-2000+ TIME PERIOD
• Advanced Resources/Pollution Observatory • Fire Detection • Water Level and Fault Movement Indicator • Multinational Air Traffic Control Radar • U. N. Truce Observation Satellite • Nuclear Fuel Locator • Border Surveillance • Atmospheric Temperature Profile Sounder • Synchronous Meteorological Satellite	• Coastal Anti-Collision Passive Radar • Astronomical Super Telescope • High Resolution Earth Mapping Radar

CIVILIAN COMMUNICATIONS INITIATIVES

1980-1990 TIME PERIOD	1990-2000+ TIME PERIOD
• Global Search + Rescue Locator • Urban/Police Wrist Radio • Disaster Control Satellite • Electronic Mail Transmission • Transportation Services Satellite • Advanced T.V. Broadcast • Voting/Polling Wrist Set • National Information Services • Personal Communications Wrist Radio • Diplomatic/U.N. Hot Lines • Vehicle/Package Locator • 3-D Holographic Teleconferencing	

CIVILIAN SUPPORT INITIATIVES

1980-1990 TIME PERIOD	1990-2000+ TIME PERIOD
• Near-Term Navigation Concept	• Energy Generation - Nuclear/ Microwave
• Nuclear Waste Disposal	• Energy Generation - Solar/ Microwave
• Night Illuminator	• Aircraft Laser Beam Powering
• Energy Monitor	• Multinational Energy Distribution
• Vehicular Speed Limit Control	• High Efficiency Solar Energy Generation
• Space Debris Sweeper	
• Personal Navigation Wrist Set	
• Ozone Layer Replenishment/ Protection	

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SECTION 2

FUNCTIONAL SYSTEM OPTIONS

This space functional system options section presents the initiative options and systems from the current mission models in a time-phased form containing phased system options for the future. The options are presented for each of the space functions, categories, and sub-categories of function presented on the facing page.

FUNCTIONS IN CIVILIAN SPACE PROGRAMS

- OBSERVATION
  - SURFACE ---- Resources/Pollution; Boundaries; Disaster Areas
  - OCEAN ---- Sea State/Ocean Physics; Collision Avoidance
  - ATMOSPHERE ---- Weather; Atmosphere Physics
  - SPACE ---- Astronomy; Geodetics; Planetary Exploration; Physics
- COMMUNICATIONS
  - INTERGOVERNMENT LINKS ---- International/Diplomatic
  - GOVERNMENT/PEOPLE LINKS ---- Voting/Polling
  - PEOPLE/PEOPLE LINKS ---- Personal
  - INTRAGOVERNMENT LINKS ---- Routine; Emergency
  - ENTERTAINMENT/COMMERCIAL LINKS ---- Profit-Oriented
- SUPPORT
  - NAVIGATION ---- Vehicular; Personal
  - TRANSPORTATION AID/CONTROL ---- Air/Sea/Ground
  - ENERGY ---- Delivery; Management
  - ENVIRONMENT MODIFICATION ---- Atmosphere; Weather; Illumination
  - DISPOSAL AND CONTROL OF WASTES ---- Toxic/Radioactive
  - NEW MEDIUM FOR RESEARCH AND MANUFACTURING
  - SPACE TRANSPORTATION DEVELOPMENT ---- Low/High/Planetary

The functional system options data bank is presented in the form of seven data sheets, one for each of the major functions in the civilian and military areas. A particular sample is shown on the facing page for the purposes of illustrating the contents of the data bank. Each sheet contains the system options for near-term, midterm, and far-term space projects which apply for each subcategory of functions to be fulfilled. For the purposes of this report, we define near-term as 1980 ± five years, midterm as 1990 ± five years, and far-term as the year 2000 ± five years.

The functions in civilian observation are shown as an example, with the subcategories of surface observation for resources and pollution, and ocean observation detailed. The system options shown in the example are synthesized from the initiatives developed in the covise of this report, the NASA and the DoD STS mission models, and other information from past NASA and DoD planning studies. The definitions of alternate or follow-on programs such as "LANDSAT-I, II, and III" were developed by the authors for this particular report and have no official significance. As an example of the system options, the near-term LANDSAT-I is assumed to be an operational Earth Resources Test satellite with somewhat improved readout and resolution from the current LANDSAT. LANDSAT-II is assumed to be a further improved LANDSAT-I with much more spatial and spectral resolution, incorporating an active on-board radar with a synthetic aperture array and real-time correlation of the passive and active signals either on board or off board. LANDSAT-III, which is a far-term program, is assumed similar to LANDSAT-II except for the addition of an active mode-locked laser radar with pico-second pulses for ± 0.3 mm ranging capability, and correlation between the active radar, the active lidar, and the passive optics on board. The numbers at the bottom right-hand corner of the near-term, midterm, and far-term system options are the estimated costs of R&D, acquisition, and transportation for establishment of the required constellation of each of the system options, measured in billions of dollars. No operational costs are included in these numbers, and the numbers are assumed to be constant 1975 collars.

Similarly, SEASAT-I is assumed to be a low-power active radar similar to the current SEASAT development program, with data added from the postulated DoD programs on specialized surveillance which are assumed to have a somewhat similar capability. In the midterm SEASAT-II, the power of the active radar is assumed to increase to 25 kW, with data added from more advanced postulated military surveillance satellites including imaging in optical-through-infrared, should such systems be simultaneously selected for a program plan. SEASAT-III is assumed to have an increase in power to 100 kW with the addition of a far-infrared laser radar for possible imaging through clouds, as well as data added from the far-term equivalent military space surveillance systems if available. Thus, the data bank of system choices for program plans shows capability increasing with time, and is composed of components ranging from single initiatives to combinations of various civilian and military initiatives.

Functional System Options Data Bank

MILITARY WEAPONS
MILITARY SUPPORT
MILITARY COMMUNICATIONS
MILITARY SURVEILLANCE
CIVILIAN SUPPORT
CIVILIAN COMMUNICATION
CIVILIAN OBSERVATION

Functions		Near-Term (1980±5)	Mid-Term (1990±5)	Far-Term (2000±5)
Surface Observation	Resources/ Pollution	LANDSAT-I • Operational ERTS • Improved Readout • Improved Resolution • More Channels 0.2	LANDSAT-II • Improved LANDSAT-I - More Resolution • Active On-Board Radar • Real-Time Correlation 0.4-0.6	LANDSAT-III • as LANDSAT-II • Add Active Laser - Picosecond Ranging • Correlate with Active Radar, Passive Optics 0.9-1.28
	Boundary	~	~	~
	Disasters	~	~	~
Ocean Observation		SEASAT-I • Low-Power Active Radar • Add Data From DOD 0.2	SEASAT-II • 25 kw Radar • Add Data From DOD 0.3-0.4	SEASAT-III • 100 kw Radar • Add Far-IR Laser Radar • Add Data From DOD –
	Collision Avoidance	~	~	~
Atmosphere Observation	Weather	~	~	~
	Atm. Physics	~	~	~
Space Observation	Astronomy	~	~	~
	Geodetics	~	~	~
	Planet Exploration	~	~	~
	Physics	~	~	~

SEVEN DATA SHEETS

CIVILIAN OBSERVATION SPACE SYSTEMS

FUNCTIONS		SYSTEMS			
		CURRENT	NEAR-TERM (1980 ± 5)	MID-TERM (1990 ± 5)	FAR-TERM (2000 ± 5)
FC01 SURFACE OBSERVATION	FC01-1 RESOURCES, POLLUTION	FC01-1C ERTS - passive - multispectral - low altitude - low resolution	FC01-1N LANDSAT-I - operational ERTS - World-wide real time readout 0.2	FC01-1M LANDSAT-II • same as LANDSAT-I but with - better resolution - correlated with active on-board radar 0.4-0.6	FC01-1F LANDSAT-III • same as LANDSATII but - add active laser - correlate with radat + optical sensors - very high resolution <1 ft 0.9-1.2
	FC01-2 BOUNDARY	NONE	FC01-2N INTRUSION ALARM-I - large sensors - leased channel comsat readout - central medium size antenna terminal on ground 0.1	FC01-2M INTRUSION ALARM-II - many large sensors - direct readout - multibeam antenna satellite 0.25	FC01-2F INTRUSION ALARM-III - very many sensors - wrist-radio (small) sensors - very large comsat - direct readout 0.4
	FC01-3 DISASTERS	NONE	FC01-3N DISASTER CONTROL -I • SEASAT-I • Military • LANDSAT-I Uses Data From	FC01-3M DISASTER CONTROL-II • forest fire detection - passive IR, synch. equat. • SEASAT-II • Military • LANDSAT-II 0.27-0.5	FC01-3F DISASTER CONTROL-III Uses data from: • LANDSAT-III • Military
FC02 OCEAN OBSERVATION	FC02-1 SEA STATE, OCEAN PHYSICS	NONE	FC02-1N SEASAT-I • active radar • low altitude • low power Data from: • Military 0.2	FC02-1M SEASAT-II • same as SEASAT-I but - higher power - better resolution • Military 0.3-0.4	FC02-1F SEASAT-III • same as LANDSAT-III (FC01-1F) • Military
	FC02-2 COLLISION AVOIDANCE	NONE	NONE	NONE	FC02-2F COLLISION AVOIDANCE - space radar illuminator - active - ship radar receivers - passive - bistatic mode - coastal coverage 1.1

CIVILIAN OBSERVATION SPACE SYSTEMS (Continued)

FUNCTIONS		SYSTEMS: CURRENT	NEAR-TERM (1980 ± 5)	MID-TERM (1990 ± 5)	FAR-TERM (2000 ± 5)
FC03 ATMOSPHERE OBSERVATION	FC03-1 WEATHER	FC03-1C TIROS, NIMBUS, SMS, ITOS • passive optical and LWIR - medium resolution • passive optical - sync equatorial - low resolution	FC03-1N METSAT-I • SAME AS CURRENT but - higher resolution - more channels (includes EOS, SES, SPS, TIROS, SMS) • solar flux satellite 0.3	FC03-1M METSAT-II • improved Metsat-I for - more resolution - more spectral channels • synchronous equatorial Metsat - high resolution - 3-5 ft optics 0.35-0.4	SAME
	FC03-2 ATMOSPHERIC PHYSICS	FC03-2C SAME AS FC03-1C	FC03-2N SAME AS FC03-1N	FC03-2M ATMOSPHERIC PROFILOMETER - laser radar - low orbit - temperature and pressure gradients (profiles) directly 0.34-0.5	FC03-2F SAME AS FC03-2M
FC04 SPACE OBSERVATION	FC04-1 ASTRONOMY	FC04-1C • OAO - optical, UV, particulate flux - γ, x-ray • OSO, Explorer	FC04-1N ASTRONOMY-I • LST - 2 meter optical telescope • OSO o SPS • Explorer • HEAO 1.0-1.5	FC04-1M ASTRONOMY-II • VLST + (3-10 meter) • large radio observatory • focusing x-ray observatory • large solar observatory • large radio observatory • focusing x-ray telescope 2.0-3.0	FC04-1F ASTRONOMY-III • 240 meter telescope - optical • 100 kilometer radio telescope • advanced solar observatory • advanced focusing x-ray telescope 4.0-5.0
	FC04-2 GEODETICS	FC04-2C • OGO • GEOS	FC04-2N GEODETICS-I • SEASAT-I • LAGEOS - laser, geodetic satellite • GRAVSAT - gravity sat. • MAGMON - magnetic field monitor • GEOPAUSE 0.8-1.2	FC04-2M GEODETICS-II SAME AS GEODETICS-I - Improvements 1.0-1.5	SAME

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CIVILIAN OBSERVATION SPACE SYSTEMS (Continued)

		FUNCTIONS	SYSTEMS: CURRENT	NEAR-TERM (1980 ± 5)	MID-TERM (1990 ± 5)	FAR-TERM (2000 ± 5)
SPACE OBSERVATION (Continued)	PLANETARY EXPLORATION	FCP1 INNER PLANETS/SUN	FCP1-C • Helios	FCP1-N • Viking Orbiter/Lander • Prioneer Venus • Inner Planet follow-on • Venus radar mapper 1.0	FCP1-M • Surface Sample return • Venus buoyant station • Mercury orbiter • Venus Large Lander 1.0-2.0	FCP1-F • Satellite Sample return 1.3-2.3
		FCP2 OUTER PLANETS	FCP2-C • Pioneer Jupiter flyby • Viking Mars 75 • Mariner Jupiter/ Saturn 77	FCP2-N • Mariner Jupiter/Uranus flyby • Pioneer Jupiter/Uranus flyby • Pioneer Saturn Probe • Pioneer Saturn/Uranus flyby • Mariner Jupiter Orbiter 0.9	FCP2-M • Pioneer Jupiter Probe • Mariner Uranus/Neptune flyby • Mariner Orbiter Saturn 0.9-1.5	FCP2-F • Jupiter/Saturn orbiter-lander • Pluto flyby • Pluto lander 1.5-2.6
		FCP3 COMETS + ASTEROIDS	FCP3-C NONE	FCP3-N • Dual Comet flyby • Encke slow flyby • Encke rendezvous 0.2	FCP3-M • Halley flyby • Asteroid rendezvous 0.2-0.4	FCP3-F • Comet sample return • Asteriod sample return 0.4-0.7
	PHYSICS	FCP4 PHYSICS PROGRAMS	FCP4-C • Explorers	FCP4-N • Gravity + relativity sat. • Environ. perturb. sat. • High energy astro-physics 0.3-1.0	FCP4-M • Helio + interstellar satellite 0.2-1.2	FCP4-F • Cosmic ray lab. 1.2-2.2

CIVILIAN COMMUNICATIONS SPACE SYSTEMS

FUNCTIONS	SYSTEMS: CURRENT	SYSTEMS: NEAR-TERM (1980 ± 5)	SYSTEMS: MID-TERM (1990 ± 5)	SYSTEMS: FAR-TERM (2000 ± 5)
FCC1 INTERGOVERNMENT LINKS	FCC1-C US-USSR HOT-LINE - I - dedicated channel on common-user satellites - DSCS-II/MOLNIYA - teletype	FCC1-N INTERGOVERNMENT-I • Hotline-II - dedicated Comsat - a few large terminals 0.25	FCC1-M INTERGOVERNMENT-II • Hotline-III - dedicated large Comsat switch - small user terminals - one for each nation - secure coded • National Information Services - large multibeam satellite - small international users 0.5-0.7	FCC1-F INTERGOVERNMENT-III • integrated international - all section users - small terminals throughout 0.6-0.8
FCC2 GOVERNMENT-TO-PEOPLE LINKS	NONE	FCC2-N VOTING-POLLING-I - leased channels on existing Comsats - Precincts tied to government computer 0.05	FCC2-M VOTING-POLLING-II - dedicated or shared large multibeam Comsat - personal "wrist radio" terminals - vote collection, polling the population 0.28	FCC2-F INTEGRATED COMMUNIC. SERVICES - Integrated form of: FCC2-M, FCC3-M, FCC4-1M, FCC4-2M 0/or 0.5-0.6
FCC3 PEOPLE-TO-PEOPLE LINKS	NONE		FCC3-M PERSONAL COMMUNICATIONS - large dedicated multibeam Comsat - personal "wrist radio" terminals - voice channels between wrist radios or into telephone networks 3-D CONFERENCING - video - audio - hologram conferencing - large Comsat small terminals 0.35	INTERGRATED COMM. SERVICES - Same as FCC2-F 0/or 0.67

CIVILIAN COMMUNICATIONS SPACE SYSTEMS (Continued)

FUNCTIONS		SYSTEMS: CURRENT	SYSTEMS: NEAR-TERM (1980 ± 5)	SYSTEMS: MID-TERM (1990 ± 5)	SYSTEMS: FAR-TERM (2000 ± 5)
FCC4 INTRAGOVERNMENT LINKS	FCC4-1 ROUTINE	Experiments in TWX postal service delivery	FCC4-1N ELECTRONIC MAIL-I - leased channel on Comsat - selected mail between post offices - large terminals INFORMATION LINKS - leased channel for medical library data 0.1	FCC4-1M ELECTRONIC MAIL-II - large dedicated multibeam Comsat - all mail - all post offices - small terminals INFORMATION SERVICES - medical, library, FBI, etc. data - dedicated Comsat 0.38-0.55	FCC4-1F INTEGRATED COMMUNIC. SERVICES Same as FCC2-F 0/or 0.8
	FCC4-2 EMERGENCY	NONE	FCC4-2N EMERGENCY-I SEARCH AND RESCUE - global - small user terminals - dedicated Comsats 0.27	FCC4-2-M EMERGENCY-II • Disaster control • Urban C&C • Search and Rescue - Same as FCC4-1N • Information Services - Same as FCC4-1M 0.5-0.7	FCC4-2F INTEGRATED COMMUNIC. SERVICES Same as FCC2-F 0/or 0.95
FCC5 ENTERTAINMENT/COMMERCIAL LINKS		FCC5-C COMMON CARRIER - Comsats integrated into ground networks for commercial traffic	FCC5-N TV BROADCAST-I - limited application - few channels - large terminal antennas (12 ft) 0.3	FCC5-M TV BROADCAST-II - all TV traffic - all channels - small user antenna 0.5-0.7	FCC5-F INTEGRATED COMMUNIC. SERVICES SAME 0/or 0.95

CIVILIAN SUPPORT SPACE SYSTEMS

FUNCTIONS		CURRENT	NEAR-TERM (1980 ± 5)	MID-TERM (1990 ± 5)	FAR-TERM (2000 ± 5)
		SYSTEMS			
FCS1 NAVIGATION	FCS1-1 VEHICULAR	NONE	FCS1-1N USE INITIAL GPS - U.S.A. - accurate - high speed users - expensive user sets	FCS1-1M USE GPS - global	FCS1-1F USE GPS - Same, but less expensive receivers
	FCS1-2 PERSONAL	NONE	FCS1-2N PERSONAL NAV-I - dedicated small satellites - compact radio user sets - inexpensive - 1 mile accuracy 0.1	FCS1-2M PERSONAL NAV-II - dedicated large satellite - wrist radios - cheap - 100 ft accuracy 0.4	FCS1-2F PERSONAL NAV-III • Add direction + speed to wrist readout
FCS2 TRANSPORTATION AID/CONTROL		NONE	FCS2-N TRANSPORTATION-I • GPS (initial) • AEROSAT • MARISAT 0.1	FCS2-M TRANSPORTATION-II • AIR TRANSPORTATION SERVICES-I - surveillance - navigation - 2-way data communication • URBAN TRAFFIC CONTROL - vehicle maximum speeds controlled positively - commandable engine governors - determine car speed - then command 0.6-1.2	FCS2-F TRANSPORTATION-III • AIR TRANSPORTATION SERVICES-II - surveillance - navigation - 2-way voice and data comm. • URBAN TRAFFIC CONTROL - Same • COASTAL RADAR - passive coastal radar - large, powerful satellite - passive users 1.7-2.3
FCS3 ENERGY	FCS3-1 DELIVERY	NONE	NONE	NONE	FCS3-1F DELIVERY-I • Nuclear • Solar • RTG - microwave beam delivery - large, heavy spacecraft 10.0-15.0
	FCS3-2 MANAGEMENT	NONE	FCS3-2N MANAGEMENT-I • CONSUMPTION MONITOR 0.15-0.25	FCS3-2M MANAGEMENT-II • CONSUMPTION MONITOR-II - Same as I, but more sensors. • NUCLEAR FUEL LOCATOR - tracks fuel rods everywhere 0.6-1.0	FCS3-2F SAME

CIVILIAN SUPPORT SPACE SYSTEMS (Continued)

FUNCTIONS		SYSTEMS: CURRENT	SYSTEMS: NEAR-TERM (1980 ± 5)	SYSTEMS: MID-TERM (1990 ± 5)	SYSTEMS: FAR-TERM (2000 ± 5)
FCS4	FCS4-1 ATMOSPHERE	NONE	NONE	FCS4-1M OZONE LAYER-I - replenish/protect - spray chemical from shuttle - deactivate freon radicals 1.6	FCS4-1F OZONE LAYER-II • Add other compounds 2.0
	FCS4-3 ILLUMINATION	NONE	NONE	FCS4-3M ILLUMINATION-I • CITY NIGHT ILLUMINATOR - large thin film mirrors - solar reflection - synchronous equatorial orbit 1.1	FCS4-3F ILLUMINATION-II • SPACE SEARCHLIGHT - laser on ground - mirrors in space - searchlight to illuminate selected regions on command • CITY NIGHT ILLUMINATOR 2.0-3.5
FCS5 DISPOSAL AND CONTROL OF WASTES		NONE	FCS5-N WASTE-I • SPACE DEBRIS SWEEPER - tug resident in orbit - deorbit space debris 0.13	FCS5-M WASTE-II • NUCLEAR WASTE (EXPERIMENTAL) • SPACE DEBRIS SWEEPER 0.2-0.3	FCS5-F WASTE-III • NUCLEAR WASTE-OPERATIONAL - shuttle payload + tug - escape orbits for waste • SPACE DEBRIS Same 0.5-0.6
FCS6 TRANSPORTATION DEVELOPMENT	FCS6-1 LOW EARTH ORBIT	EXPENDABLE X	SHUTTLE X	SINGLE-STAGE-TO ORBIT X	• LLV • LASER BOOSTER X
	FCS6-2 HIGH EARTH ORBIT	EXPENDABLE Y	TUG Y	SEPS Y	• LARGE MANNED TUG • LARGE SEPS Y
		X + Y = 1B	X + Y = 5.0	X + Y = 10.0-15.0B	X + Y = 15.0-30.0B

The military space systems data sheets are omitted for security classification reasons.

SECTION 3

FUTURE ENVIRONMENTS, NATIONAL GOALS, AND RELATED SPACE OBJECTIVES 1980-2000

1. INTRODUCTION

In the future, in contrast to the past, the space program will not be severely limited by the state of technology. Our capability for space activities will undoubtedly exceed the prudent capacity of the nation to afford them. It is necessary then to examine what we really should do in space, rather than catalog simply what we could do.

To treat what we should do, this appendix first considers broad trends in the future which we believe will dominate the activities in our society for the 1980-2000 period. With these trends in mind a set of ideal goals is proposed -- goals to strive for even when predictions are discouraging. Then a variety of space functions or opportunities are suggested leading towards those goals.

Both military and civil goals are treated here, the latter somewhat more fully. By seeing the total picture of space activities, we may be able to discern common uses in the civil and military areas.

2. DYNAMICS OF FUTURE INTERNATIONAL POWER RELATIONSHIPS AND U.S. NATIONAL DEFENSE

This section discusses important trends in international relations which could affect the balance of military power in the world. By understanding these trends, the U. S. may better plan those aspects of its space program which contribute to its military capability. By knowing the most significant military applications in space in the future, the U. S. may make more economical use of its space facilities by exploiting common requirements for both military and civil space activities, particularly common requirements in support functions.

The details of the military goals and applications are only included in the classified version of this report.

2.1 FIVE REGIONAL GREAT POWER CENTERS

From the end of World War II until about 1970, international relations were dominated by the positions of restrained conflict of the two great military powers of the world, the U. S. and the USSR. In the future, international relations probably will be much more complicated, because the group of great powers will be enlarged. Already the PRC has attained considerable military power, and its capabilities, particularly in strategic weapons, will continue to increase. The complexities of the relationships which will grow up among the three nations, the U. S., the USSR, and the PRC, and the serious consequences of any nuclear conflict, will generally preclude the use of extreme force. The influence of purely military power in international relations will be limited, and instead other types of power -- economic, technological, even cultural -- by other nations and by geographical areas, will gain important leverage.

Today five areas, only three of which possess significant nuclear force, are emerging as regional great power centers: (1) the U. S. and Canada, (2) Western Europe and Britain, (3) the USSR and its western border satellites, (4) the PRC, and (5) Japan. The basis of their future strength is suggested in Table 2-1. With the exception of Japan, these areas have the potential for long term economic strength based upon a combination of rich land and favorable climate for agriculture, abundant natural resources, population balanced for industrial production and internal food supply, high capital investment in productive industrial capacity, high level of technology and educated population capable of exploiting it, and internally stable governments and institutions. Japan is a special case, for it is a country lacking in fertile land and natural resources. Nevertheless, Japan has rapidly expanding industrial productivity fostered by specific traditions of cooperation of labor, business, banking and government. Barring a major international war, all the five areas should continue as great power centers into the 21st century.

Table 2-1. Year 2000: Regional Great Power Centers - Sources of Strength

	Nuclear Force	Conventional Military Force	Industry	Agriculture	Resources	Technology	Institutions
1. U. S. and Canada	+	0	+	+	+	+	+
2. Western Europe and Britain	-	0	+	-	0	+	+
3. USSR and Eastern Europe	+	+	+	+	+	+	+
4. China	0	+	-	+	+	0	?
5. Japan	-	-	+	-	-	+	+

+ Unusual strength, 0 Moderate strength, - Low strength, ? Unknown

The remainder of the world is now fragmented into many small political and economic units, only a few of which are progressive or productive of economic surplus. Most of the units are economically marginal, and some way be operating at a net productivity deficit. In the future, while the gross production of these areas will increase, and may even increase on a per capita basis, the productivity will continue to lag so far behind that of the surplus areas that the economic gulf between the developed and underdeveloped areas will widen.

2.2 BASIC CAUSES OF STRESS IN INTERNATIONAL RELATIONS

The past three decades have seen strong tensions in international relations, and although there has not been a serious threat of major war, several intermediary scale conflicts and many minor violent changes of government have occurred. Future prospects for reduced tensions do not look good. While some of the present ideological causes for tension may be reduced in their effects, other causes probably will grow in importance -- demographic, racial, cultural, technological and economic. The world is becoming more complicated and more interdependent economically. The pace of cultural change is straining the adaptability of advanced societies. The underdeveloped areas of the world will have real as well as self-perceived causes for dissatisfaction, ranging from serious food shortages to the disappointment of rising expectations. The great power regions, while enjoying an era of high and increasing wealth, will be faced with real international competition for raw materials, for markets, and for technology. Some further illustrations of the basic causes for stress between nations are given in Table 2-2. Although we cannot predict when or in what specific form stress will develop, nor which regions will be affected, we have little doubt that the stresses will be both widespread and severe.

Table 2-2. Basic Causes of Stress

1. <u>Affecting Less Developed Areas</u>

   a. Food-population maldistribution
   b. Depletion of natural resources
   c. Natural catastrophes -- floods, drought, biological condition
   d. Unstable markets for raw materials
   e. Difficulty of rapid cultural adaptation to modern civilization
   f. Cultural or ethnic clashes
   g. Disappointment of accomplishment compared to rising expectations
   h. Direct great power economic or military pressure
   i. Great power involvement in local troubled areas

2. <u>Affecting Great Power Areas</u>

   a. Competition for raw materials and industrial supplies
   b. Competition for markets.
   c. Competition for advanced technology
   d. Delicate interdependence of great power economies.
   e. Reluctance to accommodate to changing power positions.
   f. Small country conflicts as vehicles for great power maneuvering for advantage.
   g. Idelogical antagonism

2.3 COMPLEX PATTERN OF INTERNATIONAL RELATIONS 1980-2000

The general pattern of international relationships which will develop in the last two decades of the 20th century is shown in the diagram of Figure 1-1. In striking contrast to today's bipolar world characterized either by confrontation or detente between the U. S. and S. U. alliances, tomorrow's world will be essentially multipolar. The five regional military-economic great power centers will vie for political or economic as well as military advantages. As a result, there will be many transient coalitions, arranged for specific situations, dissolving and reforming as situations change. Japan, for example, now so closely tied to the U. S., may move towards China as a natural source of raw materials, particularly oil, and as a natural outlet for consumer products, industrial equipment, and possibly even venture capital. New Chinese leadership after the passing of Mao possibly even may cover over at least temporarily the present ideological gap between the two communist superpowers, the PRC and the USSR. But also as Chinese crop yields fluctuate from years of scarcity to years of sufficiency, China, to arrange agricultural imports, may alternately seek or reject rapproachment with the U. S. The maneuvering will be complicated, the alignments temporary, the results will be not so much power instability as shifting successive conditions of power balance.

Strategic nuclear war could of course destroy any of the super powers. Each region will seek to protect itself, the nuclear great powers by direct deterrence of some form, the non-nuclear great powers by ententes with the nuclear powers. Towards the end of the 20th century the three nuclear powers will all be advanced enough technologically to devise such protection, and determined enough nationalistically to maintain such protection. As a result, a fairly stable nuclear stalemate will be maintained,

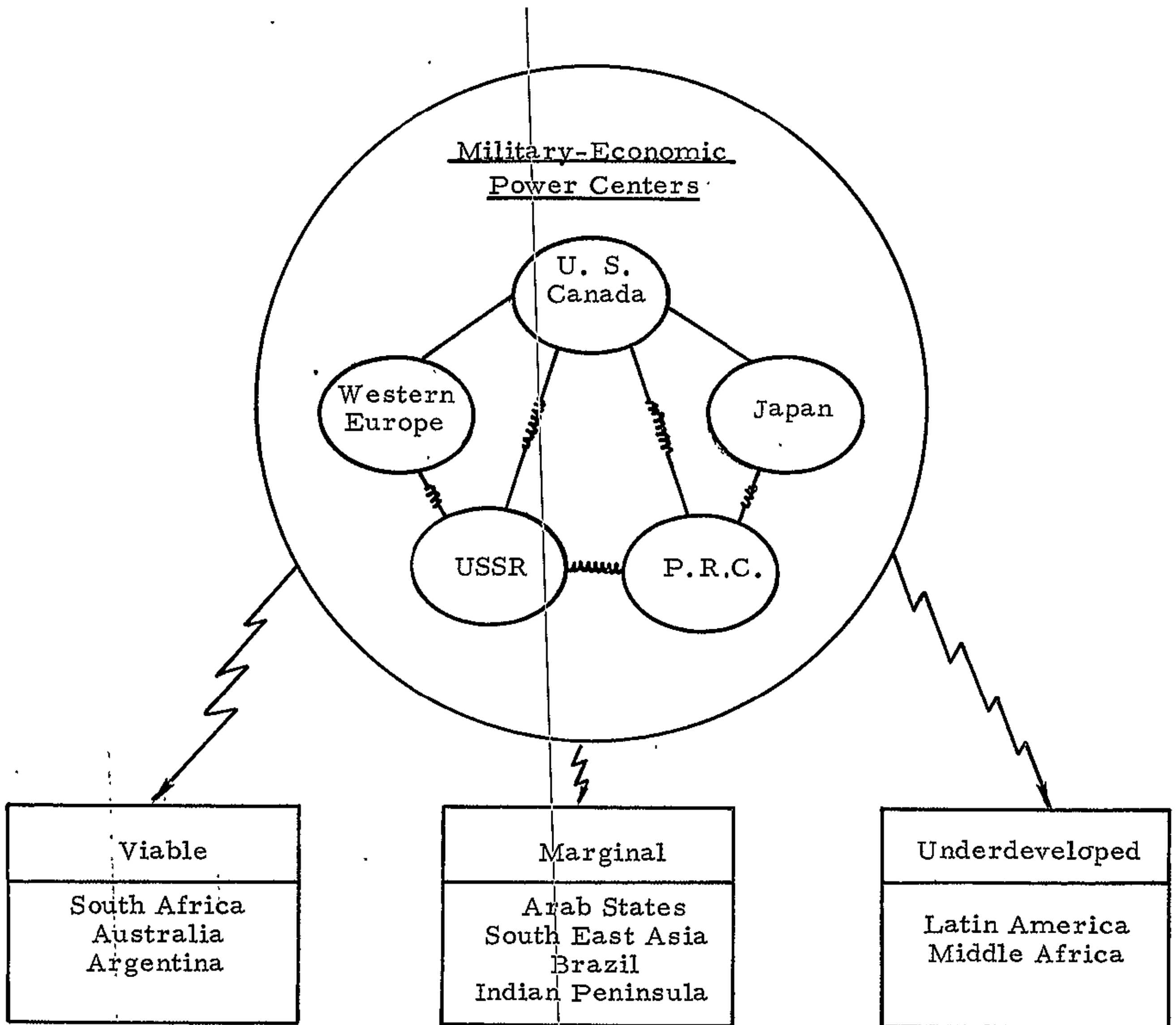

Figure 1-1. The Power Centers and Stress Relationships 1980-2000

perturbed sometimes by real, and more often by perceived, technological developments or force deployments that temporarily upset the nuclear balance. The nuclear stalemate will not only preclude any severe nuclear war among the five regional great powers, but it will deter any serious conventional war as well. However, limited military action by one great power in which the vital interests of the others are not involved will not only be permitted, but actually encouraged by the incredibility of full nuclear reaction under stalemate conditions.

The complicated relationships between the great power centers and the remainder of the world are indicated by the jagged lines in Figure 1-1. Not all the countries are listed here, just examples of three types, the economically viable, the marginal, or the underdeveloped. In the less developed regions of the world there will be ample cause for severe conflict, and ample opportunity for military action to occur. The nuclear stalemate will exercise no restraint on these conflicts. Instead, unfortunately, in the multiparty maneuvering of the great power centers, the legitimate local conflict situations may be exacerbated by great power involvement. Local conflicts will not be rare. According to past experience, in unstable developing areas such as Latin American and Middle Africa, the time between more or less violent changes in governments or local wars is only a few years in each country. Among the many national units in such areas and over the next quarter of the century, there could be hundreds of conflicts at some level of intensity. Wisdom in great power actions will be needed to prevent, to ameliorate, to limit, or at the least not to inflame such conflicts.

2.4 POSSIBILITY OF SCARCITY - OPPORTUNITY FOR PLENTY

As just discussed, international relations in the multipolar world will be very much more complex than in today's bipolar world. The nature of these relations will depend very much on overall world conditions -- on whether the future develops as a world of potential plenty or of definite scarcity. There are some indications of impending scarcity -- continued rapid population growth particularly in underdeveloped regions, almost complete utilization of prime farming lands, decline in productivity of fisheries, relative scarcity of some industrial raw materials, shortages in energy supply, and partial destruction of the general environment. In such a future, international relations might be viciously competitive, since one power can enrich itself only at the expense of its neighbors. But there is promise of a world of plenty. Population growth has slowed wherever it was apparent that large families were not needed for parental economic security. Industrial productivity is still increasing at least linearly with capital plant, and capital plant investment is increasing exponentially with time in the great power centers. Scientific knowledge and technology are also exponentiating, and the applications gap of technology to industrial productivity is now much less than a human generation. Basic energy resources in coal and in nuclear fission are adequate for centuries, even though not immediately available because of lack of capital plant; and solar energy, hot rock geothermal energy, or nuclear fusion energy, each of which might be exploitable, all are virtually unlimited. The combination of advanced knowledge and large supplies of energy can repair the environment, expand the agriculturally profitable land area, and eliminate shortages of industrial raw materials. Where there is potential for plenty, international relations can emphasize cooperation and fair play, because increasing total productivity will enlarge everyone's fair share.

It appears plausible that during the last quarter of the 20th century, the world may actually have the choice of whether the intermediate future is one of plenty or one of scarcity. In the fear of scarcity, the great power centers could expend their resources and energies in frantic competition including wasting military conflicts, and so reduce the net world productivity. The lack of surplus would result in diminished capital growth, further loss in productivity, and so bring on just the scarcity which was feared. The expectation of plenty could likewise become a self-fulfilling prophecy, as wise economic cooperation increases overall productivity, which generates surpluses for capital investment, which in turn increases production.

2.5 MAJOR CONCLUSIONS AND MAJOR U. S. GOALS IN INTERNATIONAL RELATIONS

We have just outlined our view of the general dynamics of interational relations for the remainder of the 20th century. The dynamics gives the framework but stops short of predicting the details of what will occur. Just because it is general, not specific, we have some measure of confidence in its predictions. But knowledge of the dynamical relations without specifics, nevertheless can be useful in setting our national goals.

Major conclusions based upon this viewpoint of international relations lead to four major goals or policy guidelines.

1. Maintenance of Balance of Power

The world will have five regional power centers. The U.S. should seek to preserve the multipolarity of the relationships among the five by maintaining a balance of power in the shifting alignments that will develop. We should foster the doctrine of "rule of the concurring majority" rather than that of unilateral action.

2. Increased Global Economic Productivity

There is the potential but not the historical necessity for a world of plenty. The U. S. should foster economic cooperation and keep political competition bounded to increase global economic productivity.

3. Non-Prejudicial Avoidance of Local Conflict Involvement

Throughout the world there will be hundreds of more or less violent changes in government, revolutions, minor international military actions, local wars. Generally the U. S. should avoid direct military involvement in the local conflicts. However the U. S. should uphold its position of leadership and good influence among nations by maintaining the capability of credible intervention when required.

4. Minimize Great Power Confrontation in Minor Conflicts

The large number of minor conflicts could provide a field for great power maneuvering which unfortunately will be exploited to some extent. U. S. involvement should attempt to be non-confrontation and non-escalatory.

The viewpoint developed here will be used later as a basis for a rather complete set of goals for the U. S. in international relations and accompanying military objectives for the 1980-2000 period.

3. EVOLVING FUTURE PROBLEMS - CIVIL AREA

3.1 COMPLEXITY OF LIFE PATTERN

In future international relations, a general dynamic behavior has been discerned, the pattern of labile coalitions in a multipolar world. From this pattern, independent of the details of the future developments, many important goals for U. S. policy can be obtained. In the field of internal affairs, however, no comparable general pattern has emerged to guide us towards a set of national goals.

Instead it appears that U. S. society will become both more fragmented and more complex. The early 20th century melting pot ideal which was leading to a homogeneous society has been replaced by a pluralistic ideal. But this ideal is confronted with the pressure towards conformity of a nationwide market economy and of nationwide press and communications media. In this conflict of the pluralistic ideal with the real world, the strength of diversification in the culture, could be lost while much of the divisiveness will remain.

The complexity of the society also, instead of being a source of richness, will probably be largely a source of frustration. The former patterns of personal life, -- a stable family, dependable church ideals, a steady structured job -- are disintegrating, and definite new patterns have not emerged. Even the tremendously productive American economy may become stalled by this complexity. At present neither the tools nor the techniques of production, either industrial or agricultural, pose any great problems. But rapidly changing technology is making our capital plant obsolete, while rapidly changing marketing preferences are straining the adaptability of our distribution systems.

Some significant problems are listed in the following Table 3-1.

Table 3-1. Significant Problems of the 1980-2000 Period

INTERNATIONAL

1. Overpopulation - Loss of Expansion Space
2. Limited Natural Resources
3. Disaffection of World with U. S. Affluence
4. Stress, Conflict and Warfare

NATIONAL

5. Local, Not Global Optimization of Industrial Activity
6. Stable Energy Supplies at Adiabatic Price
7. Agricultural Management at Adiabatic Price
8. Government Responsibility for Health and Safety
9. Feeling of Exclusion from "The Establishment"
10. Frustrated National Greatness, National Morality

Some general trends, particularly in our attitudes are suggested in the next Table 3-2. While the details may not be confirmed by future history, the general pattern may well be.

Table 3-2. Some General Trends 1980-2000

1. World of limited horizons. Pessimism and pragmatism replace optimism and idealism.

2. Popular faith and support of central governments low. Government stability low, although regional stability good.

3. In emerging nations political parties, civil service, business organization all weak. Center for organization is likely to be military forces. Practical exercise of government gravitates to military.

4. Trend away from idealistic or pragmatic internationalism.

   - Trade wars.
   - Dog-in-the-manger control of resources.
   - Hard-hearted as well as hard-headed approach to international aid.
   - Technology hoarding.

The pressing problems of the future appear to demand flexible organization and management of our economic system and our social institutions so that the plurality of aims, including conflicting goals of other nations can be accommodated. In this era, information and information management will be key tools, replacing in importance industrial production and political control. Because space facilities are well suited for acquiring large amounts of information, and routing it in very flexible fashion, space operations could play a crucial role in helping the world through the difficult period of the late 20th century.

4. U.S. GOALS IN SPACE EXPLOITATION 1980-2000

The set of trends, and possible developments, that may characterize the last part of this century that has just been discussed in this appendix form an amorphous background of material on which to develop rational goals for a space program of the 1980-2000 period. Actually in this work no rigorous pattern of deductive reasoning was used to go from this background to a set of goals. Instead a set of goals was suggested by the potential capabilities of space systems, and then ordered under logical categories significant for human welfare under almost any projection of historical circumstances.

The following sections of this appendix discuss the national goals which should serve as a basis for planning the space program for the remainder of the 20th century. The set of goals selected are responsive to the views of the key problems of our society that have just been discussed. However, the goals are to a considerable extent independent of the particular problems. By their nature, goals represent somewhat distant ideals, but these ideals may be worthwhile under a variety of imperfect conditions of the real world. So many of the goals, both in the military and in the civil areas, are general "motherhood" statements. They are worthwhile for planning nonetheless, since we have attached relatively specific space functions or objectives to the general goals.

One purpose of establishing a set of goals is to aid in assigning priorities and resources to specific programs. The goal structure here is too general and inclusive to aid in this task. To make progress in assigning priorities, the relative importance and urgency of the goals should be established, and that has not been done here. However, the prior discussion of the dynamics of international relations and of the problems in the civil area can help in generating some perspective on the importance of the various goals.

While still quite general, the goals selected form only a subset of the goals for the future society, a subset chosen because these goals may be significantly affected by space activities. Particularly emphasized here are goals due to newly developed needs that can be satisfied by the opportunities presented by the world's emerging space capability. Among the new needs is the care of our planet earth -- man's activity is reaching the level where he may seriously disturb the physical as well as the biological equilibrium in nature. Space platforms provide a matching opportunity for monitoring these disturbances on a global level while they are still small and hopefully correctable.

The military goals will be treated first in outline form. Space applications are suggested by most of these goals so much so that we believe space systems can vitally affect the balance of military power. Then the civil area goals are discussed in somewhat greater detail.

5. U.S. GOALS IN INTERNATIONAL RELATIONS 1980-2000

5.1 GOALS

A. General

1. Continuity of U. S.: Continuance of U. S. as a national entity with self-determined political institutions conforming to its constitution.

2. Defense of homeland: Protection of U. S. homeland from damage by military force.

3. Climate of peace: Promotion of climate of international peace to relieve burden of fear of war from all nations, and reduce burden of excessive armaments engendered by that fear.

4. International leadership: Maintain a position of leadership in international community.

5. Evolutionary development: Promotion of evolutionary development of nations by peaceful means.

6. Limited reaction to revolution: Case by case determination of U. S. reaction to revolutionary changes in foreign political structures (including changes brought about by local international military forces), based upon principle of U. S. enlightened self-interest.

7. Protection of U. S. citizens abroad: Protection of U. S. citizens in foreign lands from unlawful force.

B. Economic

8. Secure foreign supplies of materials: Securing of stable supplies of materials from foreign countries at close to free market values.

9. Reciprocal trade for U. S. farm produce: Management of U. S. farm product surpluses to secure orderly world markets in those commodities, and fair reciprocal supplies of materials to the U. S.

10. Expanded vegetable protein: Encouragement of worldwide vegetable protein production -- soy beans, new forms of corn, future developmental crops.

11. Ocean resource exploitation: Foster international exploitation of ocean resources.

12. Space exploitation: Foster international economic exploitation of space for communications, meteorology and earth resources development.

13. International nuclear plant regulation: International regulation of nuclear electric power plant operation to promote safety, control fission products and radioactive by-products, and prevent diversion of dangerous nuclear materials.

C. Political

14. Multi-power international community: Development of a true multi-power international community. Power centers probably as follows: (a) U. S. (b) Western Europe including Britain. (c) S. U. (d) P.R.C. (e) Japan. Institutionalize the "rule of the concurring majority" in determining international relations.

15. True detente with S. U.: Agreements to be based upon practical mutual advantage, not merely to foster a spirit of detent. Mutual reduction of offensive strategic nuclear armaments, perhaps by agreement to scrap overage force elements on a substantially equivalent basis.

16. Normalized relations with P.R.C.: Full normalization of relations with P.R.C. Substantial mutual trade with P.R.C. Negotiation of trade benefits and U. S. to P.R.C. technology transfer contingent upon Chinese restraint in entering nuclear arms race.

17. Pattern of regional common markets: Support of regional associations, somewhat analagous to European common market, in Latin America, Middle Africa, Middle East, Oceania.

18. Organization of Asian states: Development of an organization of Asian states with major policy determinations left to the Asian community.

19. Economic viability of Indian peninsula: Support of India and Pakistan on a goal oriented program to achieve substantial economic self-sufficiency.

D. Geophysical

20. International environmental agency: Establishment of international commission to prevent deterioration of geophysical environment. Initially the commission should have purview over radioactive contamination, but eventually over inorganic chemical poisons, and organic chemical poisons as well.

21. Law of weather alteration: Negotiation of international agreements, and development of international law on weather alteration.

22. Study of long-term environmental deterioration: Establishment of international geophysical study agency to predict long term environmental deterioration possibilities such as CO_2 release.

5.2 PROJECTED U.S. MILITARY OBJECTIVES 1980-2000

(These objectives are found only in the classified version of the report.)

6. GOALS AND RELATED SPACE OPPORTUNITIES - CIVIL AREA

The goals are grouped into three categories, representing different aspects of human nature. The categories are (1) materialistic, (2) humanistic and public service, (3) intellectual. Under each general goal, some specific contributing space functions or opportunities are listed.

C.2

6.1 MATERIALISTIC GOALS

1. Promotion of international peace

   1.1 UN space based truce monitoring system
   1.2 International treaty verification.
   1.3 Complete system of heads of state "hot line" communications for crises avoidance

2. Position of world leadership for the U. S.

   2.1 Space developments indicating technology leadership
   2.2 International space enterprises with major U. S. contribution

3. Optimization of industrial activity

Industrial productivity will continue to be one of the pillars of our social well being towards the end of the 20th century. Techniques of production per se will be more than adequate. But management of production -- matching production to the needs and desires of the consumers, balancing efficient exploitation of resources against conservation and preservation of desirable environmental characteristics, and arranging for effective distribution -- will become much more complex and difficult. In management, information, gathered from all over the country, and to some degree from all over the globe, will be the key; and space can provide the natural platform for obtaining this information. The following list includes general space functions which will be significant in contributing to the goal of optimizing industrial activity. In every case specific space initiatives as described in the body of this report are available to support these functions.

3.1 Exploration for land resources
3.2 Discovery and management of industrial ocean resources
3.3 Monitoring industrial activity and wastes
3.4 Overseeing and controlling ground transportation
3.5 Overseeing and controlling ground energy distribution
3.6 Possibly providing for energy distribution via space links
3.7 Weather prediction and warning
3.8 Provision of wide variety of communication capabilities.
3.9 Prediction of ionospheric disturbances and management of communications to lessen their efforts.

4. Agricultural, Forest, and Fishery Management

World food supply will be critical in this future period, and the U. S. should continue to produce a local food surplus. While individual farming efforts in the U. S. are now extremely productive, farming as a business is cyclical, unpredictable, and risky due to weather. World fisheries are now poorly managed, locally overfished for highly desirable species, but globally underutilized as a source of protein. Forests, as a source of lumber and as a valuable stabilization of watershed, will always be subject to disease, insect infestation and fires. Management of all these resources could be aided by world-wide information, and space platforms by their global coverage could be an efficient medium for getting this information. General space functions in support of this goal are

4.1 Long range weather prediction for agriculture
4.2 Short range weather prediction of heavy rains for agriculture and of lightning storms for forest fire prevention

4.3 Short range weather prediction and warning at sea
4.4 Worldwide crop surveys and prediction
4.5 Forests surveys for general ecological effects
4.6 Early forest fire detection
4.7 Survey of fishery resources and monitoring of fishing activity and catches

5. Provisions of New Resources from Space

In principle space sources might be useful in supplying new resources to earth, particularly once economical supplies on earth are exhausted. For the remainder of this century it appears premature to attempt to supply materials from space. But in this time period solar energy could be converted to microwaves and beamed to earth possibly to supply bulk electric power needs. The technical method exists, essentially unlimited solar energy is freely available, space generation eliminates hazard and pollution accompanying energy generation on earth -- the question is whether space power can compete economically with earth supplies. A valid goal for space activity in this area is therefore

5.1 Verification of economical bulk power generation in space and transport to earth.

6. Exploitation of Space Environment for New Technological Capabilities

The future will see requirements for "high technology" at least in some areas. The unusual qualities of the space environment may prove economically useful in development or in production in some aspects of high technology application. A valid goal for the remainder of the 20th century is a modest, limited, balanced industrial exploitation of the space environment with due consideration for ground alternatives. Particularly promising space functions appear to be

- 6.1 Use of extremely high vacuum in large volume for industrial exploitation
- 6.2 Use of extremely pure surfaces, stable for long periods
- 6.3 Preparation of carefully tailored multi-layer surfaces
- 6.4 Exploitation of zero-gravity effects in industrial processes.

7. Use of Space to Remove Hazards from Earth

Chemical and nuclear technology have already advanced to the point where some processes and some products pose hazards on earth. Biological technology may soon pose even greater hazards. Space can provide an effective isolation from the earth. Potentially useful space functions then could be

- 7.1 Chemical processing, which on earth poses unacceptable environmental hazards
- 7.2 Similar nuclear processing
- 7.3 Similar biological processing
- 7.4 Disposal of hazardous waste products -- chemical, biological, and particularly radioactive waste from the nuclear power industry

8. Preparation for Space Habitation

As the economic utility of space grows, so will the need for some manned functions in space -- not so much as scientist, researcher, and explorer as in the 1960's and 1970's, but as a worker, assembler, service technician. Limited space habitation is considered as a reasonable goal for the end of the 20th century. It is too early to have any informed perspective on the colonization of space -- space settlements as a home rather than as a hotel for space workers. Limited experimentation to provide some facts for decision on space colonization, however, appears appropriate. Space habitation goals are then

- 8.1 Development of space habitation for temporary residence of support personnel for orbital assembly and supply yards
- 8.2 Development of space habitation for space research facilities
- 8.3 Limited experimentation leading towards long term space habitation.

6.2 HUMANISTIC AND PUBLIC SERVICE GOALS

1. International cooperation

- 1.1 International space laboratory
- 1.2 International space communications systems
- 1.3 International hazard warning system
- 1.4 International energy sharing

2. Aid to General Safety

Even more than in the past, the U. S. citizens will look to their national and local governments to provide for their general safety in an increasingly complex and hazardous world. It will be expected that expenditures for safety far greater than those strictly justifiable on economic grounds will be allocated on humanistic grounds. Space systems can provide some measure of government response to this public requirement, in those cases where the large area information gathering or dispensing capability of of space platforms are useful in aiding the general safety. Some of those cases are

2.1 Hurricane prediction and warning
2.2 Flood condition prediction - months
2.3 Flood warning, short term - hours
2.4 Tsunami location, prediction of size, warning
2.5 Transportation safety
    air collision avoidance
    ship and small boat monitoring
    railroad safety
2.6 Earthquake prediction
2.7 Management of disaster aid

3. Protection of the General Environment

As economic development progresses, some deterioration of the environment will undoubtedly occur. More and more it has become the responsibility of government to regulate this deterioration as a public service. In many cases, space systems can provide the information for regulatory action more easily than ground based systems. Some areas for space application are

3.1 Monitoring of industrial atmospheric pollution
3.2 Monitoring of water pollution on a river system scale
3.3 Monitoring large scale ocean pollution
3.4 Monitoring and preservation of the atmospheric ozone layer
3.5 Diagnosis of large scale climatic changes

4. Aid to Individuals in Peril

As a humanistic goal, the governments in the U. S. will be expected to aid individuals endangered or in distress. In this particular category only non-criminality related perils are considered. But as we develop a more mobile and more individualistic society, more and more people will engage in potentially hazardous activities -- backpacking, mountain climbing, personal aircraft flying, small boating, hang glidering -- over widespread areas. Space systems can aid in search and rescue operations of world-wide scope. They can also obtain and transmit information to aid in avoiding particularly hazardous circumstances. Significant space functions that might be provided are

4.1 Emergency personal communications
4.2 Search for lost private aircraft, boats, people
4.3 Direction of rescue operations, worldwide
4.4 Hazard warning communications
4.5 Provisions of personal navigation capability
4.6 Navigation aid to small boats and light aircraft

5. Aids to Crime Control

Unfortunately crime in the U. S. will not disappear with the continued development and even with the increased well being of the nation. Particularly distressing are the crimes of personal violence. Space concepts to prevent such crimes, or to aid victims are

5.1 Emergency personal communications
5.2 Police communications systems
5.3 Command and control of police operations
5.4 Local area surveillance aided by space systems
5.5 Monitoring burglar alarm systems
5.6 Night illumination

6. Aids to Internal Security

   6.1 Border surveillance to prevent illegal entry
   6.2 Limited area surveillance for physical security
   6.3 Control of fissile or radioactive materials to prevent diversion and blackmail

7. Improved relations of citizens to government

   7.1 Improved communications systems
   7.2 Instant referendums

6.3 INTELLECTUAL GOALS

Only a sample of these activities is given since intellectual goals are in principle limitless. Here we emphasize those questions which are so basic as to interest many non-technical people, not only the scientific specialists.

1. Aid in determination of origin and early history of the solar system

   Planetary exploration and geology
   Nature of asteroids
   Cometary research

2. Aid in understanding of galactic structure and dynamics

   Infrared astronomy using wavelengths from 5-500 μm.
   UV astronomy

3. <u>Aid in understanding cosmology</u>

X-ray astronomy
Observations of distant objects - all electromagnetic frequencies
Intergalactic material - particles, atoms, and ions, molecules.
Low noise measurement of 3K universal background blackbody radiation

4. <u>Verification of physical laws in the large</u>

General relativity experiments
Invariance, spatial and temporal of velocity of light
Homogeneity of "empty" space
Isotropy of "empty" space in the large

5. <u>Precision measurements to verify physical laws in the small</u>

Precise value of gravitational constant
Equivalence of inertial and gravitational mass

SECTION 4

RELATION OF INITIATIVES TO GOALS

Not unexpectedly, there is a good correlation between the space functional goals which were outlined as requirements in the first part of the work and the initiatives themselves, and in fact, as is seen in the next three pages, there is at least one initiative in the catalog that contributes toward the attainment of almost every goal identified. These pages clearly show that space can be made relevant to the problems of society and this country in this time period.

RELATION OF INITIATIVES TO DESIRED GOALS

PUBLIC SERVICE AND HUMANISTIC GOALS	INITIATIVES
1. PROMOTION OF INTERNATIONAL PEACE	CC-10 Diplomatic/U.N. Hot Lines CC-8 National Information Services CO-1 Advanced Resources/Pollution Observatory CO-6 U.N. Truce Observation Satellite CS-8 Multinational Energy Distribution CO-5 Multinational Air Traffic Control Radar
2. AID TO GENERAL SAFETY	CC-3 Disaster Communications Set CO-3 Water Level and Fault Movement Indicator CO-7 Nuclear Fuel Locator CC-5 Transportation Services Satellite CS-10 Vehicular Speed Limit Control CS-13 Rail Anti-Collision System CS-9 Energy Monitor CO-9 Coastal Anti-Collision Passive Radar
3. PROTECTION OF THE GENERAL ENVIRONMENT	CO-1 Advanced Resources/Pollution Observatory CS-4 Nuclear Waste Disposal CS-1 Energy Generation - Solar/Microwave CS-2 High Efficiency Solar Energy Generation CS-3 Energy Generation - Nuclear/Microwave CO-4 Ocean Resources and Dynamics System CS-11 Space Debris Sweeper CO-13 High Resolution Earth Mapping Radar CS-12 Ozone Layer Replenishment/Protection

RELATION OF INITIATIVES TO DESIRED GOALS (Continued)

PUBLIC SERVICE AND HUMANISTIC GOALS	INITIATIVES
4. AIDS TO INDIVIDUALS AND CRIME CONTROL	CS-7 Personal Navigation Wrist Set CS-16 Near-Term Navigation Concept CC-9 Personal Communications Wrist Radio CC-1 Global Search + Rescue Locator CS-6 Night Illuminator CC-2 Urban/Police Wrist Radio CC-3 Disaster Communications Set CC-14 Burglar Alarm/Intrusion Detection
5. PROMOTION OF INTERNAL SECURITY	CO-8 Border Surveillance CO-7 Nuclear Fuel Locator
6. IMPROVED RELATION OF CITIZENS TO GOVERNMENT, AND ENHANCEMENT OF SATISFACTION	CC-7 Voting/Polling Wrist Set CC-8 National Information Services CC-6 Advanced T.V. Broadcast

RELATION OF INITIATIVES TO DESIRED GOALS

MATERIALISTIC GOALS	INITIATIVES
1. AID IN INCREASING INDUSTRIAL ACTIVITY	CO-1 Advanced Resources/Pollution Observatory CO-4 Ocean Resources and Dynamics System CO-12 Synchronous Meteorological Satellite CC-3 Disaster Communications Set CC-8 National Information Services CC-11 3D Holographic Teleconferencing CC-12 Vehicle/Package Locator CS-1 Energy Generation - Solar/Microwave CS-3 Energy Generation - Nuclear/Microwave
2. AID IN AGRICULTURAL, FOREST, AND OCEAN RESOURCES MANAGEMENT	CO-4 Ocean Resources and Dynamics System CO-13 High Resolution Earth Mapping Radar CO-2 Fire Detection CO-12 Synchronous Meteorological Satellite CO-1 Advanced Resources/Pollution Observatory

RELATION OF INITIATIVES TO DESIRED GOALS (Continued)

MATERIALISTIC GOALS	INITIATIVES
3. PROVISION OF NEW RESOURCES	CS-1 Energy Generation - Solar/Microwave CS-2 High Efficiency Solar Energy Generation CS-3 Energy Generation - Nuclear/Microwave CS-4 Nuclear Waste Disposal CS-5 Aircraft Laser Beam Powering CS-8 Multinational Energy Distribution CS-15 Power Relay Satellite CS-6 Night Illuminator
4. AID IN MAINTAINING U. S. POSITION OF WORLD LEADERSHIP	CS-8 Multinational Energy Distribution CS-1 Energy Generation - Solar/Microwave CS-2 High Efficiency Solar Energy Generation CS-3 Energy Generation - Nuclear/Microwave

RELATION OF INITIATIVES TO DESIRED GOALS

SCIENTIFIC AND INTELLECTUAL GOALS	INITIATIVES
1. AID IN DETERMINATION OF ORIGIN AND NATURE OF SOLAR SYSTEM, GALAXY, AND UNIVERSE	CO-10 Astronomical Super Telescope CO-14 Interplanetary T. V. Link
2. AID IN UNDERSTANDING TERRESTRIAL PROCESSES	CO-4 Ocean Resources and Dynamics System CO-13 High Resolution Earth Mapping Radar CO-11 Atmospheric Temperature Profile Sounder CO-3 Water Level and Fault Movement Indicator CO-1 Advanced Resources/Pollution Observatory CO-12 Synchronous Meteorological Satellite

SECTION 5

WEIGHT AND COST ESTIMATION

WEIGHT AND COST ESTIMATION

I. INTRODUCTION

The purpose of this appendix is to present data pertinent to the ground rules used for size, weight, and cost estimation of the initiatives.

II. LAUNCH VEHICLE ELEMENTS

Launch vehicle design and rocket performance computations are outside the scope of this effort. Nevertheless, it is necessary to define a set of candidate launch vehicle elements in gross terms in order to conduct the study. The selected launch vehicle combinations are listed in Table 5-1, together with their estimated gross payload capabilities. The payload weights represent deployment only; the costs represent launch costs only.

The candidate launch vehicle element set is by no means exhaustive, but is considered to be sufficiently comprehensive to serve the objectives of the Study 2.5 activity.

All launch vehicle elements are considered to be reusable and are identified as follows:

Element A

A standard shuttle with characteristics approximating to the NASA April 1974 shuttle configuration.

Element B

A Large Launch Vehicle (LLV), not defined in detail, but providing approximately 20 times the payload capability of Element A to low-earth orbit.

Table 5-1. Candidate Launch System Payload Capabilities (lb)

Item	Launch Vehicle Combination	Code	Low Altitude		High Altitude			Launch Veh. Cost/Flight $\$ \times 10^{-6}$ *
			Low Inclination	High Inclination	Elliptical	Geosynch.	Translunar	
1	Shuttle	A	60,000	30,000	-	-	-	12.0
2	Shuttle + Tug	A + C	-	-	15,000	7,000	6,000	13.0
3	Shuttle + Tandem Tug	2A + 2C	-	-	37,000	18,000	15,000	26.0
4	Shuttle + Large Tug	A + D	-	-	24,000	11,000	10,000	14.0
5	Shuttle + Large Tandem Tug	2A + 2D	-	-	60,000	29,000	24,000	28.0
6	Shuttle + SEPS	A + E	-	-	21,000	10,000	8.500	12.5
7	Shuttle + Nuclear	A + G	-	-	42,000	20,000	17,000	15.0
8	Shuttle + Tug + SEPS	A + C + E	-	-	30,000	14,000	12,000	13.5
9	Shuttle + Large Tug + Large SEPS	A + D + F	-	-	48,000	22,000	19,000	14.5
10	LLV	B	1,200,000	600,000	-	-	-	15.0
11	LLV + Large Tug	B + D	-	-	300,000	140,000	120,000	17.0
12	LLV + Large SEPS	B + F	-	-	420,000	200,000	170,000	16.0
13	LLV + Nuclear	B + G	-	-	840,000	400,000	340,000	18.0
14	LLV + Large Tug + Large SEPS	B + D + F	-	-	600,000	280,000	240,000	18.0

CODE: A = Shuttle
B = LLV (Large Launch Vehicle)
C = Tug
D = Large Tug
E = SEPS (Solar Electric Propulsion Stage)
F = Large SEPS
G = Nuclear Stage

*Does not include amortization of RDT&E costs

Element C

A standard tug upper stage having performance capability approximately equivalent to the Interim Cryogenic Space Tug described in NASA Baseline Space Tug Document (see Reference 1). The Interim Upper Stage can be considered roughly equivalent to this element if operated in tandem.

Element D

A large tug, not defined in detail, but providing approximately a 60 percent increase in payload capability to geosynchronous orbit over the A + C combination, when combined with the standard shuttle.

Element E

A Solar Electric Propulsion Stage (SEPS) similar to the configuration described by Rockwell International (RI) and used by RI in their SEPS applications studies (see Reference 2).

Element F

A large SEPS, not defined in detail, but when combined with the LLV, providing 20 times the payload capability to geosynchronous orbit as the A + E combination.

Element G

A nuclear upper stage which utilizes an advanced nuclear orbital propulsion system having an I_{sp} comparable to the solar electric propulsion stage, but a thrust level comparable to present-day chemical rockets.

In order to permit investigation of the potential utility of SEPS from low-earth orbit, it is assumed:

a. By the time period interest, solar cells will be developed which are highly resistant to radiation degradation.

b. Long transfer times (280-350 days) to final orbit are acceptable for most of the initiatives.

c. The nuclear stage is considered for initiatives where on-orbit maneuvering is an essential characteristic of the mission (for instance, for survivability) and the satellite orbital configuration is large.

d. The SEPS and the nuclear stage are available on orbit for extended periods of time and do not require refurbishment after every use. The costs listed in Table 5-1 reflect this assumption.

III. MISSION EQUIPMENT ADVANCED TECHNOLOGY

During the course of the study, a number of new mission equipment concepts were identified which would require technological advances to develop and deploy. In addition to large, lightweight solar arrays, nine generic types were identified and these can be divided into two specific categories. In addition, all the nine generic types appear to have the common characteristic of needing large structural assemblies in space. These structural assemblies may or may not need to be rigid structures.

The hierarchial structure is illustrated in Figure 5-1, together with the code numbers of typical initiatives which appear to be candidates for utilizing the nine generic concepts. Briefly, the nine generic types can be described as follows:

Type 1

Type 1 is a plane optical reflector subject to relatively low flux densities. It provides a large aperture rather than a small spot size and therefore a surface quality considerably below the diffraction limit is adequate. It is constructed of a thin mylar or kapton film rigidized by a graphite composite deployable structure. The rigid structure supports the necessary househeeping subsystems.

Type 2

Type 2 is a spherical optical reflector subject to relatively low flux densities and requiring the same surface tolerance as Type 1. It is constructed of a

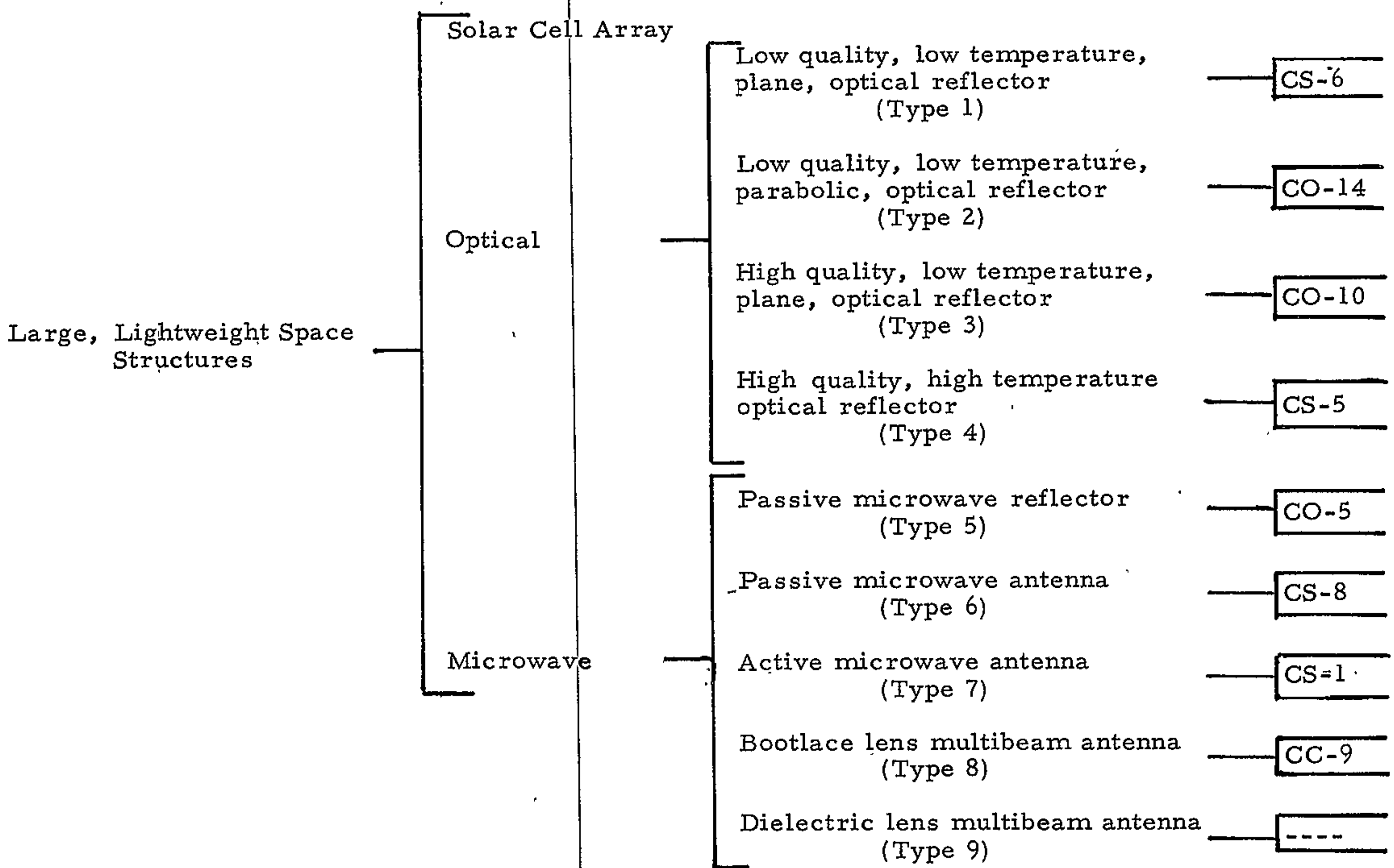

Figure 5-1. Large, Lightweight Space Structure Applications

double layer of thin mylar or kapton film, sealed at the edges, one layer being silvered and one layer being clear. By pressurizing the space between the layers, an approximately parabolic surface is realized. Structural rigidity is maintained by a pressure stabilized toroidal edge structure constructed by utilizing the Goodyear "Airmat" concept. The necessary housekeeping subsystems, including the attitude control thrusters, are located on this outer ring structure.

Type 3

Type 3 is an optical reflector which is subject to relatively low flux densities, but requires close surface tolerance control and, therefore, probably cannot be made of thin mylar or kapton film. Instead, it is a rigid structure of graphite composite with the front face silvered and the back face used to radiate surplus heat. The necessary housekeeping subsystems are attached to the mirror. The mirror may or may not be gimbaled.

Type 4

Type 4 is an optical reflector which is subject to high flux densities and also requires close surface tolerance. It is therefore constructed of a rigid graphite epoxy structure, heavier than Type 3 because of a heavier and more complex thermal control system. The necessary housekeeping subsystems are attached to the mirror and the mirror may or may not be gimbaled.

Type 5

Type 5 is a simple microwave reflector constructed of a very lightweight open metalized graphite epoxy cobweb structure or a thin mylar or kapton film with printed circuit type dipoles. The structure may be deployed, assembled on orbit or possibly even fabricated on orbit. The structure may be monolithic or consist of independently stationkept subarrays. A housekeeping subsystem package is required.

Type 6

Type 6 is a microwave antenna, constructed in a similar way to Type 5, but contains receiving components and is electronically more complex to allow beam formation and is therefore heavier and more costly.

Type 7

Type 7 is an active microwave antenna which radiates microwave energy generated in orbit. The antenna is electronically controlled for beam formation and steering. The structure may be monolithic or consist of independently stationkept subarrays.

Type 8

Type 8 is a near-term technology multibeam antenna which utilizes the bootlace lens concept. Conceptually, it is similar to a configuration studied by the Hughes Aircraft Company (See Reference 4).

Type 9

Type 9 is a far-term technology multibeam antenna using very lightweight structures and incorporating a dielectric or wave delay lens.

IV. TYPE 1 CONCEPTUAL DESIGN

A. Design

Detailed design is outside the scope of the Study 2.5 effort. However, a conceptual design was developed for the Type 1 optical reflector and is illustrated in Figure 5-2.

Figure 5-2 illustrates a triangular planform shape of reflector which is based on previous study activities described in Reference 5. The method used for supporting the three sides of the reflector in tension uses a catenary support concept. Support is provided at each of the three corners of the reflector by booms that deploy from the central spacecraft structure. The primary difference between Figure 5-2 and the configuration shown in Reference 5 is that the concept presented

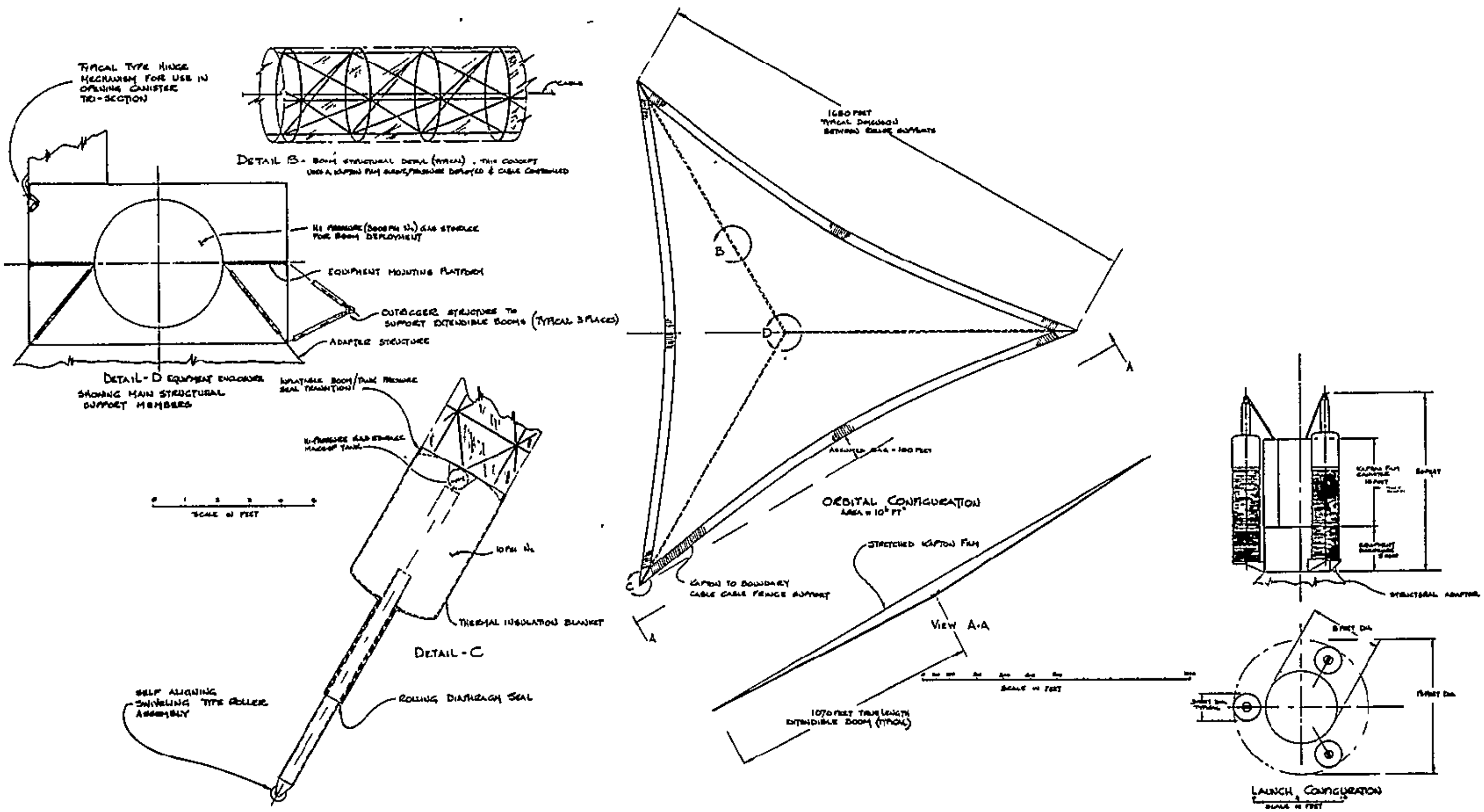

Figure 5-2. Type 1 Optical Reflector

makes use of a complete triangular film reflector in contrast to a three segment reflector. The single reflector eliminates the necessity for supporting the radial edge members of the respective segments.

The reflector is assumed to be fabricated from 0.00025 in. kapton polyimide film in contrast to the present state-of-the-art polyimide film thickness of 0.0005 in. The edges of the triangular shaped film are connected to the edge cable (catenary support) by means of a myraid of separate cables which forms essentially a continuous attachment that eliminates undesirable side forces which would tend to wrinkle the film. Based on information contained in Reference 5, the kapton is assumed to be stressed at 10 psi. This film stress was used to determine the loads required at the corners of the reflector, (and, hence, the ends of the booms), to stretch the reflector to obtain a taut surface. The 10 psi stress level is defined as the minimum stress (Reference 5) required to remove wrinkles in the material. The corner loads that were derived, using the 10 psi stress level and assuming the catenary to have a 100-ft sag, were computed to be 260 lb at each corner.

A thermal excursion of $\pm 425^{\circ}F$ was assumed to derive the expansion/contraction dimensional changes in the kapton film. Based on a thermal expansion of 2.0×10^{-5} in./in./$^{\circ}C$, the length of each corner of the reflector was estimated to vary $\pm$ 3 ft. Detail C shown in Figure 5-2, shows a pressure cylinder and sliding member for adjusting the boom length to accommodate the $\pm$ 3-ft deflection associated with maintaining a taut reflector surface. The cylinder dimensions, (diameter = 3 ft, length = 4 ft), and internal pressure, (10 psi), were selected to minimize the force variation that would occur at the end of the sliding member due to the expansion/

contraction of the kapton. The maximum and minimum end loads computed for the fully extended and retracted positions were 234 and 286 lb respectively, based on the assumption that the temperature of the pressurant would remain constant. It was further assumed that the pressurant can be maintained at a constant temperature by insulating the external surfaces. Discussions held with thermal control specialists indicated that, in all probability, low power consumption heaters would be required to maintain the gas at constant temperature. A high pressure gas tank (12.0 in. dia; 3000 psi) is incorporated inside the main tank to provide the necessary makeup gas that may be required due to possible leakages occurring in the seal of the sliding member.

A concept depicting a typical structural arrangement utilizing three booms is shown in Detail B. The section properties of each boom were computed, using an equation in Reference 6, assuming an end load of 280 lb and a boom length of approximately 1100 ft. Each of the three boom longerons shown in Detail B are 0.3 in. in diameter. The boom assembly is inscribed in a circle 36 in. in diameter. The frame spacing is 36 in. The boom concept depicted in Detail B does not define in detail the specific folding technique that is necessary to collapse the structure for the launch phase. Further study effort would be required to determine methods for folding and deploying the structure as well as maintaining the deployed alignment accuracy.

The launch configuration is also shown in Figure 5-2. A canister used to house the kapton reflector is provided and is supported from the equipment enclosure. The canister consists of three sections that may be rotated away from the enclosure during deployment. The three booms, equally spaced about the canister, are hinge-supported from the equipment enclosure. An adapter structure attached to the equipment enclosure is also defined to indicate typical interface characteristics and identifies a method that may be used to react loads introduced due to the launch environment.

B. Weights

Two weight statements for the concept described above are given in Tables 5-2 and 5-3. Table 5-1 assumes conventional attitude control thruster clusters located at the apexes of the triangular structure. However, although insufficient resources were available to conduct a dynamic analysis, it is suspected that a distributed attitude control system (e.g., an ion thruster system) would be required for such a large structure. If this were the case, the weight would be increased and this increase is reflected in Table 5-3.

V. SATELLITE LIFETIME

Satellite lifetime parameters that are of interest are as follows:

a. system useful life

b. satellite design life

c. satellite MTBF

d. Satellite MMD

e. Satellite resupply or service period (for satellites which are resupplied on orbit)

f. satellite module lifetime parameters (for satellites which are modularized for replacement of failed subsystem components on orbit).

Table 5-2. Type 1 Conceptual Design Weight Statement - Chemical Thrusters

SIZE: 1680 ft side
SHAPE: Triangle
AREA: 1,000,000 ft^2
REFERENCE: Thin kapton film; chemical thrusters at triangle apexes

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	7602	8742	0.604
ELECT. POWER	242	278	0.019
TT&C	150	173	0.012
GUID. & NAV.	1222		
		1455	0.101
ACS INERTS	44		
ACS PROPELL.	445	512	0.035
MISSION EQUIP.	2888	3320	0.229
LIFE SUPPORT	-	-	-
CONTINGENCY	1888	-	-
TOTAL WT.	14,481	14,481	1.000
UNIT WT. = 0.01185 lb/ft^2			

*Distributed contingency

Table 5-3. Type 1 Conceptual Design Weight Statement - Distributed Ion Thrusters

SIZE: 1680 ft side
SHAPE: Triangle
AREA: 1,000,000 ft^2
REFERENCE: Thin kapton film; distributed ion thrusters

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	6371	7327	0.136
ELECT. POWER	33,086	38,048	0.709
TT&C	150	173	0.003
GUID. & NAV.	310		
		1277	0.024
ACS INERTS	800		
ACS PROPELL.	3084	3546	0.066
MISSION EQUIP.	2888	3321	0.062
LIFE SUPPORT	-	-	-
CONTINGENCY	7003	-	-
TOTAL WT.	53,692	53,692	1.000
UNIT WT. = 0.04393 lb/ft^2			

*Distributed contingency

Associated with each of the above characteristics is a probability that it will be achieved. Of secondary importance are the probabilities associated with assembling, on orbit, a satellite which is composed of separately launched subassemblies and with achieving an operational state.

Lifetime parameters for future systems are notoriously difficult to estimate and, in any case, a detailed reliability investigation is inappropriate for the Study 2.5 effort. For this reason, the following judgmental factors were used to assign lifetime characteristics to the initiatives of interest.

Discussions with industry personnel have established that a 10-year design life for communication satellites is possible in the near-term. For DoD satellites, 10 years is very close to the system useful life. Optical component degradation on some observation satellites tend to limit their lifetime to about five years, and to consider deploying a 10-year observation satellite would involve provisions having to be made for cleaning lenses, replacing critical components, and so on.

Space servicing studies have indicated that three-year servicing intervals are a reasonable compromise, considering launch costs, increased costs required to make a satellite serviceable in space, and the uncertainties associated with the current level of understanding of the general concept of space servicing.

For the purpose of the Study 2.5 effort, therefore, it was assumed that, in general, all satellites would be designed for space servicing and that they would have a 10-year design life (assumed coincident with useful life) and a three-year service period.

Exceptions to the above rule are as follows:

a. Observation satellites utilizing large apertures or extremely complex electronics which need adjustment by man. These are serviced at one-year intervals.

b. Manned systems, which are serviced at one-year intervals.

c. Highly survivable systems, which are not serviced.

d. Very large, high cost space-assembled satellites, which are considered to be capable of being updated by on-orbit block changes and therefore have virtually unlimited life.

VI. WEIGHT ESTIMATION

In order to estimate the weights of the approximately 100 initiatives of interest with the limited resources and time available, the initiatives were first divided into three groups:

a. Satellites which can be approximated to near-term design communication satellites.

b. Satellites which can be approximated to near-term design observation satellites.

c. Far-term satellites which incorporate advanced technology and utilize non-traditional mission equipment advanced design concepts.

Category (c) was further divided into the nine generic types described briefly in Section III. A specific example for each of these generic types was selected and the weights estimated. These weights were then extrapolated to determine the weights of other satellites which utilized mission equipment of the same generic types, but having different performance characteristics (such as size and power).

Because of the limited resources available, considerable dependence was placed on existing study results. This is summarized in Table 5-4 which identifies the contractor

Table 5-4. Large Space Structure Types

Type Number	Description	Contractor Reference
1	Optical Reflector - Thin Film Mirror	Reference 5
2	Optical Reflector - Double Thin Film Mirror	Reference 5
3	Optical Reflector - Cool Graphite Epoxy Mirror	Reference 7
4	Optical Reflector - Hot Graphite Epoxy Mirror	Reference 7
5	Passive Microwave Reflector	Reference 5
6	Passive Microwave Antenna	Reference 8
7	Active Microwave Antenna	Reference 9
8	Bootlace Lens Multibeam Antenna	Reference 4
9	Dielectric Lens Multibeam Antenna	Reference 4

references used to construct typical weight statements for the nine generic types. These weight statements are given in Tables 5-5 through 5-13.

A certain amount of interpolation between present-day technology and year 2000 technology was necessary. The way in which this was accomplished to aid in deriving power system weights is illustrated in Figure 5-3. Figure 5-4 through 5-9 illustrate the relationship between size and weight for the different types of mission equipment.

VII. INITIATIVE MISSION EQUIPMENT

An examination of each initiative was made to determine what kind of mission equipment would satisfy its primary mission requirements. Basic descriptions for each satellite were determined.

VIII. INITIATIVE WEIGHTS AND COSTS

Weights for the whole spectrum of initiatives were developed using the weight models described in Section VI.

In accordance with the scope and depth appropriate to this study, the data from Table 5-1 was utilized to come to a judgmental decision on launch vehicle combinations appropriate to each concept. In most cases a modularized version of each large satellite could be conceived and therefore the shuttle vehicle, combined with an appropriate upper stage could handle the mission in an acceptable number of flights. The maximum number of shuttle flights identified for a single initiative was 120. The initiative spectrum includes a number of extremely large satellites and, for these, the LLV was selected. The maximum number of LLV flights identified for a single initiative was 500.

Table 5-5. Type 1 (Optical Reflector - Thin Film Mirror) Typical Weight Statement

SIZE: 400 ft side
SHAPE: Triangle
AREA: 69,200 ft^2
REFERENCE: Thin Kapton Film

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	693	796	0.680
ELECT. POWER	20	23	0.020
TT&C	10	12	0.010
GUID. & NAV.	90 }	115	0.098
ACS INERTS	10 }		
ACS PROPELL.	40	46	0.039
MISSION EQUIP. (FILM)	156	179	0.153
LIFE SUPPORT	---	---	-----
CONTINGENCY	152	---	-----
TOTAL WT.	1171	1171	1.000
UNIT WT. = 0.016922 lb/ft^2			

*Distributed contingency

Table 5-6. Type 2 (Optical Reflector - Double Thin Film Mirror) Typical Weight Statement

SIZE: 400 ft side
SHAPE: Triangle
AREA: 69,200 ft^2
REFERENCE: Thin Kapton Film

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	667	767	0.564
ELECT. POWER	33	38	0.028
TT&C	10	12	0.008
GUID. & NAV.	104 }	133	0.098
ACS INERTS	12 }		
ACS PROPELL.	46	53	0.039
MISSION EQUIP. (FILM)	311	358	0.263
LIFE SUPPORT	---	---	-----
CONTINGENCY	177	---	-----
TOTAL WT.	1360	1360	1.000
UNIT WT. = 0.01965 lb/ft^2			

*Distributed contingency

Table 5-7. Type 3 (Optical Reflector - Cool Graphite Epoxy Mirror) Typical Weight Statement

SIZE: 16.4 ft dia
SHAPE: Circular
AREA: 211.2 ft^2
REFERENCE: Cool Mirrors = 10 lb/ft^2

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	558	642	0.115
ELECT. POWER	60	69	0.012
TT&C	50	57	0.009
GUID. & NAV.	300	1665	0.297
ACS INERTS	1148		
ACS PROPELL.	650	747	0.133
MISSION EQUIP. (MIRROR)	2112	2429	0.434
LIFE SUPPORT	----	----	-----
CONTINGENCY	731	----	-----
TOTAL WT.	5609	5609	1.000
UNIT WT. = 26.54 lb /ft^2			

*Distributed contingency

Table 5-8. Type 4 (Optical Reflector - Hot Graphite Epoxy Mirror) Typical Weight Statement

SIZE: 16.4 ft dia
SHAPE: Circular
AREA: 211.2 ft^2
REFERENCE: Hot Mirrors = 30 lb/ft^2

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	1836	2111	0.177
ELECT. POWER	60	69	0.006
TT&C	50	58	0.005
GUID. & NAV.	300	1665	0.139
ACS INERTS	1148		
ACS PROPELL. (2 YRS)	650	748	0.063
MISSION EQUIP. (MIRROR)	6336	7286	0.610
LIFE SUPPORT	----	----	-----
CONTINGENCY	1557	----	-----
TOTAL WT.	11,937	11,937	1.000
UNIT WT. = 56.573 lb/ft^2			

*Distributed contingency

Table 5-9 Type 5 (Passive Microwave Reflector) Typical Weight Statement

SIZE: 4500 x 4500 ft (64 modules)
SHAPE: Square
AREA: 20,250,000 ft^2
REFERENCE:

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	128,827	148,151	0.703
ELECT. POWER	1180	1357	0.006
TT&C	6400	7360	0.035
GUID. & NAV.	1200	2624	0.012
ACS INERTS	1082		
ACS PROPELL.	5131	5900	0.028
MISSION EQUIP. (REFLECTOR)	39,488	45,412	0.216
LIFE SUPPORT	-------	-------	----
CONTINGENCY	27,496	-------	----
TOTAL WT.	210,804	210,804	1.000
UNIT WT. = 0.01041 lb/ft^2			

*Distributed contingency

Table 5-10. Type 6 (Passive Microwave Antenna) Typical Weight Statement

SIZE: 88.6 x 16,405 ft
SHAPE: Rectangle
AREA: 1,453,500 ft^2
REFERENCE: Ion Propulsion

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	9907	11,393	0.427
ELECT. POWER	700	805	0.030
TT&C	100	115	-----
GUID. & NAV.	400	1840	0.069
ACS INERTS	1200		
ACS PROPELL.	3668	4218	0.158
MISSION EQUIP. (ANTENNA)	7329	8428	0.316
LIFE SUPPORT	----	------	-----
CONTINGENCY	3495	------	-----
TOTAL WT.	26,799	26,799	1.000
UNIT WT. = 0.018437 lb/ft^2			

*Distributed contingency

Table 5-11. Type 7 (Active Microwave Antenna) Typical Weight Statement

SIZE: 3,281 ft dia
SHAPE: Circular
AREA: 8,450,500 ft^2
REFERENCE: Ion Propulsion

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	593,477	682,499	0.116
ELECT. POWER	574,069	660,179	0.112
TT&C	100	115	-----
GUID. & NAV.	6,500		
		352,475	0.060
ACS INERTS	300,000		
ACS PROPELL.	21,320	24,518	0.004
MISSION EQUIP. (ANTENNA)	3,630,000	4,174,500	0.708
LIFE SUPPORT	-------	-------	-----
CONTINGENCY	768,820	-------	-----
TOTAL WT.	5,894,286	5,894,286	1.000
UNIT WT. = 0.697508 lb /ft^2			

*Distributed contingency

Table 5-12. Type 8 (Bootlace Lens Multibeam Antenna) Typical Weight Statement

SIZE: 131.23 ft dia
SHAPE: Circular
AREA: 13,537 ft^2
REFERENCE: Bootlace Lens

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	623	717	0.018
ELECT. POWER	150	173	0.004
TT&C	220	253	0.006
GUID. & NAV.	525		
		932	0.023
ACS INERTS	285		
ACS PROPELL.	1245	1432	0.036
MISSION EQUIP. (LENS)	31,947	36,737	0.913
LIFE SUPPORT	------	------	-----
CONTINGENCY	5249	------	-----
TOTAL WT.	40,244	40,244	1.000
UNIT WT. = 2.9729 lb/ft^2			

*Distributed contingency

Table 5-13. Type 9 (Dielectric Lens Multibeam Antenna) Typical Weight Statement

SIZE: 131.23 ft dia
SHAPE: Circular
AREA: 13,537 ft^2
REFERENCE: Dielectric Lens

	Weight (lb)	Cost* Weight (lb)	Ratio
STRUCTURE	1041	1197	0.200
ELECT. POWER	150	173	0.029
TT&C	220	253	0.042
GUID. & NAV.	175	385	0.064
ACS INERTS	160		
ACS PROPELL.	260	299	0.050
MISSION EQUIP. (LENS)	3195	3674	0.615
LIFE SUPPORT	----	----	-----
CONTINGENCY	780	----	----
TOTAL WT.	5981	5981	1.000
UNIT WT. = 0.441826 lb/ft^2			

*Distributed contingency

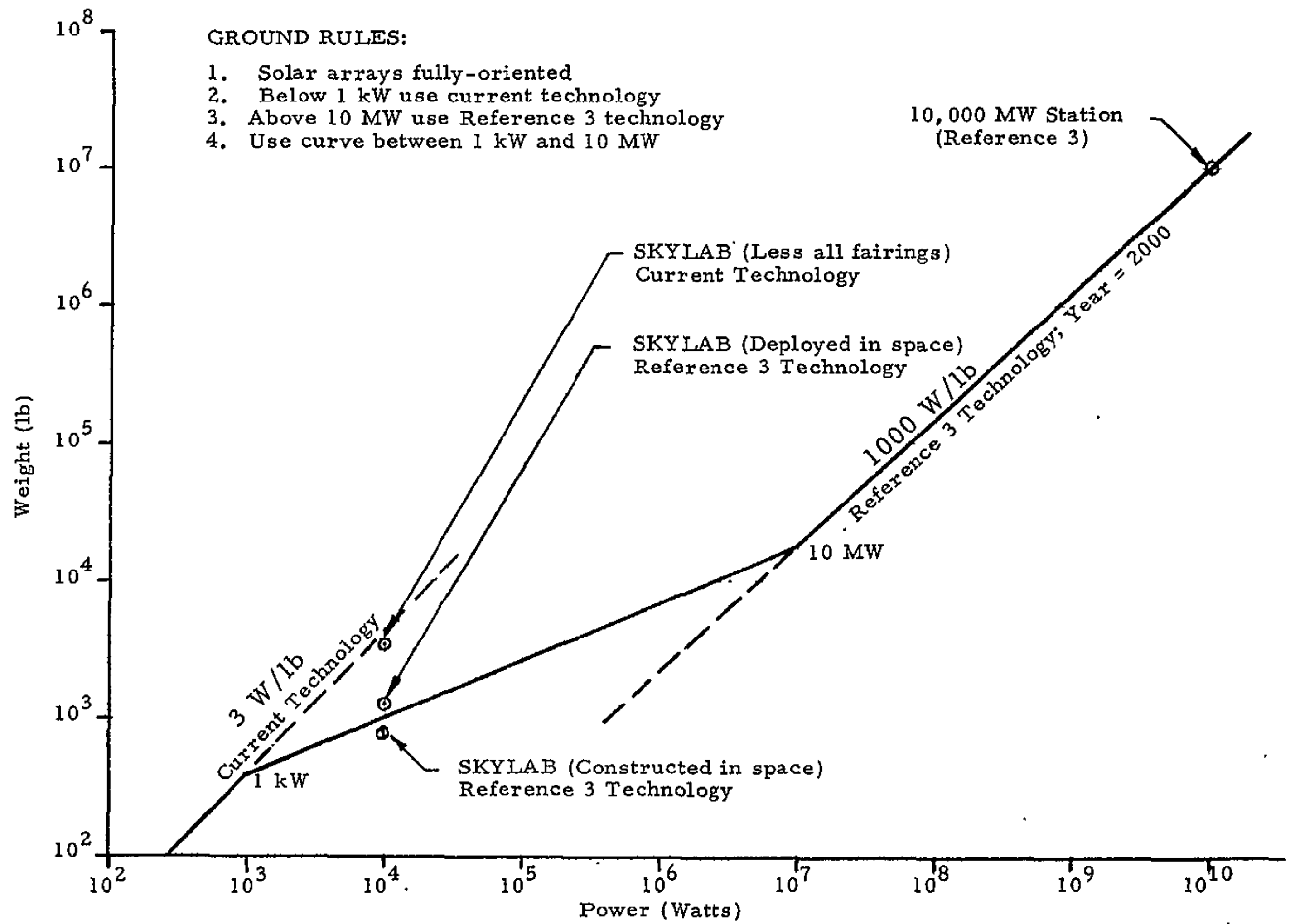

Figure 5-3. Electrical Power System Weight vs. Power Level

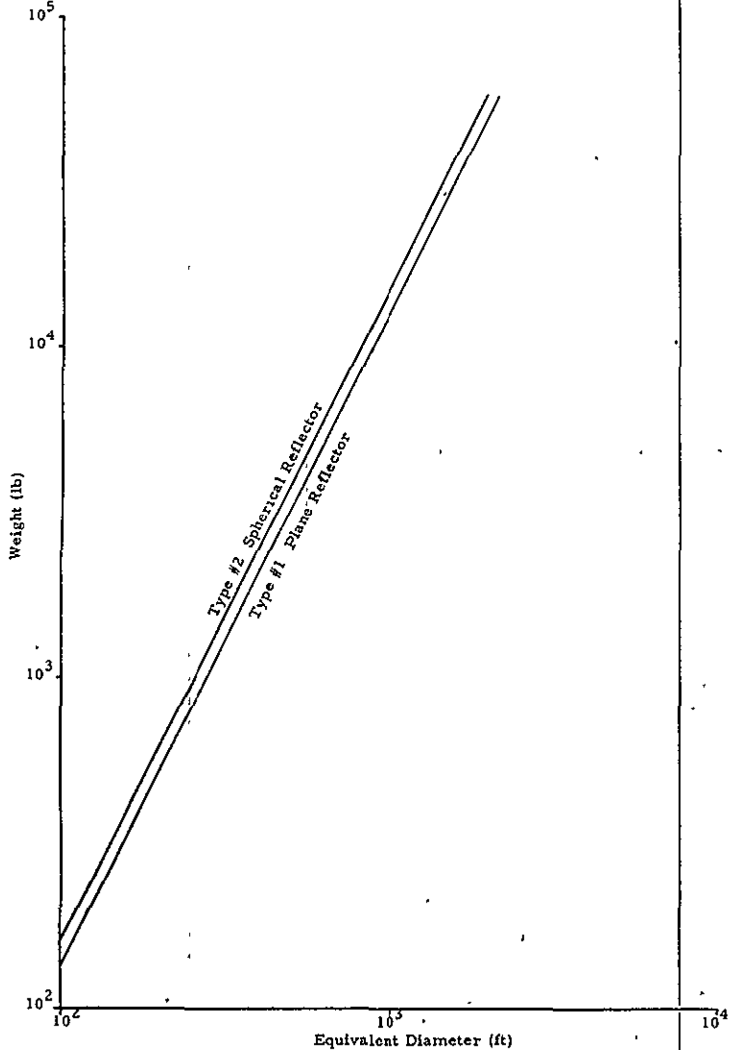

Figure 5-4. Thin Film Reflector Weight vs. Equivalent Diameter

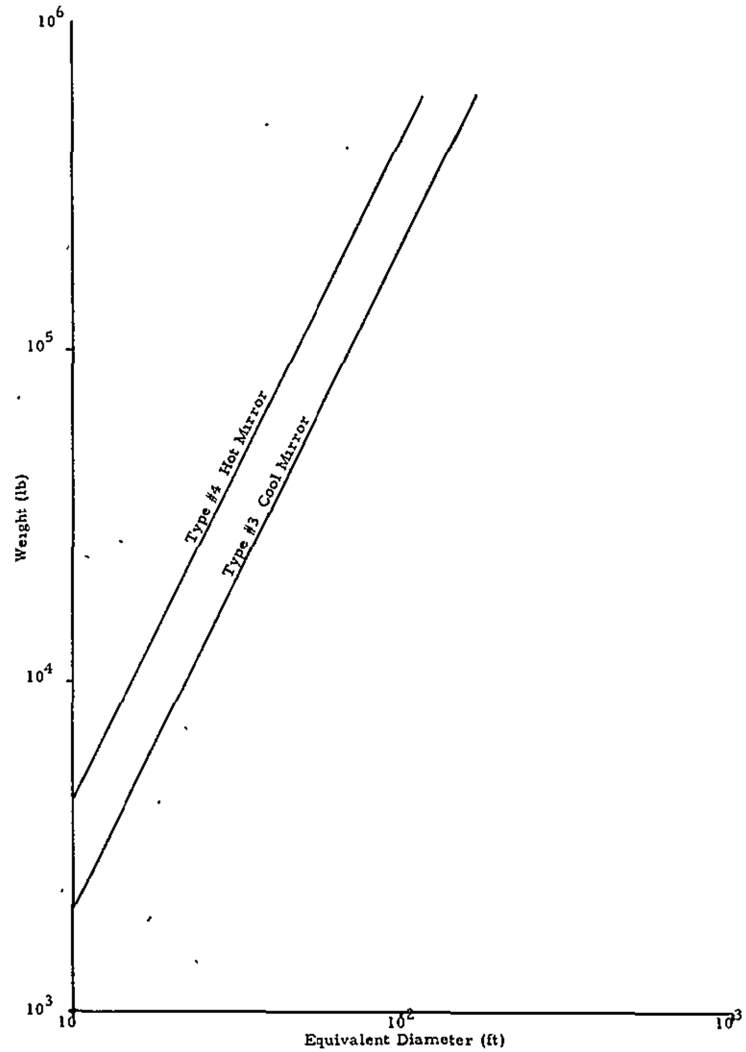

Figure 5-5. Optical Mirror Weight vs. Equivalent Diameter

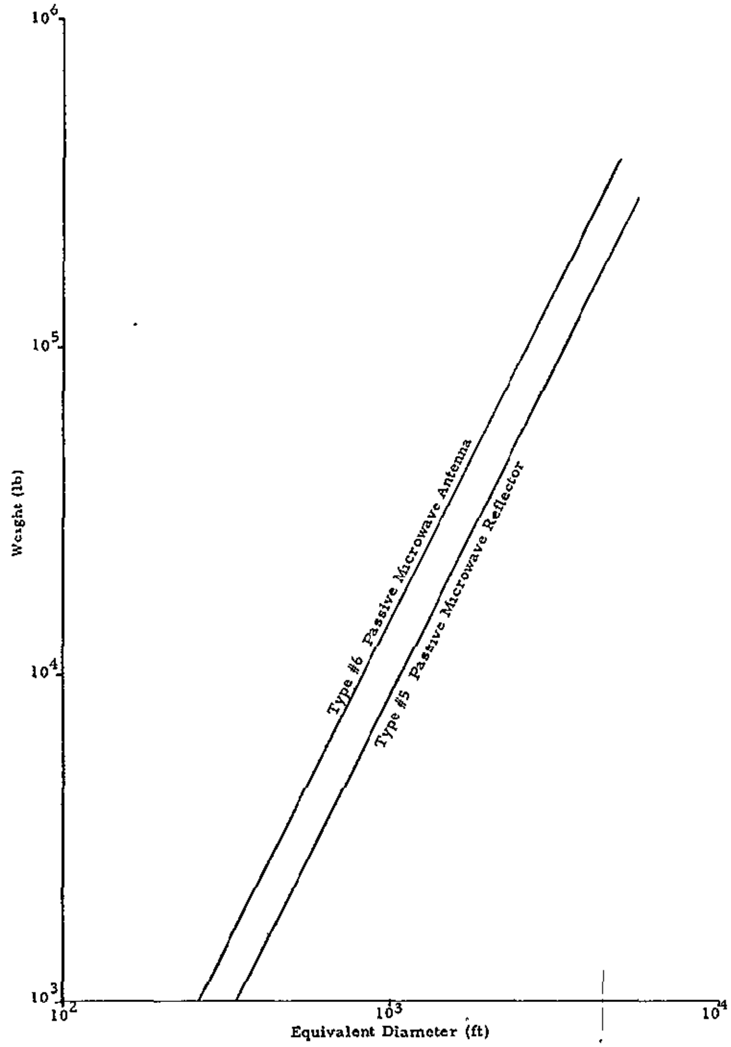

Figure 5-6. Passive Microwave Antenna/ Reflector Weight vs. Equivalent Diameter

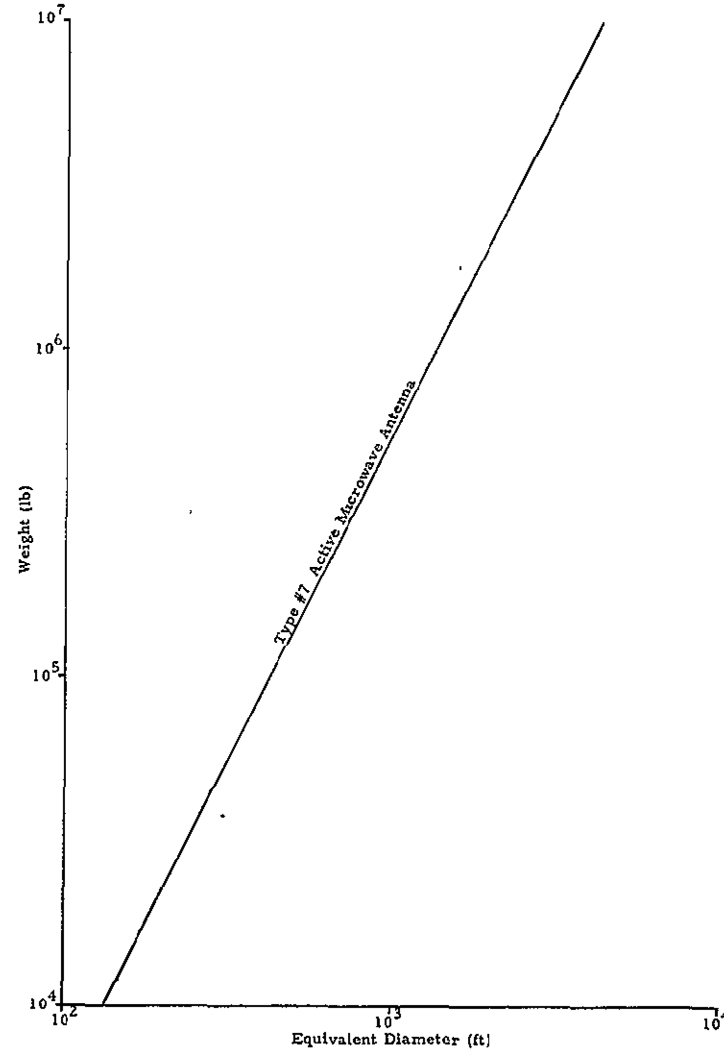

Figure 5-7. Active Microwave Antenna Weight vs. Equivalent Diameter

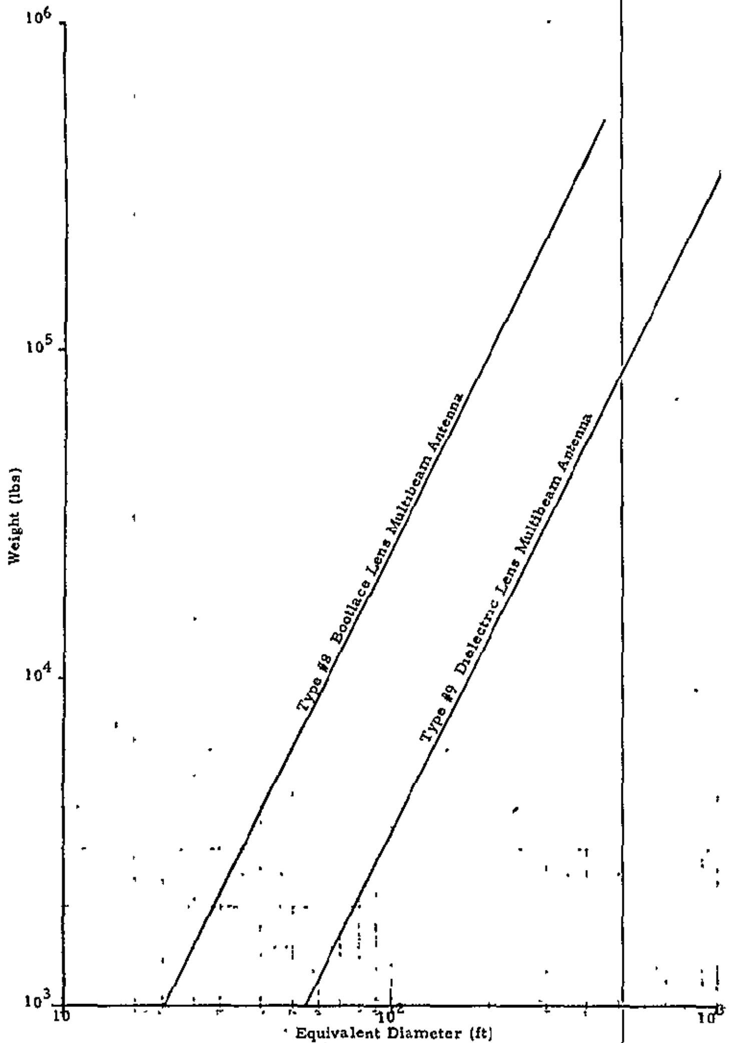

Figure 5-8. Multibeam Antenna Weight vs. Equivalent Diameter

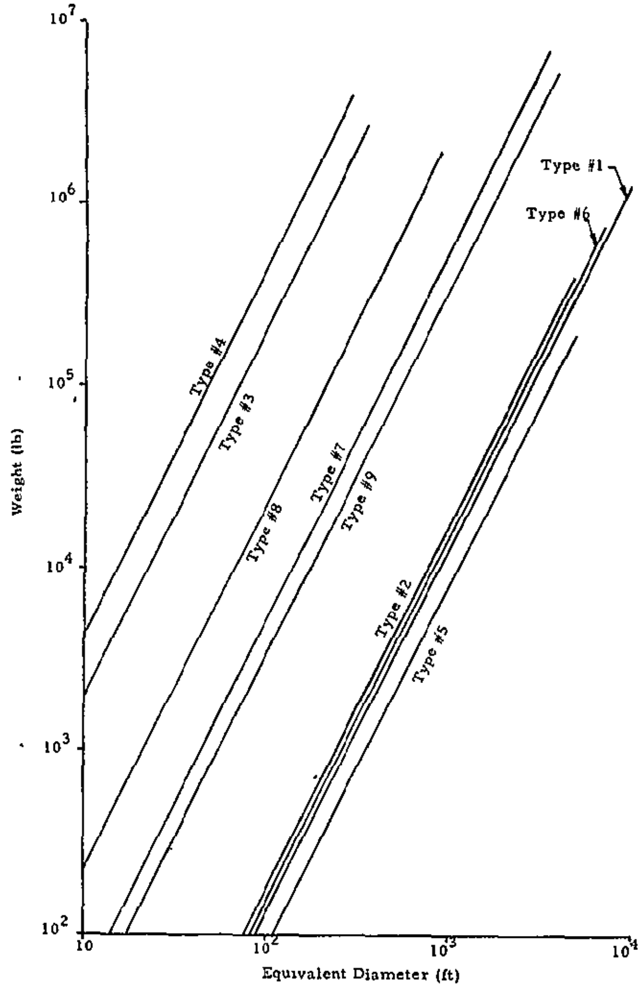

Figure 5-9. Large Space Structures Weight vs. Equivalent Diameter

Recurring costs of the concepts were estimated utilizing cost estimating relationships varying from \$200/lb for type 1 systems to \$20,000/lb for type 9, the exact cost used for any concept being dependent on the IOC year, the magnitude of that effort, and the kind of system concept. R&D costs were estimated at 1-4 times the recurring satellite costs. Transportation costs were calculated from the type and number of flights discussed above. Costs for several concepts in which the weight of the subsystems could be confidently identified were calculated using an existing computer program.

APPENDIX A

CONTACTS

APPENDIX A

CONTACTS

Discussions were held by the study team with a number of individuals during the early portion of the study in order to obtain a cross section of ideas and experience to add to those of the team members. The following people had significant impact on the perspective of how to operate in space, on types of initiatives which might be meaningful, on requirements, or on all the foregoing.

NAME	AFFILIATION
Washington Area	
Bob Cooper	ODDRE
Dan Brockway	"
Howard Barfield	"
Jim Wade	"
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Frank Edelman	"
Jasper Welch	OSD
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Dan Dustin	"
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Dr. Bhatachari	"
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Mal Ruderman	"
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Ken Watson	"
Ben Alexander	GRC
John Ise	"
Dick Holbrook	"
James Baker	IND.
Milt Birnbaum	Aerospace Corporation
Tom Hartwick	"
Tom Taylor	"