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CR - 119886

REPORT NO. GDC-DCF70-002
CONTRACT NAS 8-21036

TELEVISION BROADCAST SATELLITE STUDY

VOLUME I • EXECUTIVE SUMMARY

N71-31406
(ACCESSION NUMBER)
53
(PAGES)
CR-119886
(NASA CR OR TMX OR AD NUMBER)
(THRU)
63
(CODE)
(CATEGORY)
FACILITY FORM 602

GENERAL DYNAMICS
Convair Aerospace Division

JUL 1971
RECEIVED
NASA STI FACILITY
INPUT BRANCH

REPORT NO. GDC-DCF70-002

TELEVISION BROADCAST SATELLITE STUDY

TVBS SYSTEM

EXECUTIVE SUMMARY

VOLUME I

CONTRACT NAS 8-21036

31 December 1970

Prepared for
E. C. Hamilton, COR
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama

Prepared by
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San Diego, California

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FOREWORD

This report was prepared by the San Diego operation of the Convair Aerospace Division of General Dynamics under Contract NAS8-21036, Television Broadcast Satellite Study, for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Astrionics Laboratory of the George C. Marshall Space Flight Center.

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ABSTRACT

TELEVISION BROADCAST SATELLITE STUDY

The contract (Contract No. NAS 8-21036) for this study was awarded to the Convair Aerospace Division of General Dynamics Corporation in December 1968 with a go-ahead of 1 January 1969. Originally intended as a 9-1/2 months study, the study was interrupted for a 1-year period (September 1969 to September 1970). This report represents the final documentation from the original study activities. The primary objective of the study was to define and examine in detail the technological and cost factors affecting the feasibility of Television Broadcast Satellites in the 1970 - 1975 time period. This objective was met by synthesizing feasible spacecraft configurations to meet realistic user requirements.

The spacecraft considered were unmanned or used Apollo hardware and were initially man-assisted during the first 15-45 days of orbital operation. In order to provide some range to the spacecraft considered the payload capability of the assigned Saturn V launch vehicle was configured for single and multiple satellites. The multiple satellites were each compatible with the payload capability of a smaller launch vehicle.

The synthesis approach adopted included consideration of the total communication system elements -- space and ground. Minimum total cost solutions were derived from each case from which the proper balance between the space and ground segments was identifiable.

The final product of the study is a selection of three candidate spacecraft configurations, one unmanned and two potentially man-assisted for further analysis.

The Convair Aerospace Division was supported by the Space Systems Division of Hughes Aircraft Company in the performance of this study.

1

INTRODUCTION

In December 1968 the Convair Aerospace Division of General Dynamics Corporation was awarded a contract by the Astrionics Laboratory of the NASA - George C. Marshall Space Flight Center to study television broadcast satellites for the 1970 - 1975 time period. Specifications and guidelines under which this study was conducted were:

- LAUNCH VEHICLE

  Saturn V/Apollo System
  - Command/Service Module
  - LEM laboratory
  - Spent S-IVB stage
  - LEM Adapter

- SPACECRAFT

  - Unmanned
  - Man-assisted during the initial 15-45 days
  - Minimum 2-year life

- ORBIT AND COVERAGE

  - Synchronous equatorial
  - 0.5M to 10M sq. mi. area within 3db beamwidth of the antenna pattern
  - Single and multiple beams

- TRANSMISSION

  - Television, monochrome and color
  - ERP: 40 to 80 dbw
  - FM and AM/VSB
  - Frequencies: 470 to 890 MHz
    2 to 3 GHz
    8.3 to 8.5 GHz
    11.7 to 12.7 GHz

- RECEIVING SYSTEMS

  - Direct to conventional home receivers.
  - Direct to modified home receiving systems.
  - To specialized equipment for necessary broadcasts.

Within these guidelines the immediate study goals were, as shown. A three-phase program was outlined to define and select the three best concepts for detailed analysis.

TVBS STUDY GOALS

PHASE I & II

- ASCERTAIN REAL TVBS USER REQUIREMENTS
- DEVELOP OPTIMIZATION SYNTHESIS PROGRAM
  - OPTIMUM-COST TOTAL SYSTEM
  - SENSITIVITIES OF OPTIMUM SYSTEMS
- DEVELOP SATURN V CLASS TVBS CONFIGURATIONS
- DETERMINE CRITICAL TECHNOLOGY
- SELECT BEST USER/SYSTEM APPLICATION

PHASE III

- REFINE 3 BEST SPACECRAFT & GROUND SYSTEMS
- PERFORMANCE, COST, OPERATIONAL SCHEDULE

USER ANALYSIS

Convair's user analysis was based primarily upon personal contacts with potential users of television broadcast techniques. More than thirty such contacts were with key representatives in the seven major categories being considered. These contacts were supplemented by more than a hundred other contacts -- both personal and by correspondence. As a result, ten users and their technical requirements were analyzed and the results compiled for comparative evaluation. The top three users, in their order of rating are:

1. U.S. Armed Forces Radio and TV Services -- This group provides a complete entertainment service to overseas military personnel and their dependents, as well as to base civilian employees. Nine worldwide coverage zones are indicated. These can be served by two satellites at optimized orbital positions.

2. U.S. Parochial Schools -- The problems of this system, based on a decreasing teacher availability and rising costs, have been widely publicized. A satellite system can do much to relieve these burdens.

3. U.S. Biomedical Communications Network -- HEW, under the Networks for Knowledge legislation, is initiating this network to interconnect the medical centers around the nation. The proposed system will include all aspects of medical information transfer and will serve all members of the medical and paramedical community. These, and all other potential users considered, were processed through the synthesis program to determine their nominal costs and system parameters.

COMPUTER ANALYSIS

The TV Broadcast Satellite system synthesis/optimization computer program is a flexible, comprehensive design tool for the analysis of cost and technology requirements over a broad range of user requirements and system configurations. The program uses a total system approach in which the ground uplink, spacecraft, launch vehicle and ground downlink systems are simultaneously synthesized to determine minimum total-system cost designs. In addition, the selection of feasible configurations, the sensitivities of the selected configurations to pertinent system parameters -- e.g. design parameters and weight and volume constraints -- and subsystem models can be determined.

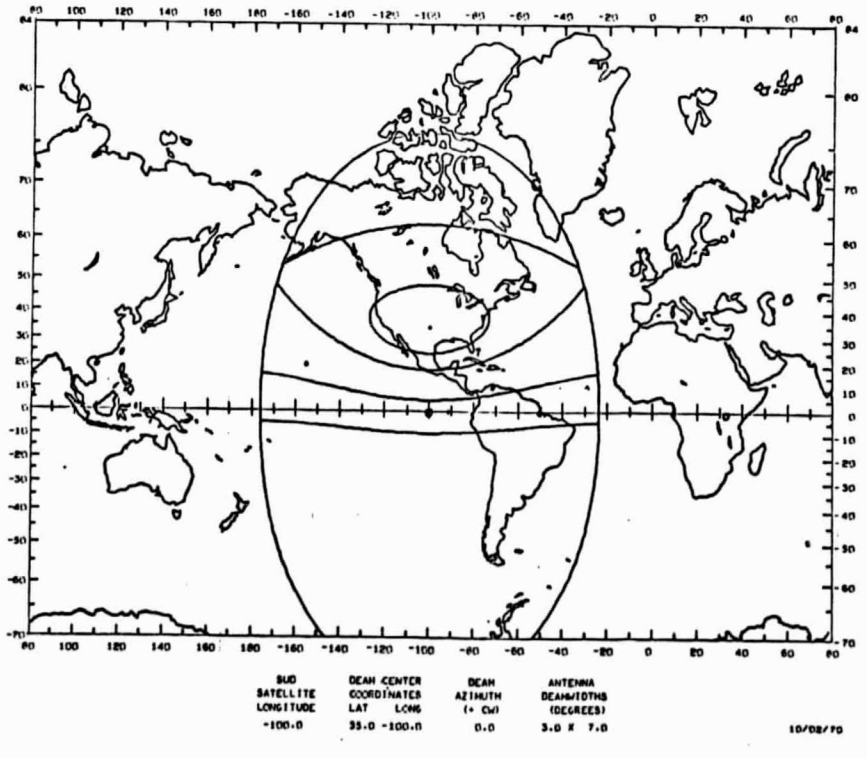
Configuration variations significantly impact the optimization of the subsystems and parameters. Optimization occurs for most systems at 2.5 GHz, but variations in population of receivers, coupled with configuration limitations, can shift the slope of the optimum system curve. While TASO Grade 1 is affected by frequency, TASO Grade 3 is relatively insensitive.

COMMUNICATION SYSTEM ANALYSIS

FM and AM/VSB TV communication subsystems were analyzed in detail. Data for the analysis was derived, primarily, from related NASA-funded studies of high-power amplifying devices, and low-cost ground receivers. Additional technical and cost data was developed during the study to support areas such as telemetry and control, uplink transmission systems, multiple sound channels per video channel, transmitter efficiency, and reliability. Computer analyzed antenna patterns were plotted for each area of coverage to illustrate probable interference. An optimization, using overlays of these projections, can be used to select an "optimum" position for the satellite. Sidelobe effects will preclude co-channel usage from the eastern to the western time zones in the U.S.

Based on a typical user broadcast beamwidth of 2 degrees, size requirements for TVBS antennas range from 40 feet at 0.8 GHz to less than 3 feet at 12 GHz. Antennas twice these sizes could be required by optimized coverage and sidelobe suppression considerations. In general, rigid antennas satisfy S-band and X-band requirements, with erectable antennas required at UHF.

CONTINENTAL UNITED STATES COVERAGE



Erectable antenna weight (including feed support and deployment mechanism) varies from 0.17 to 0.4 pound per square foot of aperture, depending on material selection, surface accuracy requirements, and use of folding feed structures. Antennas can be erected in space with gains greater than 50 db. The commensurate pointing accuracy if 0.05 degree or less. Typical time-zone coverage requires a gain of 35 to 40 db with a pointing accuracy of the order of 0.1 degree.

Reflector type antennas appear to be advantageous over phased arrays for the TVBS mission in terms of weight, cost, pattern shaping, and sidelobes. Phased arrays can generate a large number of beams from the same aperture and, potentially, could be competitive in the UHF range, where a large number of individual reflector apertures would be difficult to package.

POWER SYSTEMS

The range of applications for each potential electrical power generation system -- solar cells, nuclear reactors, and radioisotopes -- has been analyzed. Radioisotopes were eliminated primarily because of the prohibitive development required, as well as the uncertainties in isotope costs and availability. Reactor systems have been limited to already developed systems (e.g., SNAP-10A) or those now under development (SNAP-8). The wide range of power under consideration is best satisfied by solar cell systems. In turn, solar cell systems are limited to silicon cells, representing the best available technology.

The complete system, including power generation, transfer, control, and conditioning, is considered and pertinent parmetric data included. Batteries, for energy storage, are also included.

DYNAMICS

The dynamics portion of the study included consideration of the attitude control and stationkeeping propulsion systems, and the dynamic requirements of large solar arrays. The attitude control study indicates a preference for the ion engine system for satellites with array sizes exceeding about 20 kw. The ammonia Resistojet system is preferred below 20 kw. Active three-axis control is used. Momentum wheels were studied but do not save weight and may increase thrust requirements. A sensor system using horizon and sun sensors and rate gyros will give accuracy of about 0.1 degree. By using star trackers or interferometers instead of rate gyros, accuracies of about 0.05 degree can be achieved.

Full N-S and E-W stationkeeping is used exclusively. For satellites of two years or less life time, the Resistojet is preferred. Above a two-year life, the ion propulsion system is more desirable.

Two- and four-winged solar arrays were considered, as well as rollup arrays, in the array dynamic study. Foldout arrays appear to have sufficient stiffness (at reasonable weight) up to about 100 kw; rollup arrays (assuming a maximum width of 15 feet) are limited to 10 kw each. Assuming four rollups to be maximum number that can be used on each satellite, the rollup system will produce 40 kw maximum before severe dynamic problems occur.

LAUNCH VEHICLE ANALYSIS

The Saturn V launch vehicle is capable of delivering up to 60,000 lb. to synchronous orbit. This permits a wide range of approaches to be taken to user requirements:

1. Multiple short-lived satellites can be orbited to fulfill a long life requirement.

2. Large redundancies can also be considered for long-life systems.

3. Multiple satellites for multiple users can be launched simultaneously.

EFFECT OF SATURN V ON TVBS

- **GOOD**
  - EXCESS PAYLOAD & VOLUME
    - STATE-OF-ART SYSTEMS
    - INCREASED REDUNDANCY
    - REDUCED DEVELOPMENT TIME
  - COST EFFECTIVE (2:1 COMPARED TO TITAN)
  - MULTIPLE USERS ACCOMMODATED
  - PHYSICAL INTERFERENCE REDUCED
  - RESUPPLY, REPAIR, MAINTENANCE, FEASIBILITY
- **BAD**
  - HIGH INITIAL COST
  - LARGE LOSS WITH FAILURE
  - RF INTERFERENCE

Affecting these advantages is the large commitment in cost and payload in the event of a launch failure. If schedule is not critical this issue can be resolved by an appropriate insurance as in the Intelsat series.

CONFIGURATION ANALYSIS

The configuration studies in Phases I and II dealt primarily with concept evaluation and selection for preliminary design in Phase III. Six basic concepts were compared: three small, unmanned versions; and three large, manned versions. The small satellites produced the minimum system cost in about half the systems considered, with a large, multibeam version optimum for the other systems. Another large concept was second best in all but two of eleven cases. The selected concepts for Phase III study were the single-beam, small satellite of Concept B; and the two large, multibeam satellites of Concepts D and F. Three technology problems requiring further study are (1) switching and interconnecting the many redundant transmitters required, (2) storage and interconnection of the high volume of liquid NH_3 required for the Resistojets, and (3) supporting and packaging the widely diverse sizes and shapes of antennas required for efficient, multibeam earth coverage in real systems.

TECHNOLOGY

Technology developments necessary to support the Saturn V class of satellites have been derived from the configuration analyses performed to date and relate chiefly to the mechanical, electrical, and RF problems associated with the multikilowatt power used in the systems. Related thermal problems also have been identified. Exploitation of the excess weight and volume capabilities of the Saturn V can lead to simple,

near-term solutions to these problems. Additional tasks that should be performed are:

1. Tradeoffs of multiple single-beam satellites compared to single multi-beam satellites as they affect orbital space usage.

2. Expand the synthesis program to evaluate further the hybrid systems combining CATV, rebroadcast, and satellite direct broadcast TV systems.

3. Perform a detailed analysis of switching circuits required for multi-beam satellites.

4. Continue the user analysis, providing optimization synthesis program results to each user and reiterating his needs relative to cost.

5. Provide a workshop meeting to enlighten potential users on the applicability of TV broadcast satellites to their needs.

6. Expand the analysis of phased arrays to compare multibeam capability with the competing reflector antennas on a total system basis.

When considered in conjunction with the previous TVBS studies by GE and TRW this study should complete the perspective view of TV Broadcast Satellites over a wide range of missions and spacecraft capabilities.

2

STUDY APPROACH

As shown, the study was divided into three phases:

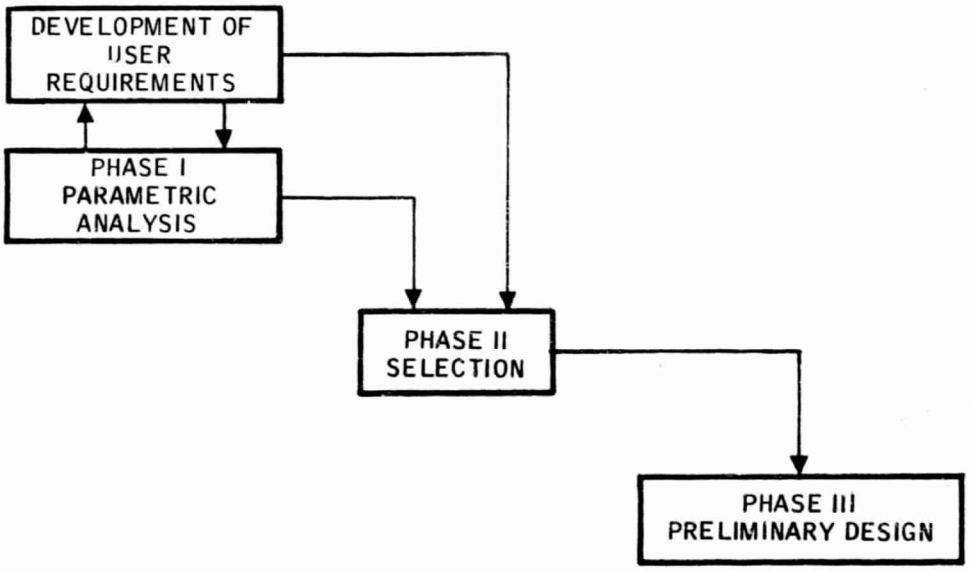


Figure 1. Top-Level Study Phasing

1. Phase I/Parametric Analysis. This phase constitutes approximately 70% of the total study. It consists of a detailed parametric analysis of all factors affecting the satellite system.

2. Phase II/Selection, approximately 10% of the study, defines the results of the computerized synthesis process in terms of a mission/configuration matrix. Three configurations were selected in this process for more detailed analysis in Phase III.

3. Phase III/Preliminary Design, the remaining 20% of the study, includes a review of each of the selected configurations and associated missions. The end product for this phase of the study is a service description for each of the candidate missions.

A simplified study flow diagram is presented in Figure 2. Study inputs are derived from:

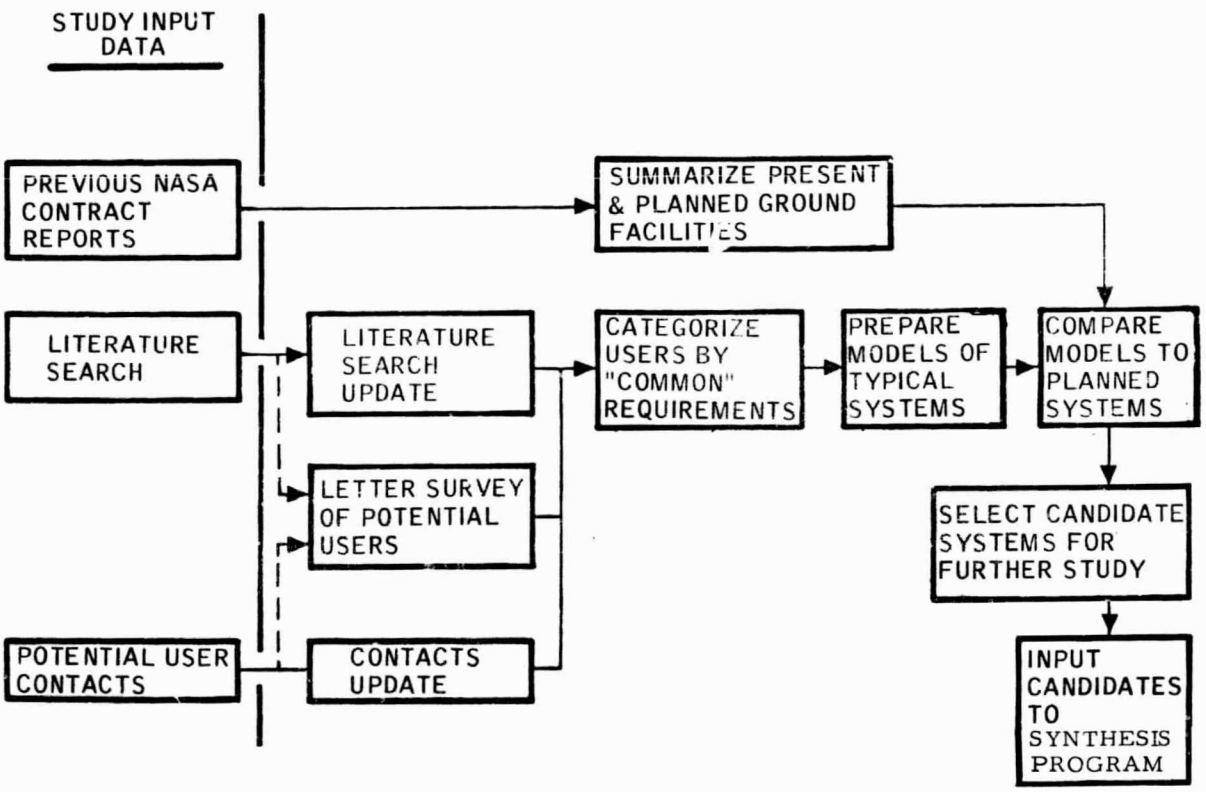


Figure 2. Study Flow Diagram

1. Previous NASA contract reports. In particular, the reports on Voice Broadcast and Television Broadcast are most directly applicable.

2. Data developed under this contract. Some reliance was placed on user data previously developed by Convair. This was supplemented by data from additional contacts, correspondence and personal, as well as data from a continuing review of standard bibliographies (STAR, C-STAR, etc.) and the open literature.

This data was then used as a base from which missions were defined and modeled. These models were then processed through the synthesis program and candidate systems selected for further analysis. The synthesis program in this program takes the input data and derives a system based on minimum total system cost. In this way the total communication system

is considered and the proper balance between ground and space segments is readily identifiable.

Figures 3 and 4 provide more details on the overall approach. As can be seen from Figure 4, approximately 10,000 manhours (including indirect charges were expended in the performance of the study.

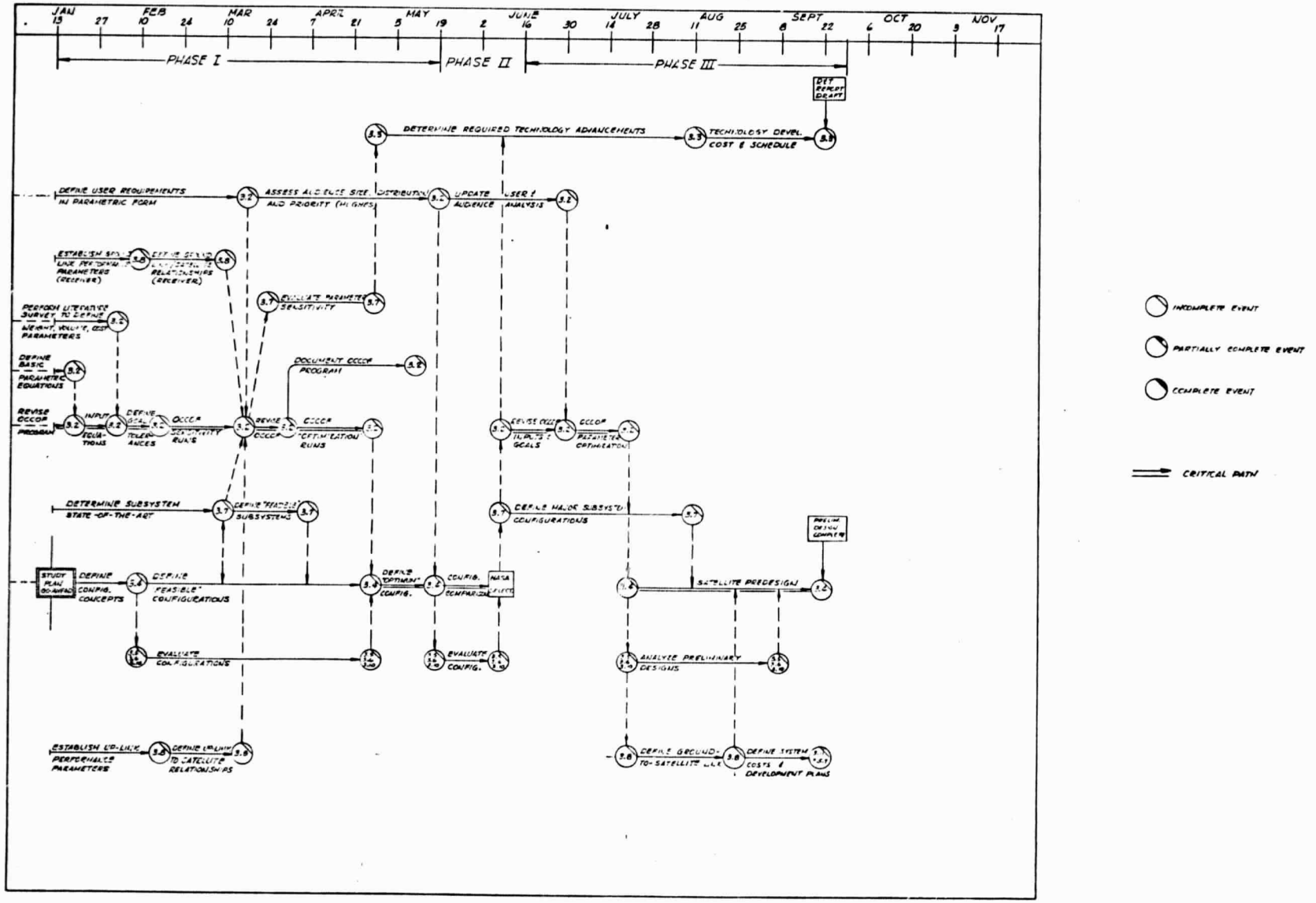


Figure 3. TVBS study schedule network.

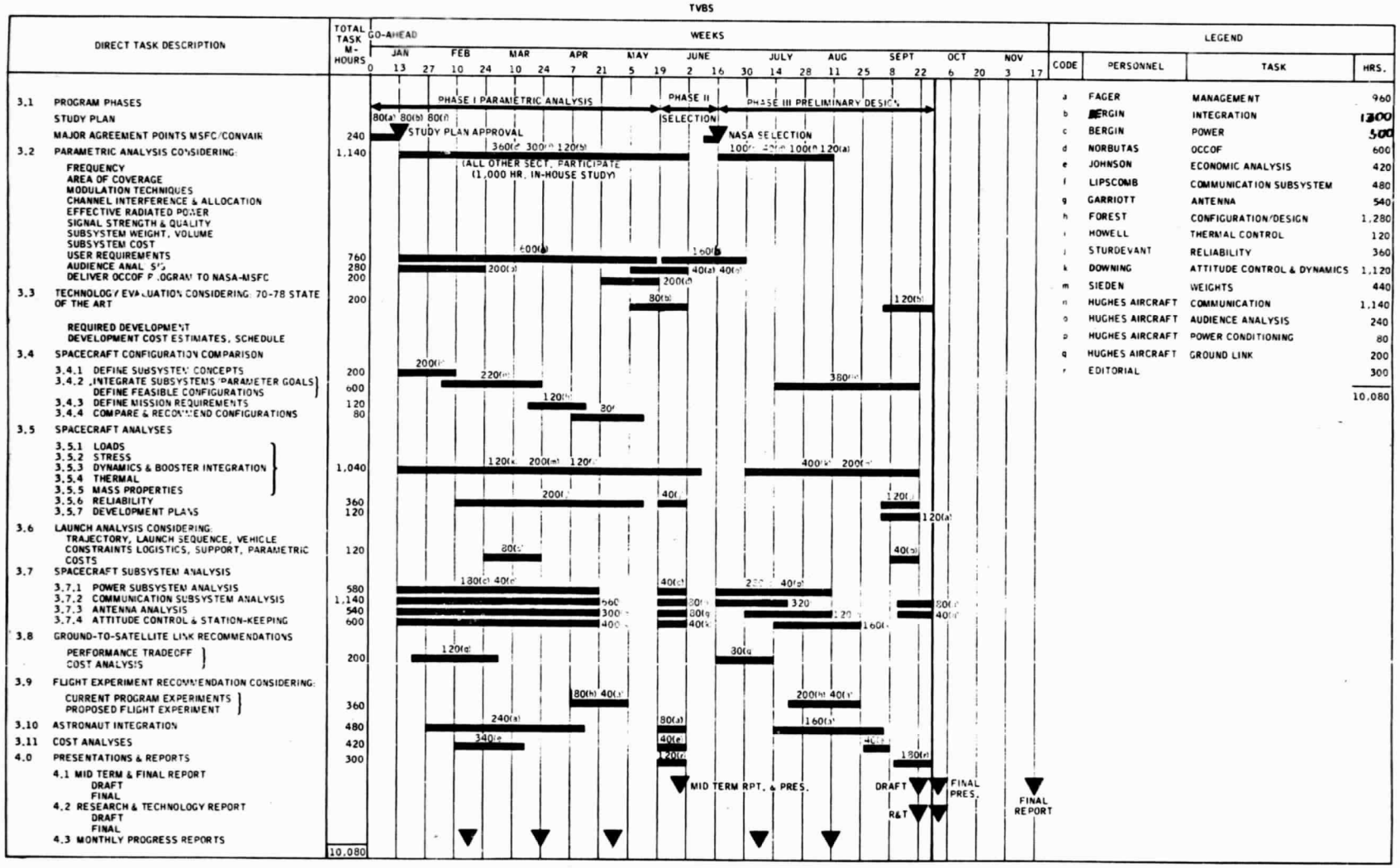


Figure 4. Program plan.

3

USER ANALYSIS

One of the goals of this study was to ascertain realistic requirements for TV Broadcast satellites. Two sources of data were used.

1. Previous studies.

2. Present study.

3.1 PREVIOUS STUDIES

A list of previous studies, general and special is presented in Table 3-1. From this table it can be seen that few of these pertinent studies undertook a detailed analysis of the potential audience or users, G.E.'s TV Broadcast Satellite study yielded the following data:

SERVICE	NUMBER OF RECEIVERS		
	MINIMUM	MAXIMUM	
BROADCAST			
Direct	8,500	51,000,000	Receivers
SPECIAL			
ITV	3,900	282,000	Primary Schools
	235	42,000	Secondary Schools
	15	2,640	Universities
Medical	60	20,700	Hospitals
Distribution	5	14,100	Transmitters

Both G.E. and RCA, as part of their Voice Broadcast studies reviewed the available number of UHF TV receivers. This data is summarized as follows:

Year	U.S. Population (millions)	Households (millions)	Number of UHF TV Receivers (millions)
1965	194.6	57.3	8.3
1966			15
1970	208	63	48.2
1971			58
1975	225	69	72
1980	245	75	83

This data shows that by 1975 the U.S. market becomes saturated. The growth rate in this market is essentially that of households.

Table 3-1. Previous Studies

Study	Study Group	Audience Analysis	
		General	Specific
1. TV Broadcast Satellite	General Electric		X
2. TV Broadcast Satellite	Thompson-Ramo Wooldridge	X	
3. Voice Broadcast Mission Study	General Electric		X
4. Satellite TV Relay For India's Development and Education (STRIDE)	W. Virginia University	X	
5. Advanced System for Communications and Education in National Development (ASCEND)	Stanford University	X	
6. Satellite Array for International and National Telecommunications (SAINT)	Stanford University	X	
7. Educational TV Satellite System (EDUSAT)	Langley Research Center/Old Dominion College	X	
8. Voice Broadcast Mission Study	RCA		X

3.2 PRESENT STUDY

Development of user data is the first of four steps in the system analysis for the TV Broadcast Satellite study:

- ESTABLISH DIALOGUE WITH CURRENT USERS OF TELECOMMUNICATIONS
  - DETERMINE THEIR LEVEL OF INTEREST
  - ASSESS PRESENT OPERATIONS
  - ESTABLISH FUTURE NEEDS
- TRANSLATE "NEEDS" INTO REQUIREMENTS
- SYNTHESIZE REQUIREMENTS INTO A BROADCAST SATELLITE SYSTEM
- EVALUATE THE SYSTEM

Table 3-2 presents a list, in alphabetic order, of the persons contacted in the course of the study. As can be seen, 53 persons provided information for the definition of the 10 missions analyzed in Phases I and II of the study. These 10 missions are categorized and discussed, as follows:

DIRECT TO HOME

As shown, systems of this type provide sufficient signal strength from the satellite to be received directly by standard, or augmented, home TV receivers.

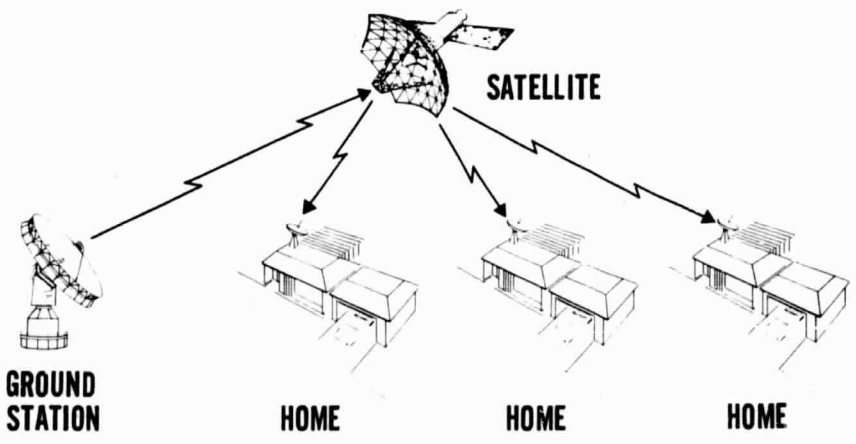


Table 3-2. Users Contacted

No.	Name	Affiliation
1.	Gerard Appy	National Educational Television New York City
2.	Julius Barnethan	American Broadcasting System
3.	Dr. Jordon Baruch President	EDUCOM
4.	Dr. Cliff Block	Dept. Of State/AID
5.	J. Broger Director	Armed Forces Radio & Television Services
6.	John T. Caldwell Manager Of Operations	Ed. Foundation/WGBH
7.	Ben Carmichael	Appalachia Educational Laboratory
8.	L. Madison Coombs	Bureau of Indian Affairs/Education
9.	Bernarr Cooper Chief, Mass Communications	State University of New York
10.	Col. L. Cruciana	Armed Forces Radio & Television Services
11.	Frank W. Cyr Director	Rural Supplementary Education Center
12.	Dr. Ruth Davis Associate Director/NLM	National Institute Health/ Health Education Welfare
13.	Mr. R. DuMont Director	AMA - Radio, TV and Motion Picture Department
14.	Rev. Walter C. Flaherty Director	Boston Catholic TV Center
15.	Wm. F. Fore Executive Director	National Council of Churches
16.	Col. Fradenberg	DOD/Office of Assistant Secretary for Education
17.	A. Fredette Coordinator of Instructional Communications	Albany Medical College

Table 3-2. Users Contacted (Cont'd)

No.	Name	Affiliation
18.	W. Harley	National Education Association & NAEB
19.	Rev. Healy Director	Diocese of New York Communications Center
20.	Thomas P. Hoving Chairman	National Citizens Communication for Public TV
21.	William J. Kirkley Captain, USCG	U.S. Mission to U.N.
22.	Claire List	Ford Foundation
23.	Norman Locke Director ITV	Boston University School of Education
24.	Len Marks	United States Information Agency
25.	Charles Marquis	National Association of Educational Broadcasters
26.	Rev. J. Meyers	National Catholic Education Association
27.	John Morrison Director of Programming	Eastern Ed. Network (EEN)
28.	Tom Nelson	Department of State
29.	Tom Nesbitt	Department of State
30.	Frank W. Morwood Executive Secretary	Joint Council on Education Telecommunications
31.	Monsignor J. O'Keefe	Diocese of New York Committee on Education
32.	Dick Oldham Chief Engineer	Ed. Foundation/WGBH
33.	Peter Perry	U.N. Information Center
34.	Rev. J. Pindar	National Catholic Office for Radio and Television
35.	Dr. Dave Pollen Deputy Assoc. Commissioner	Bureau of Research, HEW

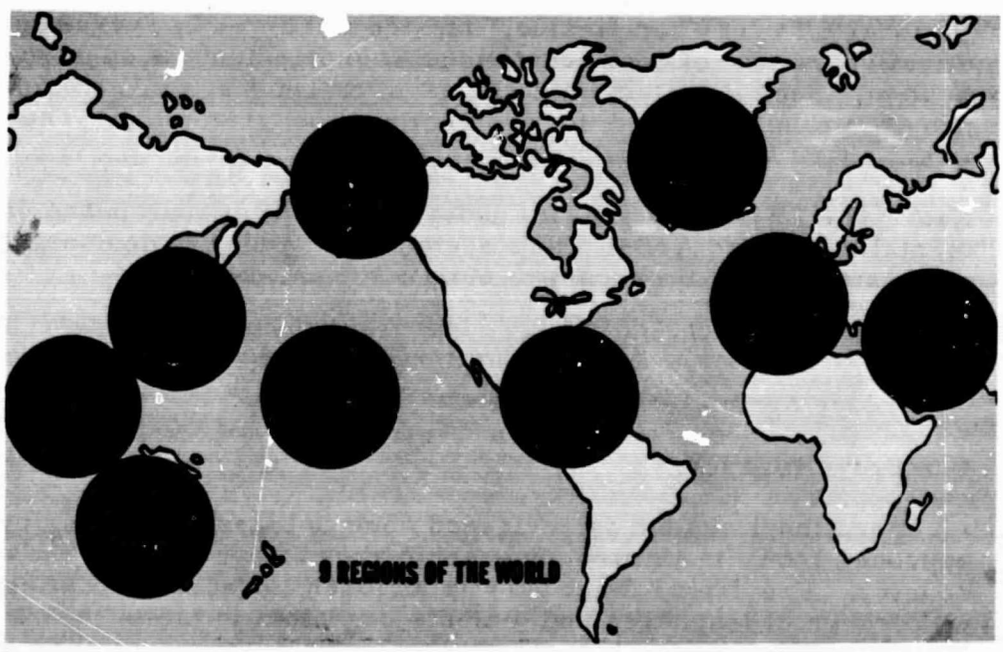
Table 3-2. Users Contacted (Cont'd)

No.	Name	Affiliation
36.	Dr. Donald G. Potter Director	Audio-Visual Center University of Nevada
37.	John Powell	Office of Economic Opportunity
38.	Don Quayle	Corp. for Public Broadcasting
39.	Ray Reid Television Coordinator	General Services Office Of State of California
40.	Mr. C. E. Reilly Executive Director	National Catholic Office for Radio and TV
41.	Marvin Robinson	U.N. Secretariat
42.	George Sitts Chief Engineer	Diocese of Brooklyn TV Center
43.	Hugh Smith Commissioner	Commission Nevada Educational Communications
44.	Lt. Col. Souville	Armed Forces Radio & Television Services
45.	R. Stanley	Health Education Welfare
46.	Herbert S. Steffens Director, Project West	Nevada State Dept. Education
47.	Dr. John Sullivan Executive Secretary	National Education Association
48.	Robert Swenson	Comsat Corporation
49.	Sidney Tickton Executive Director	President's Council on Instructional Technology
50.	Zane Thornton Network Engineer	National Institute of Health/ National Library of Medicine
51.	H. Valentino Staff	Armed Forces Radio & Television Services
52.	Dr. Harold E. Wigren President	Joint Council on Education Communications
53.	John Witherspoon	NET, San Diego

Missions in this category are:

1. U.S. National ETV System. This system would augment the existing local ETV stations (approximately 200 in the U.S.) and would extend their typical services to the entire nation. Several channels of superior programming are desirable. One such channel ould be like the Public Broadcast Laboratory and would be national in scope. Another channel would be local, at least regional, in scope. Such a system would operate in the early morning and evening hours. Optionally, the local channel would provide full-time programming if suitable material were available and if a sufficient demand were expressed.

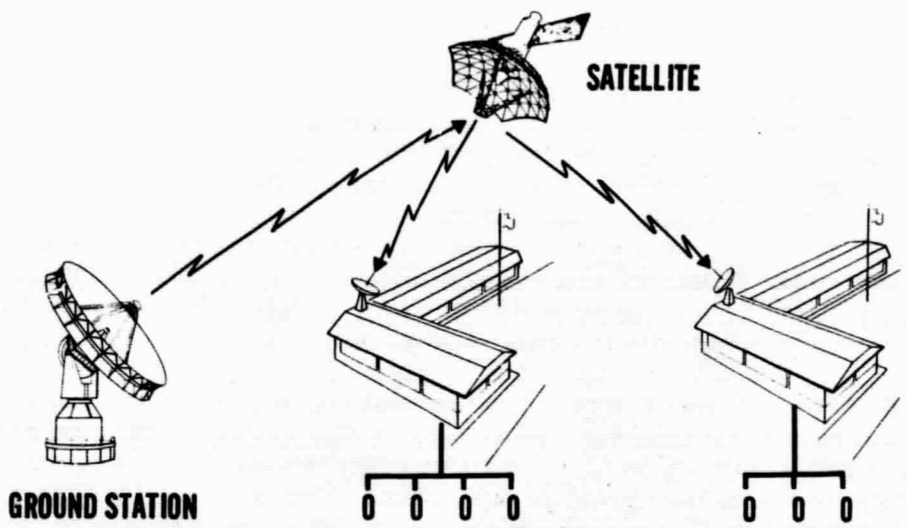
2. U.S. Armed Forces Radio and TV Services. This system is currently in operation throughout the world, in the areas shown, to bring entertainment services to U.S. military personnel, embassy staffs, civilian staffs and families located overseas. The service is offered through video tapes and films which are physically transported to these remote areas as requested and as they become available.



This system is unique in that it constitutes a foreign coverage of a U.S. domestic interest.

DIRECT TO CENTER

A more sophisticated receiving system is required to extend this service to its potential audience -- one that is suitable for community use.



Missions in this category are:

1. National ETV/ITV for Mexico. Mexico is currently searching for a cost-effective system of communications to supplement its educational system. Such a system would be used for general non-commercial programming as well as for instructional programming. These services would share the same system.

2. National ETV/ITV System for India. As currently proposed experimentally with the ATS-F, this system is intended to demonstrate the application of TV broadcast to India's top national goals:

   o Control population increase.

   o Increase agricultural productivity.

   o Improve literacy.

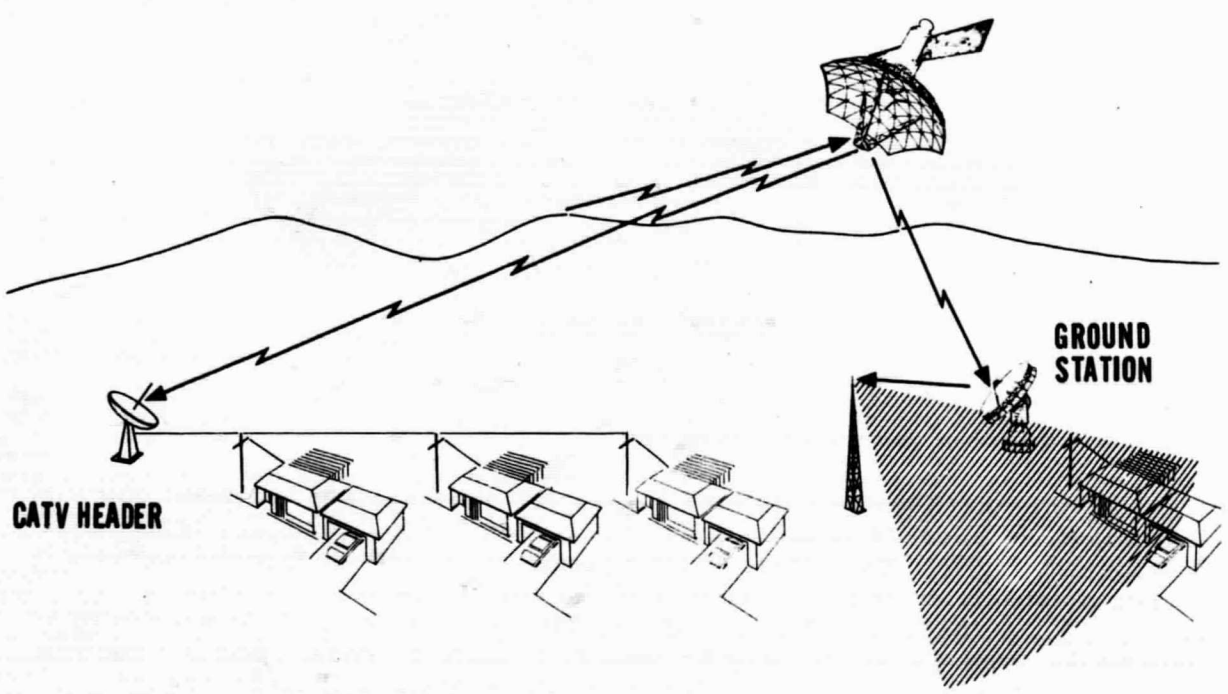
   An operational system is envisaged here to extend the experimental approach from its limited geographic area of operation to the whole country. Provisions must also be included for accommodating the wide range of languages and dialects prevalent in India.

3. U.S. National ITV System. Much concern has been expressed over the general state of the public schools in the U.S. In the present environment of increasing costs with inadequate budgets something must be done to reach more and more students with proportionately less costs. Several studies have proposed a TV broadcast system to alleviate this problem. Such a system would provide a nucleus of TV instruction around which a more cost-effective public school system could be organized.

4. U.S. Parochial School System. The same problems that beset the public schools also seriously impact Parochial schools. In addition the further problem of increasing costs due to the decline in religious vocations is of major import. Whereas in 1940 85% of the teachers in parochial schools were religious there is now only 56%. The difference is made up of lay teachers who are paid at public school wage levels -- considerably higher than those for the religious. Some of the Instructional Television Fixed Service (ITFS) systems pioneered by different dioceses are excellent working models of the application of telecommunications to education. This system would extend these unit networks into a national network to serve the 12% of the entire elementary and secondary student population that attend parochial schools.

Logically, this system would be compatible with the previous U.S. ITV System. Both could be implemented with the same satellite system.

REDISTRIBUTION



In this mode of operation the satellite transmits to a ground station which serves as a relay to disseminate the material locally through some secondary means. Cable TV and local broadcast stations are the usual means for redistribution. The ground station for this type of system is usually quite complex and expensive.

Missions in this category are:

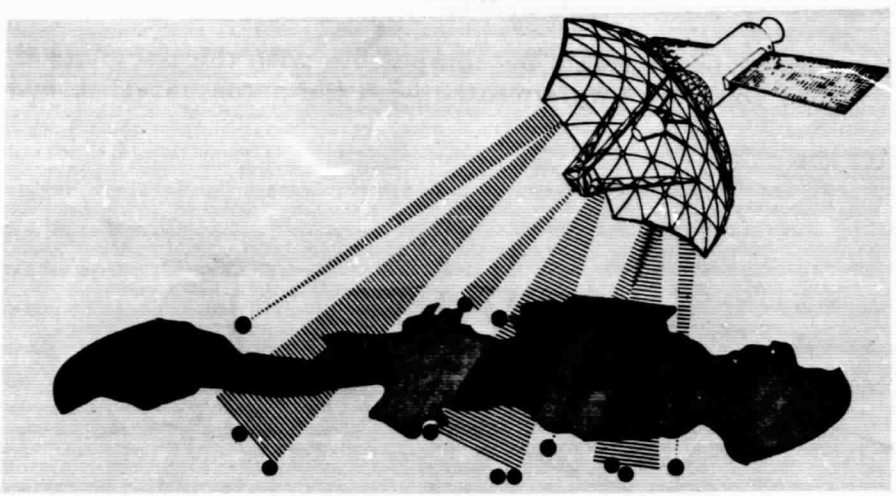
1. U.S. National ETV System.

2. U.S. National ITV System.

These systems are the counterparts in this mode of distribution for the Direct Systems discussed above.

INTER-INSTITUTIONAL CONNECTION

As the name implies, systems of this type relate to the interconnection of facilities for sharing purposes. The facility can be a computer, library or other information source. The intent is to accommodate the "many-to-many" service recommended by the National Academy of Sciences.



("MANY"-TO-"MANY")

A typical mission in this category is:

U.S. Biomedical Communications Network. This system has been under investigation since its funding under the Network for Knowledge legislation (September 1968). The intent of the system is to provide a multi-service communications system for the use of the entire medical community -- medics, para-medics, administrators, technicians, etc. Dial access to data banks, and TV for library browsing, remote diagnosis and instruction are included in this mission. Ultimately the system will interconnect medical schools (100), hospitals (over 7,000) other medical facilities and public health institutions throughout the U.S.

3.3 USER RATING

A complex system, including normalizations and weighting factors, was deliberately avoided for this study. Instead the missions were listed and compared to each other on the basis of some general, qualitative, criteria or parameters:

1. Interest. This is a measure of the interest expressed in the particular mission. Typical inputs to this parameter are: number of technical

papers, number of news releases, commentary by responsible individuals such as members of government or cognizant agencies.

2. System Operations. This parameter relates to the performance of activities, present or proposed, in support of such a mission. Present operations take precedence over proposed operations, however complex.

3. Current Funding. The extend to which funds are committed in the performance of system operations is a fundamental issue. Lever and adequacy, in the light of the proposed system, are both included.

4. Organization. In this parameter it is important whether or not a formal organization exists in support of the mission. It it exists is it right for the mission, too little or too much?

5. Viability. This parameter addresses itself to the acceptance of an operational system by the parties concerned -- the public, the using community, national government and local governments.

Combining all of these into a matrix results in Table 3-3. Here the missions are listed in the order of their final rating. They are listed vertically by parameter in the order of their preference -- 10 is the preferred number, 1 is the least. After this ordering is ac mplished by parameter, separately and independently from one another, they are combined horizontally. This is accomplished by a simple addition of the parameter scores. The highest composite score is preferred. A brief review of the table shows that such politically insecure missions as Direct ITV are at the lowest ratings. Correspondingly high-interest missions such as India and distribution of ETV in the U.S. are the upper end of the scale.

There has been no effort made to deliberately assess the social, cultural, legal or political impacts of these systems. While some subjective opinion may be included within the assessment of the parameters this is not intended. It would be highly desirable at some time to analyze such impacts and to include them properly in this type of study.

Table 3-3. User Ratings

Users*	Evaluation Parameters						
	Interest	System Operations	Current Funding	Organization	Viability		Rating
1. U.S. Armed Forces Radio & TV Services	8	10	10	8	8		44
2. U.S. ETV-Distribution	9	9	9	9	6		42
3. U.S. Parochial Schools	7	8	8	10	5		38
4. India ETV-Direct	10	4	4	5	10		33
5. U.S. Biomedical Network	6	5	6	6	9		32
6. U.S. ETV-Direct	5	7	7	7	4		30
7. U.S. ITV-Distribution	4	6	5	4	7		26
8. Mexico ETV-Direct	2	3	3	3	3		14
9. U.S. ITV-Direct	3	1	2	2	1		9
10. Mexico ITV-Direct	1	2	1	1	2		7

*Listed in the order of their rating

4

SYSTEM ANALYSIS

Incorporation of the user analysis data into appropriate missions is accomplished by means of a synthesis/optimization computer program developed by the Convair Aerospace Division. Within the limits of the study guidelines this program is capable of synthesizing a communication system and deriving an optimum solution based on the overall total systems cost -- including both space and ground segments. The specification of the Saturn V launch vehicle constitutes a major constraint on the system directly affecting the total process.

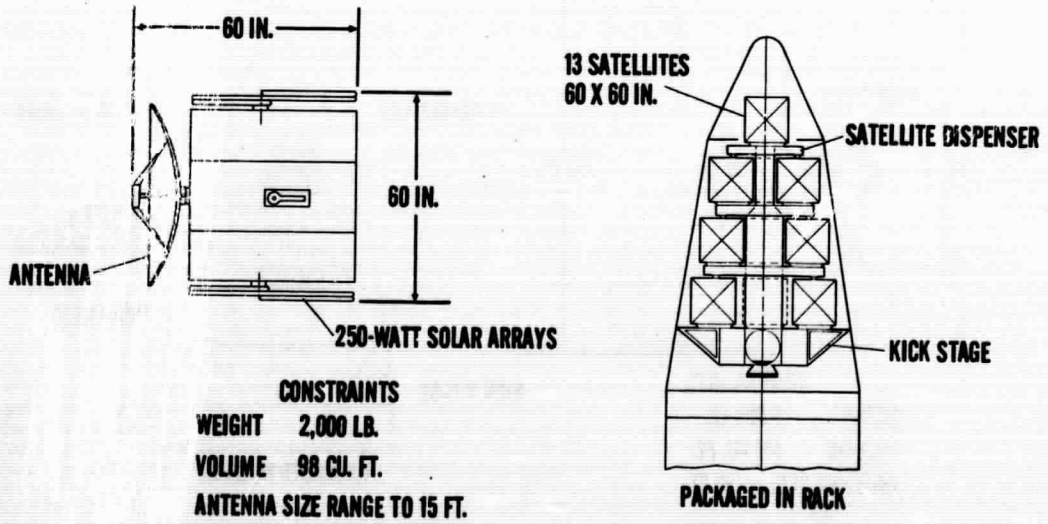
4.1 SPACECRAFT CONCEPTS

To fully exploit the Saturn V capabilities the payloads were considered to be composed of either unmanned, multiple satellites with a dispensing system or larger manned systems. Although the multiple satellite versions shown assume essentially the same satellites for a given launch in practice each satellite could be significantly different to satisfy several users with diverse requirements. The possibility of sharing the launch with non-TV satellites is also available. Eight systems within six configuration concepts provide a weight range from 2,000 to 42,000 lb. Small and large unmanned systems are considered along with large manned systems. A brief discussion of the basic spacecraft concepts follows:

CONCEPT A

A dispencer with 13 satellites is shown on the Saturn V. Each satellite is limited to the dimensions shown and weighs 2,000 lb. It is compatible with launch to synchronous orbit by a Titan IIIC.

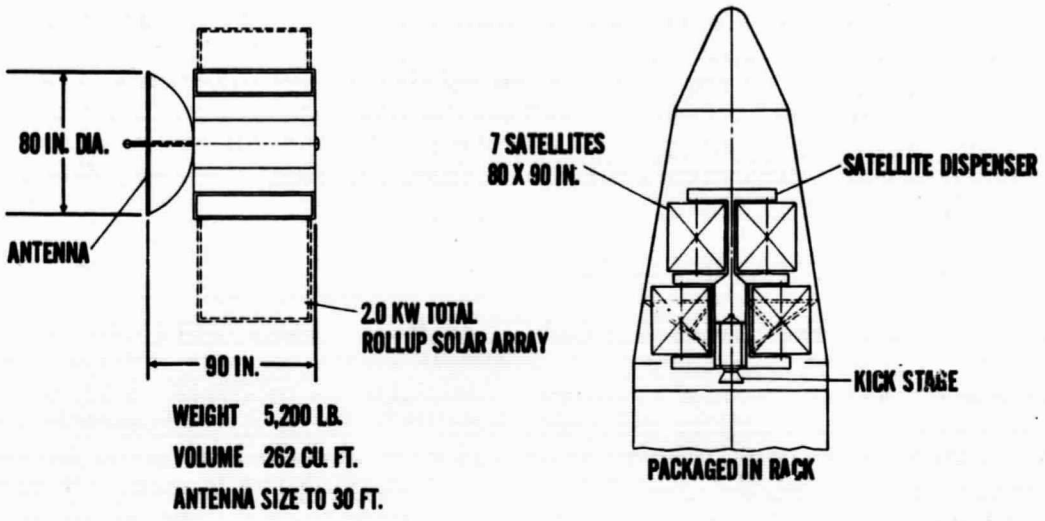
Concept A



CONCEPT B

A dispenser with 7 satellites is shown. Each satellite is limited to the dimensions shown, weighs 5,200 lb., and has a prime power capability of approximately 2KW. This satellite is compatible with a Titan IIID/Centaur launch to synchronous orbit.

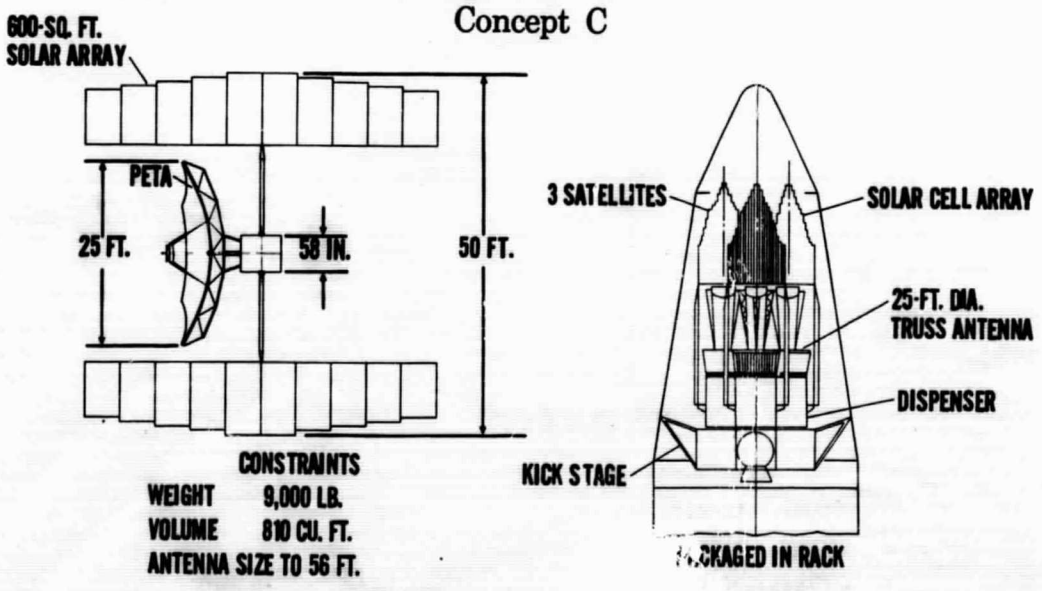
Concept B



CONCEPT C

In this concept 3 satellites are shown packaged into a dispenses on the Saturn V. Each satellite weighs 9,000 lb. and can support a large antenna and solar cell array. Each one is compatible with launch to synchronous orbit by a Saturn IB/Centaur.

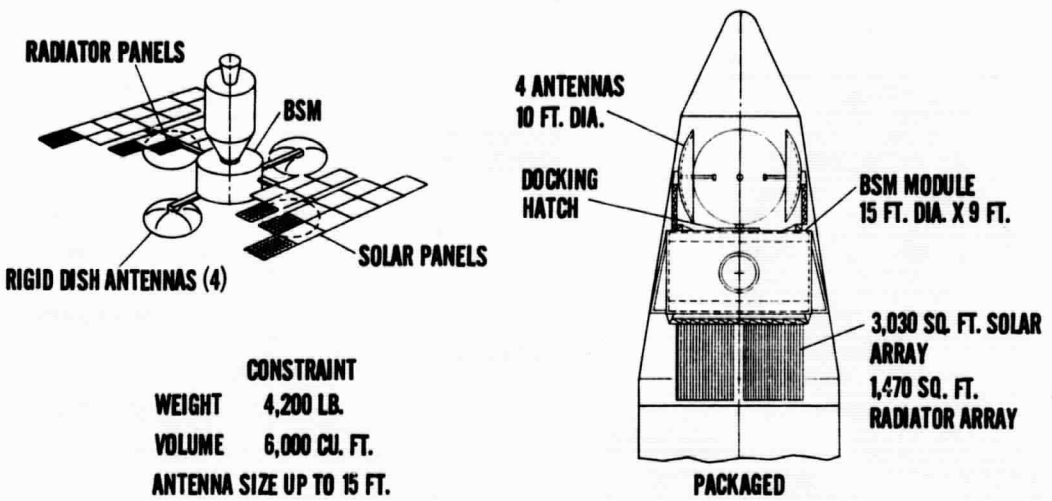
Concept C



CONCEPT D

This concept consists of a single satellite with multiple antennas to serve multiple areas. It is based on the use of the Basic Subsystem Module (BSM). Total weight of the system, including the BSM (12,700 lb.) is 42,000 lb. This system permits manned participation for extended periods.

Concept D



CONSTRAINT

WEIGHT 4,200 LB.

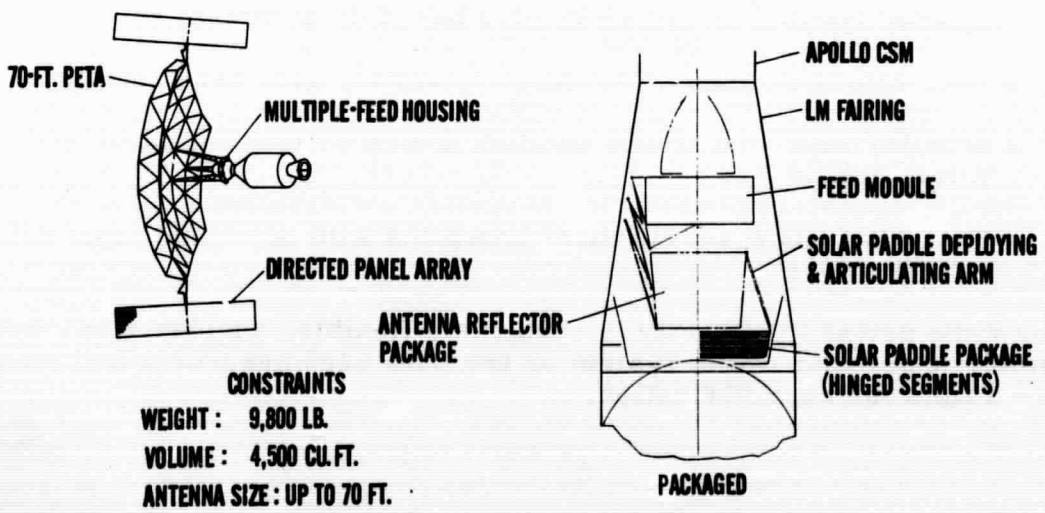
VOLUME 6,000 CU. FT.

ANTENNA SIZE UP TO 15 FT.

CONCEPT E

Concept E is a single, man-assisted concept containing a large antenna and feed module. The feed module contains all the satellite electronic equipment and permits docking of the CSM. Life support provisions for short periods is included. The weight of the system, without the CSM, is approximately 10,000 lb.

Concept E



CONSTRAINTS

WEIGHT: 9,800 LB.

VOLUME: 4,500 CU. FT.

ANTENNA SIZE: UP TO 70 FT.

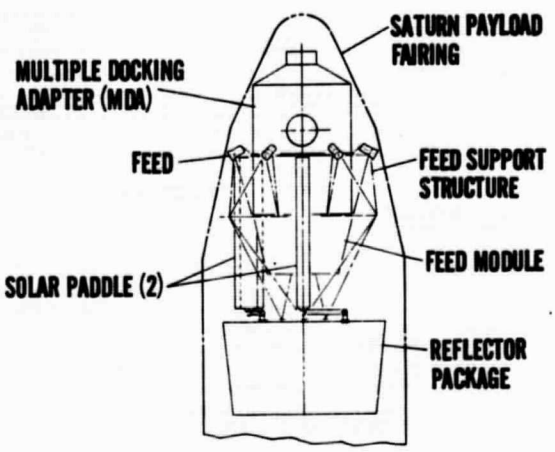
CONCEPT F

This version is designed to accommodate a number of users in one satellite. The configuration is developed around a single expandable truss antenna structure containing six apertures. A Multiple Docking Adapter (MDA) is used for the feed assembly to permit docking by the CSM and to provide life support for man-assisted operations. Weight limitation of this system is up to 42, 000 lb.

Concept F



CONSTRAINTS
WEIGHT: 42,000 LB.
VOLUME: 6,000 CU. FT.
ANTENNA SIZE UP TO 33 FT.



4.2 SYSTEM SYNTHESIS

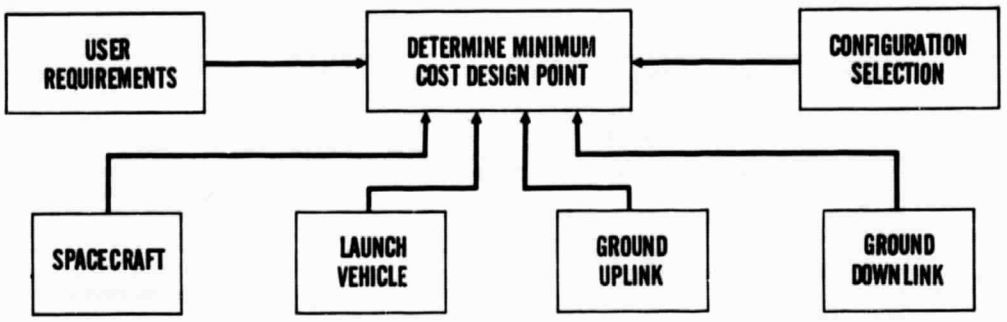
The approach to system synthesis involved the development of a computer program to derive optimum systems as defined by minimum total cost. Features of the program are shown.

- Total system synthesis considering ground uplink, spacecraft, ground downlink & launch vehicle based on minimum cost
- Determines a range of solutions to satisfy user requirements
- Modular approach allows addition of new or updated parametric relationships
- Perturbations & sensitivities computed with minimum input data modifications

They were devised primarily to result in a flexible, adaptable and fast system. Operation of the system on the CDC 6400 assures a fast turn around time for each derivation.

The Functional Block Diagram for this program is shown. It considers User Requirements, Spacecraft constraints, Launch Vehicle constraints and the uplink/downlink tradeoffs in determining the minimum cost design.

Functional Block Diagram



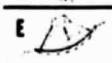
USER REQUIREMENTS

This block of data represents a minimal statement of requirement from which a TV communication system can be defined. As shown, it includes the description of the technical TV requirements as well as a definition of the desired system topology -- geography, number of facilities, environment and duty cycle(s). The required system and satellite operational lifetimes are also defined. In some cases the particular user is not able to define specific values. Then a range of inputs or system options can be defined for the input and the program will operate for each set.

USER REQUIREMENT	INPUT VARIABLE	INPUT DATA
AREA OF COVERAGE		
MAJOR AXIS (MI.)	AMAJR	1,600
MINOR AXIS (MI.)	BMINR	1,000
LATITUDE (DEG.)	LAT	35
RELATIVE LONGITUDE (DEG.)	LONG	25
PICTURE QUALITY (TASO GRADE)	ITASO	1
SIGNAL-TO-NOISE RATIO (DB)	SNGR	44.5
RECEIVER POP./BEAM (1,000)	XNGR	10,000
TOTAL POP. (1,000)		60,000
NO. DOWNLINK BEAMS	NBRQD	6
NO. VIDEO CHANNELS PER BEAM	NCB	2
NO. AUDIO/VIDEO CHANNELS	NAPV	1
NO. UPLINK FACILITIES	NF	7
NO. CHANNEL/FACILITY	NCF	2
TOTAL SYSTEM OPERATIONAL LIFE (YR.)	LSYS	10
SATELLITE LIFE (YR.)	LSAT	5
DUTY CYCLE (HR.)	DCYCLE	24
NOISE ENVIRONMENT	POP	SUBURB
GROUND DOWNLINK SYSTEM	I21	DIRECT

SPACECRAFT

The spacecraft systems, previously discussed, are summarized. They offer a reasonable range of weight and volume and include both manned and

CONCEPT CODE	ALLOWABLE WT. (LB.)	ALLOWABLE VOL. (CU. FT.)	ANTENNA TYPE	POWER	MANNED PROV.	BOOSTER TYPE	COMMENTS
A 	2,000	98	PETA OR RIGID	SOLAR CELL	NONE	S-V OR T IIIC	MULTIPLE-SATELLITE VERSION, 13 PER S-V LAUNCH, 1 PER T IIIC LAUNCH
B 	5,200	262	PHASED ARRAY, PETA, OR RIGID DISH	SOLAR CELL	NONE	S-V OR T IIID/ CENTAUR	MULTIPLE-SATELLITE VERSION, 7 PER S-V LAUNCH, 1 PER T IIID/CENTAUR LAUNCH
C 	9,000	810	PETA	SOLAR CELL	NONE	S-V OR S-1B/CENTAUR	MULTIPLE-SATELLITE VERSION, 3 PER S-V LAUNCH, 1 PER S-1B/CENTAUR LAUNCH
D 	29,300	6,000	RIGID DISH ARRAY	SOLAR CELL	BSM MODULE	S-V	BSM PROVIDES A SHIRTSLEEVE ENVIRONMENT FOR EXTENDED MANNED OPERATIONS
E 	10,000	4,500	PETA	SOLAR CELL OR REACTOR	DOCK	S-V WITH CSM	DOCK PROVIDED, ALL OPERATIONS BY EVA OR REMOTE CONTROL
F 	42,000	6,000	PETA	SOLAR CELL	PRESSURIZED FEED MODULE	S-V	MDA MODULE PROVIDES A SHIRTSLEEVE ENVIRONMENT FOR SHORT PERIODS (14 DAYS)

unmanned versions. As further shown, the full complement of subsystems is included in the analysis. Several options are considered for the subsystems where appropriate.

Weight, Volumes, Power Levels, Efficiencies

POWER SUBSYSTEMS · SOURCE, CONDITIONING, CONTROL
- SOLAR ARRAY
- NUCLEAR REACTOR

BATTERIES
- NICKEL-CADMIUM
- SILVER-CADMIUM
- SILVER-ZINC

TRANSMITTER
- GRID — CFA
- SOLID STATE — TWT

MULTIPLEXER
- STRIPLINE
- COAX
- WAVEGUIDE

MANNED PROVISIONS

RECEIVER
- LINEAR TRANSLATOR

ATTITUDE CONTROL STATIONKEEPING
- AMMONIA RESISTOJET
- ION PROPULSION
- H_2O ELECTROLYSIS

THERMAL CONTROL
- PASSIVE
- HYBRID

STRUCTURE
- CONVENTIONAL
- BSM
- MDA

TELEMETRY & COMMAND

LAUNCH VEHICLES

The basic launch vehicle specified in the TV Broadcast Satellite study is the Saturn V. Other options include the use of a multiple satellite dispensing system. Each of these satellites was then made compatible with lesser launch vehicles. The cost model includes the launch vehicle (recurring and non-recurring costs), launch site modifications, ground support equipment and systems integration.

- SATURN V
- SATURN IB/CENTAUR
- TITAN IIID/CENTAUR
- TITAN IIIC
  - LAUNCH COMPLEX MODIFICATIONS
  - GROUND SUPPORT EQUIPMENT
  - MANAGEMENT & INTEGRATION

UPLINK AND DOWNLINK

GROUND UPLINK

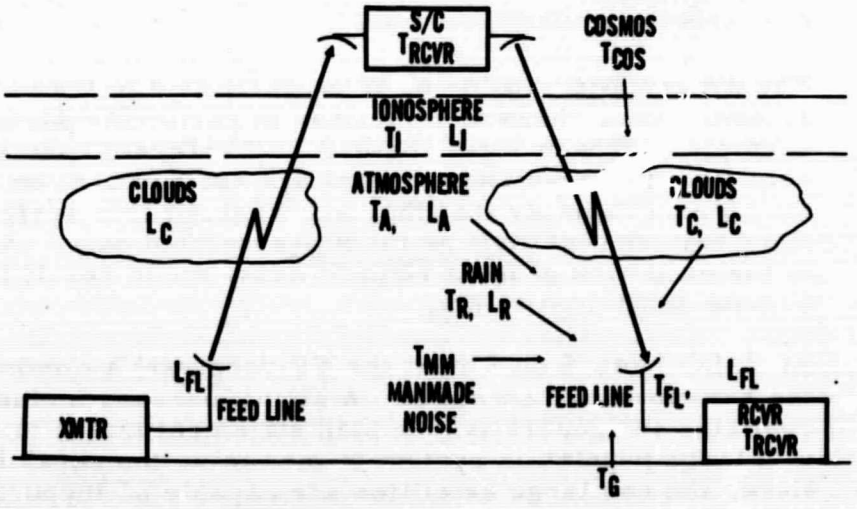
- TRANSMITTER
  - POWER/CHANNEL
- ANTENNA
  - DIAMETER (GAIN)
- RECORDING & PLAYBACK EQUIPMENT
- TELEMETRY & COMMAND
- PERSONNEL

GROUND DOWNLINK

- ANTENNA (DIAMETER, GAIN)
  - WIDEBAND
  - PARABOLIC
- RECEIVER (NOISE FIGURE)
- TRANSMISSION LINE
- MAINTENANCE
- REDISTRIBUTION
  - PERSONNEL
  - FACILITIES
  - EQUIPMENT

NOISE & PROPAGATION MODELS

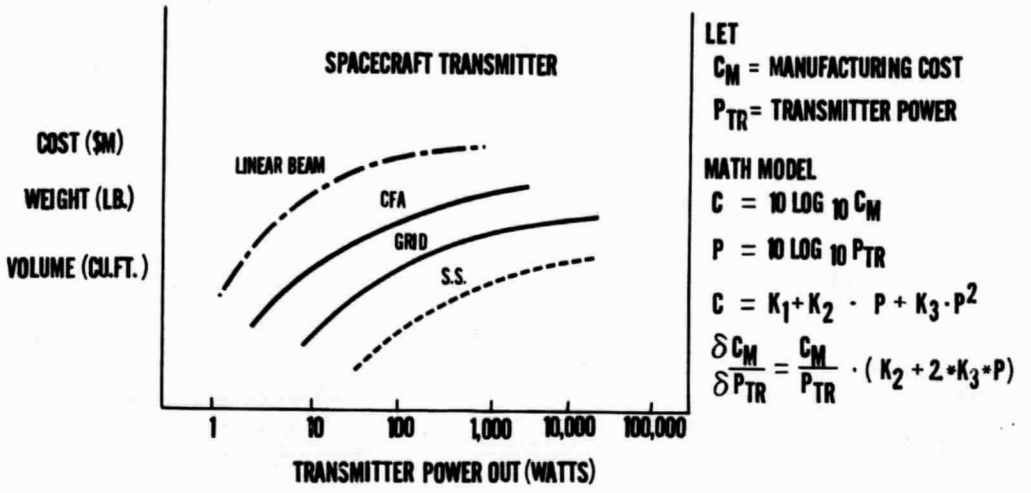
As shown the link analysis includes all the equipment, noise and propagation factors that impact the RF signal transmission.



PARAMETRIC RELATIONSHIPS

An example is shown of the typical parametric relationships. Cost, weights and volume are the 3 characteristics of interest. This data is plotted

PARAMETRIC RELATIONSHIPS



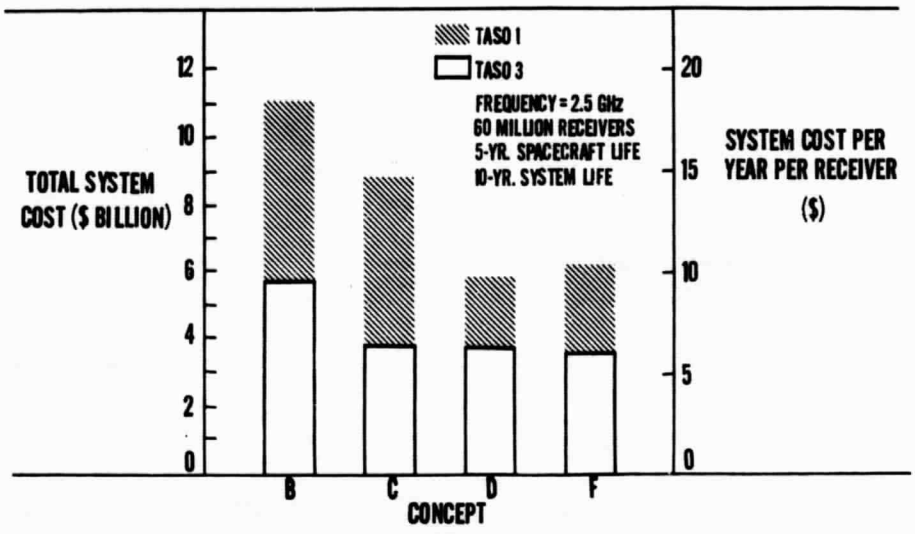
against the key parameter of the device (here transmitter output power). As many real data points as practicable are plotted and then fitted by an appropriate curve. The definition of the resulting smooth curve as a polynomial with constants and weighting factors allows this data to be modified through changes in these factors without a new redefinition each time.

The program then exercises all of the data through an iterative steepest-descent process to arrive at the minumum cost/optimized solution.

4.3 SYSTEM SENSITIVITIES

The program is capable of being perturbed to the extent of showing the system sensitivities to variations in particular parameters. As an example of this process the U.S. ETV-Direct case is reviewed in this section. The results presented are not meant to be exhaustive nor are they meant to imply that they are final for this system. In fact, they do show typical sensitivities for a pre-defined case. Any significant change in the definition of input requirements would result in a change in the outputs and sensitivities.

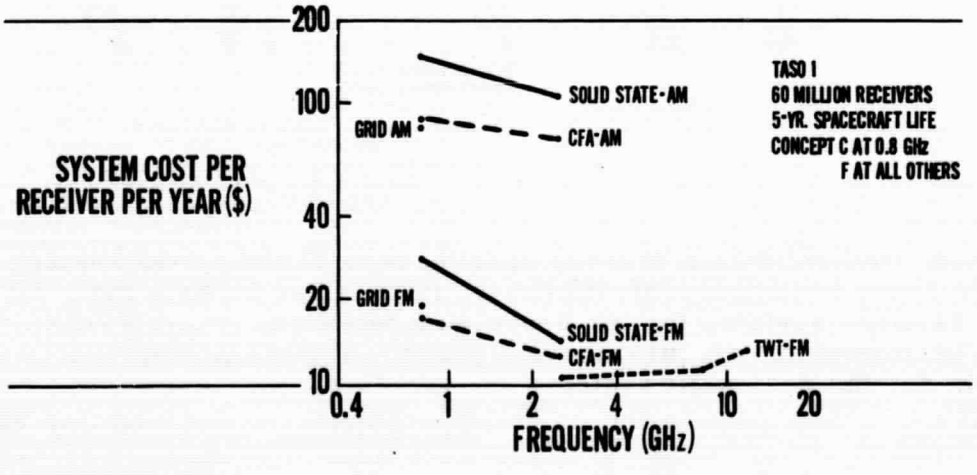
At TASO 1 (44.5 db S/N at the TV receiver) a minimum cost occurs for the system with Concept D. A slight increase includes Concept F. This confirms the generally accepted statement that it is more cost-effective in a large population system to maximize the capability of the satellite. Here, the two large satellites are capable of supporting large, high-gain antennas and high-powered transmitters.



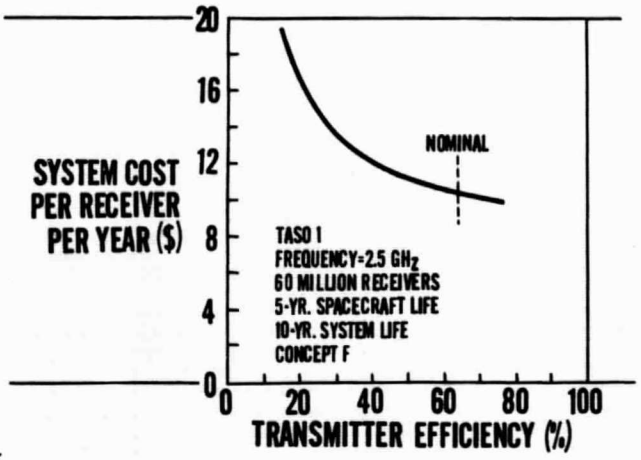
This effect is not as pronounced at TASO 3 (27.0 db S/N at the TV receiver) where considerable degradation in the performance of the system is tolerated.

The selectio f modulation type and transmitter for this system shows a definite preference for FM modulation. Below 2.5 GHz the Cross-Field Amplifier (CFA) i. superior to solid state. Above 2.5 GHz the Travelling Wave Tube (TWT) is the only acceptable approach. It should be noted that the TWT, in this case, is representative of linear tube-type devices including TWT's, Klystrons, Backward Wave Oscillators and Magnetrons.

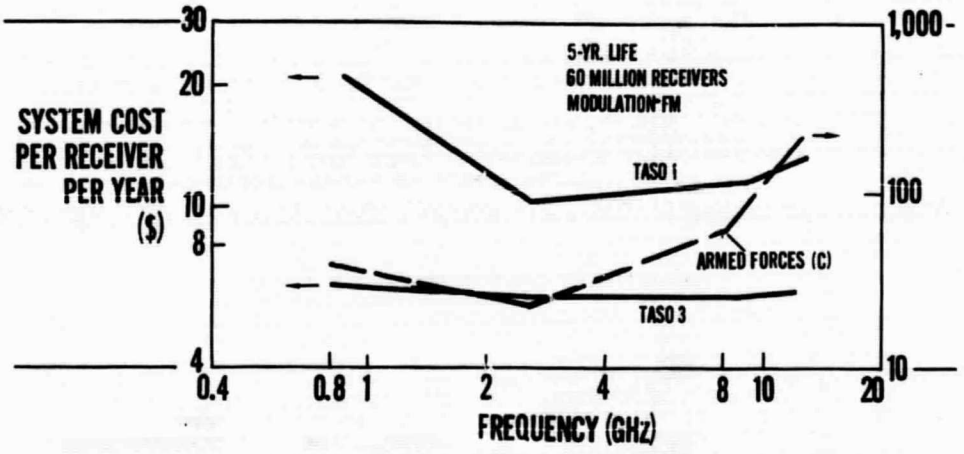
Sensitivity to Transmitter Type



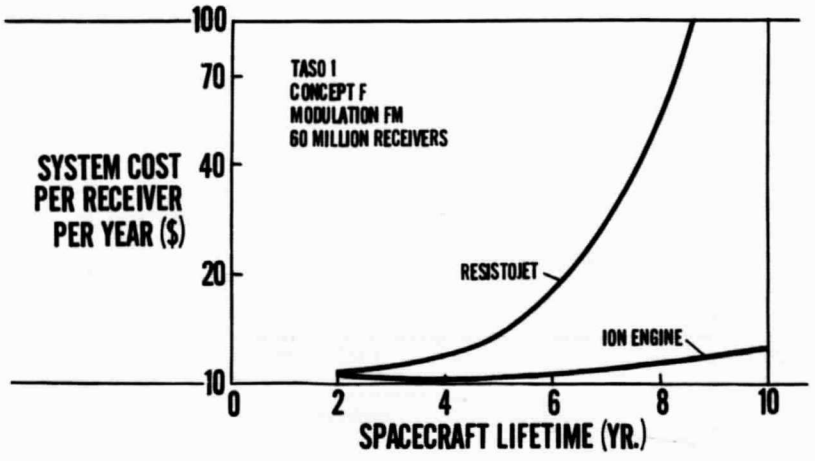
Considerable debate has surrounded the topic of transmitter efficiency. The knee of this curve corresponds to 30%, An acceptable efficiency range of 30-50%, while showing some cost improvement with improvement in efficiency, is still not startling. The "nominal" point shown is for the transmitter device only and does not include an allowance for the required power conditioning.



The significance of cost is again shown for TASO 1 being considerably more expensive than TASO 3. As a function of frequency there is a significant minimum cost at 2.5 GHz. This is scarcely discernible at TASO 3. A second set of data is included to show the difference between high and low receiver populations. The Armed Forces system is serving approximately 2 million receivers as compared to 60 million for ETV.

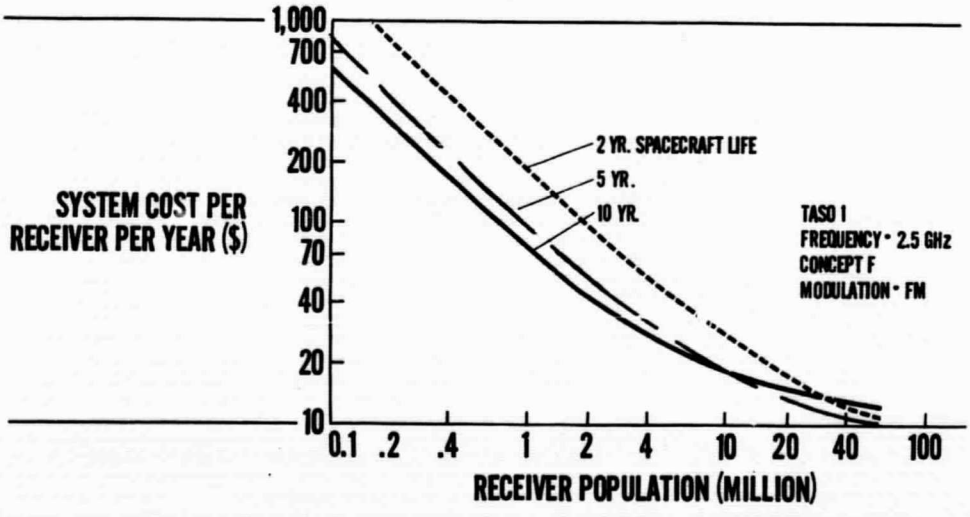


A typical tradeoff exists between attitude control and stationkeeping subsystem types and spacecraft lifetime. Here it can be seen that, for a large satellite system, the ion propulsion technique is more cost-effective than resistojets at lifetimes above 4 years. The main difficulty is reactants storage for the resistojet system.



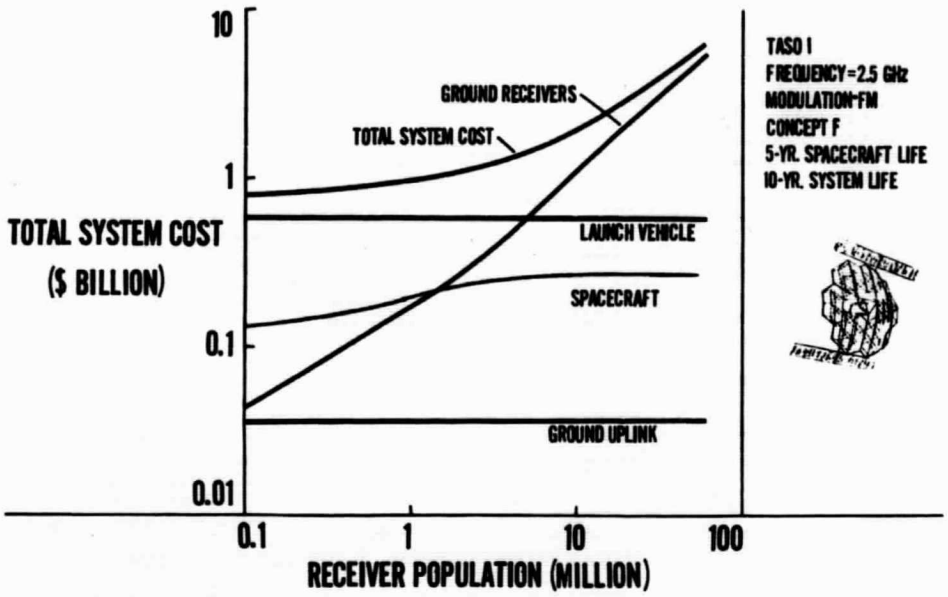
When considering the system cost per receiver per year it is intuitively clear that a cost decrease should occur with the increase in receiver population. This is shown. The further effect of spacecraft lifetime is also shown. The 10-year lifetime system is most cost-effective up to a receiver population of 10 million. At this point the 5-year system takes over. Finally, in the vicinity of 100-million receivers the 2-year life system becomes most cost-effective.

Receiver Population Sensitivity



This set of data shows how the Total System Cost is apportioned among the segments of the system. Since a large satellite concept is projected there is no significant change in launch vehicle costs. The same is true for the ground uplink. At between 2 and 3 million receivers the satellite

capability is saturated and ground receivers dominate the total cost. As more and more receivers are added to the system they continue to drive the total system cost upward.



5

SYSTEMS SUMMARY

Systems were defined for each of the selected users by:

1. Defining a set of requirements representative of their needs.
2. Synthesizing baseline systems in response to these requirements.
3. Exercising available options of frequency and system configuration to examine cost sensitivities.

Results of these analyses were reviewed and three systems selected for preliminary design.

5.1 CANDIDATE SYSTEMS

The order in which systems are discussed in the following paragraphs is that from greatest to least critical user need. The costs and resulting system configurations of these systems are compared in Section 5.2.

MISSION No. 1

U.S. ARMED FORCES RADIO & TV SERVICES

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
GLOBAL COVERAGE (SPECIFICALLY EXCLUDING U.S.) 3 SATELLITES 3 BEAMS/SATELLITE 5 CHANNELS/BEAM 10^6 SQ. MI./BEAM	10×10^6 PEOPLE (MILITARY PERSONNEL PLUS DEPENDENTS & ON-BASE STAFF) ASSUME: UNIFORM DISTRIBUTION 5 PEOPLE/RECEIVER	TWO ORIGINATING STATIONS WASHINGTON LOS ANGELES	3 CHANNELS 100% 2 CHANNELS 5:00 - 8:00 A.M. 5:00 P.M. - MIDNIGHT

This system provides 5 channels of color TV to nine regions of the world, serving 10 million people. Two large satellites are sufficient for area coverage, however arrays of as many as 9 satellites were considered to meet the requirements. Direct broadcast and a CATV type redistribution approach were analyzed.

In the direct broadcast system, the larger, higher-powered, satellites are cost effective because of the very large number of receivers in the system. Concepts D and F provide lowest system costs, using 3 and 2 satellites respectively. (System costs reflect use of 2 five-year satellites at each position to meet the 10-year lifetime).

In the alternative approach (CATV redistribution), the system cost is substantially reduced, primarily because the number of receivers is reduced by a factor of 20,000, (although individual receiver cost increases), and the redistribution system cost is not included. The latter because this capability is now available at many of the installations as part of their CCTV systems.

MISSION NO. 2

U.S. NATIONAL ETV SYSTEM
Program Distribution

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
FULL U.S. 4 TIME ZONES 2 CHANNELS/ZONE	TO GROUND STATIONS FOR REBROADCAST 50 ETV RECEIVERS PER ZONE	ONE N.Y.C. ORIGIN	100%

The existing family of 200 ETV broadcasters is served by this system in providing 2 channels of TV in each of 4 time zones on a continuous basis. Two concepts yield favorable results for TASO grade 0 service. Concept B requires 4 satellites, while use of a single large satellite is sufficient when the Concept F approach is utilized.

MISSION NO. 3

U.S. PAROCHIAL SCHOOL SYSTEM

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
FULL U.S. 4 TIME ZONES HAWAII ALASKA U.S. PACIFIC TERR. VIRGIN IS., ETC. 2 CHANNELS/AREA	PAROCHIAL SCHOOL/ SYSTEM 14,000 SCHOOLS ITFS INTERFACE	ONE ORIGINATING STATION N.Y.C.	100%

This system will serve 14,000 schools distributed through 147 dioceses. The satellite system would interface with the 2.5 GHz Instructional Television Fixed Service systems being implemented by many dioceses. A 100% duty cycle is indicated.

Two approaches were analyzed: A TASO 1, high-quality TV system using crossed-field amplifiers in the satellites, and a TASO 3, acceptable quality TV system using low-power solid-state amplifiers.

Concepts B and F, using 16 and 4 satellites respectively, are lowest in cost.

MISSION NO. 4

NATIONAL ETV/ITV SYSTEM FOR INDIA

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
INDIA 1.3 MILLION SQ. MI. 1 TIME ZONE 1 BEAM 1 VIDEO CHANNEL 15 AUDIO CHANNELS	511×10^6 PEOPLE 568,000 VILLAGES 1 RCVR/VILLAGE	ONE ORIGINATING STATION DELHI	100%

This system has been proposed in several instances prior to this study a a service to a developing nation. A baseline system of a single TV channel to a receiver in each of 568,000 villages of India is set as the requirement for the present analysis. One beam can conveniently cover the entire area, however, 15 voice channels are provided to satisfy the requirements for language diversity throughout the area.

Concept D provides a satellite capability allowing use of very low cost ground receivers ($166 ea.) and a cost of $60/year/receiver for Total System cost.

MISSION NO. 5

U.S. BIOMEDICAL COMMUNICATIONS NETWORK

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
FULL U.S. ALASKA HAWAII U.S. PACIFIC TERR. VIRGIN IS., ETC. 3 CHANNELS/AREA (NOTE: MAY NEED AN ADDITIONAL CHANNEL FOR TALK-BACK FROM MULTIPLE STATIONS)	20 MEDICENTERS PER STATE & AREA 1,040 TOTAL	FIVE ORIGINATING GROUND STATIONS 1 PER TIME ZONE	2 CHANNELS 100% 1 CHANNEL ON DEMAND ASSUME 20%

A 3-channel system is suggested to support the immediate requirements of the U.S. Biomedical Communications Network. Two channels are used for regular full-time services and one is reserved for special programming. Full U.S. coverage including non-CONUS states and trust territories is required. Concept B provides minimum system cost.

MISSION NO. 6

U.S. ETV SYSTEM - DIRECT

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
FULL U.S. 4 TIME ZONES PLUS HAWAII & ALASKA 2 CHANNELS/AREA (12 TOTAL)	DIRECT-TO-HOME ASSUME 80% OF TOTAL U.S. RECEIVERS	ONE UPLINK IN EACH AREA ON ONE CHANNEL TIME-SHARED FOR LOCAL PROGRAMMING N.Y.C. ORIGIN FOR SECOND CHANNEL	6:00 A.M. TO 9:00 A.M. & 5:00 P.M. TO MIDNIGHT

This is similar to the ETV program distribution system except that the ETV stations are bypassed and the service is direct to the home. Approximately 50×10^6 homes can be reached.

Concepts D and F are preferred, with 2 or 1 satellites respectively providing the area coverage. Costs to the individual home per year are $10.00 to $15.00 -- quite reasonable when compared to an average of $60/year for CATV service.

MISSION NO. 7

U.S. NATIONAL ITV SYSTEM

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
FULL U.S. 4 TIME ZONES HAWAII ALASKA U.S. PACIFIC TERR. VIRGIN IS. 4 CHANNELS/AREA	PUBLIC ELEMENTARY & SECONDARY SCHOOLS (~300,000) ASSUME 80% COVERAGE (~240,000 RECEIVERS)	TWO ORIGINATING STATIONS IN EACH TIME ZONE PLUS ONE EACH IN HAWAII & ALASKA	3 CHANNELS 8:00 A.M. TO 4:00 P.M. 1 CHANNEL/AREA 100% FOR PROGRAM PRE-VIEWING

(DISTRIBUTION)

This system is defined to provide 4 channels of instructional TV to approximately 240,000 schools in the U.S. Three of the channels would be used during normal school hours. The fourth channel would be operational continuously for program pre-viewing, selection and taping. In the distribution mode the system operates at a high quality of TASO 0 (C.C.I.R. Relay quality):

Preferred systems, on the basis of least cost, are Concepts D and F. Both of these versions are multibeam systems and capable of accommodating large systems, weight and power.

MISSION NO. 8

NATIONAL ETV/ITV SYSTEM FOR MEXICO

COVERAGE	POTENTIAL AUDIENCE	UPLINK	DUTY CYCLE
MEXICO 800,000 SQ.MI. 2 BEAMS (EA. 400,000 SQ.MI.) 4 CHANNELS/BEAM	45.7×10^6 PEOPLE 60 PER SQ.MI. 20,000 SCHOOLS	ONE ORIGINATING STATION MEXICO CITY	2 CHANNELS 100% 2 CHANNELS 50% (6:00 A.M. TO 6:00 P.M.)

(ETV - DIRECT)

As defined, this system provides four channels of non-commercial TV to the Mexican population during early morning and evening hours. Two beams supply the geographic coverage.

The least cost systems are reflected by Concepts D and C. Concept A and E did not yield suitable solutions. Systems costs are on the order of $100M/year. User costs per year are $45 or $50, depending on concept.

MISSION NO. 9

U.S. NATIONAL ITV SYSTEM

(DIRECT)

This mission is similar in most respects to Mission No. 7. The main difference lies in service quality (TASO 1 for this mission versus TASO 0 for the former). Concepts B and F yield lower costs with systems cost running about $100 million per year and individual school costs about $500 per year.

MISSION NO. 10

MEXICO ITV SCHOOL SYSTEM

This mission is similar to Mission No. 8 except for the user. Here the user/audience is the Mexican school system consisting of approximately 200,000 schools. The system provides 4 channels of instructional TV to each of 2 areas during normal school hours.

5.2 SELECTED SYSTEMS

Results from the previous analysis are shown in Table 5-1 which also shows the technique used in ranking the systems. Three elements are included:

1. User Ranking. This was derived in Chapter 3, above.

2. Satellite System Data. This is taken directly from the outputs of the synthesis program.

3. Competitive Ground System Data. A detailed ground system model was not generated as part of this study. Data was used by direct reference where available — India ETV-Direct, Ground System cost of $141M was taken from the G.E. TV Broadcast Satellite (TVBS) Study, Contract NAS3-9708, Report NASA CR-72579. Data was derived for the U. S. by considering a simple distribution of cable and microwave systems to provide the required service.

Combination of this data, in the given formulation, results in very high rating for U.S. Armed Forces Radio and TV Services, U. S. Parochial Schools and the U.S. Biomedical Network. Medium ratings are achieved by U.S. ETV Distribution, India ETV-Direct and U.S. ITV-Direct. These missions reflect the choice of Concepts F, B, and D, in that order. Remaining system scores are low. Further details of the optimum systems are presented in Table 5-2. Between Tables 5-1 and 5-2 it can be seen that a wide range of satellites, from 2,400 lb. to 42,000 lb. are considered along with an appropriate range of costs. There is a corresponding range in prime electrical power from 1.0 KW to 100 KW. Four of the cases optimized at 2.5 GHz downlink frequency — primarily because of the existence of the atmospheric window at this frequency. Six cases optimized at 0.8 GHz because of the direct service offered to a very large receiver population (2×10^6 and 60×10^6). Pre-existing UHF TV receivers (unaugmented) predominate in these cases.

Reviewing all of the data in terms of the utilization of the different satellite concepts results in Table 5-3. From this table it can be seen that the top three concepts are B, F, and D, in that order. Re-analysis of the systems has changed some of the specific details but has not effected the choice of concepts.

Table 5-1. System Selection

User	Minimum Cost Concept	Satellite				Total System Cost ($M)	Competing Ground System Cost ($M)	Implementation Time (yr.)		User Ranking *	System Ranking **
		Unit Wt. (lb.)	Unit Vol. (cu. ft.)	Unit Life (yr.)	Total Cost ($M)			Sat	Gnd		
U.S. Armed Forces Radio & TV (9 x 2 Sats. Req'd)	B	3,140	332	5	152	909	Unfeasible	5	-	10	Very High
U.S. Parochial Schools (8 Sats. Req'd)	B	1,328	287	10	54	314.5	1,814	4	10	8	115
U.S. Biomedical Network (8 Sats. Req'd)	B	1,142	81	10	51.8	407	1,814	4	10	6	67
India ETV - Direct	B	3,041	229	10	36	153	141	3	10	7	21
U.S. ETV - Distribution	B	998	72	10	34	460	384	4	5	9	10
Mexican ETV - Direct	D	9,495	765	10	57	326	212	3	10	3	8
Mexican ITV - Direct	B	2,519	323	10	36.5	104	212	3	10	1	7
U.S. ITV - TASO Gr. O	F	42,000	4,230	5	280	2,246	1,814	5	10	4	6
U.S. ETV - Direct	F	30,616	4,251	5	175	8,473	1,814	5	10	5	2
U.S. ITV - Direct (8 Sats. Req'd)	B	1,619	157	5	90	130,602	1,814	4	10	2	1

*User need ranked on 1 to 10 scale, with 10 greatest need.

**System Rank = $\frac{\text{competing ground system cost}}{\text{satellite system cost}} \times \frac{\text{ground implementation time}}{\text{satellite implementation time}} \times \text{User Need}$

Table 5-2. Optimum Systems

User	Ground Downlink System					Ground Uplink System					Satellite System		
	No.	Freq. (GHz)	RCVR NF(°K)	Ant. Dia. (ft.)	Initial Cost ($)	No.	Freq. (GHz)	Xmtr. Type	Ant. Dia. (ft.)	Total Cost ($M)	Prime Power (KW)	Ant. Dia. (ft.)	Xmtr. Type
U.S. Armed Forces Radio & TV	2×10^6	0.8	706	3.4	108	2	12.0	TWT	43.8	36.5	10.2	29.7	CFA
U.S. Parochial Schools	14,000	0.8	116	4.90	1,120	2	12.0	TWT	36.4	13.26	1.5	57x29	CFA
U.S. Biomedical Network	1,040	2.5	271	15.0	633	52	2.25	TWT	31.6	132.8	1.74	9x18	TWT
U.S. ETV - Distribution	200	2.5	236	17	451,470	1	12.0	TWT	39.1	6.3	1.5	9x18	TWT
India ETV - Direct	568×10^6	0.8	1549	2.6	77	1	0.85	TWT	20.5	0.66	6.6	26.9	CFA
U.S. ITV - Direct	240×10^3	2.5	2252	4.8	136,000	10	12.0	TWT	33.0	12.7	4.9	9x18	TWT
U.S. ITV - TASO Gr. O	240,000	2.5	250	12.5	3,267	10	8.2	TWT	54.5	73.0	87.4	11.4	TWT
Mexican ITV - Direct	20×10^3	0.8	130	5.1	149,000	1	0.85	TWT	32.7	1.8	2.6	33.1	CFA
Mexican ETV - Direct	1×10^6	0.8	1306	2.8	100	1	0.85	TWT	37.4	1.8	22.7	33.1	CFA
U.S. ETV - Direct	60×10^6	0.8	2610	1.9	88	7	0.85	TWT	39.7	12.94	100	29x57	CFA

Table 5-3. Satellite Concept Comparison.

Concept	Number of Users*			Frequency Range (GHz)	Max. No. Beams	Weight Range (lb.)	Volume Range (cu. ft.)	Satellite Cost Range ($M)	Range of Cost/RCVR/Yr $	Orbital Refurb. Possible?	Rank	Reason For Ranking
	Midterm	Post-Mid.	Final									
A	0**	0**	0**							No	6	Too small
B	5	4	12	UHF to 12.7	1	1,100 to 4,200	≤262	6 to 36	385 to 191,000	No	2	Wide user range good single-purpose concept
C	2	2	0	2.5 to 12.7	1	4,000 to 5,000	<810	10 to 11	50 to 71	No	4	Volume limited, seldom optimum
D	6	2	4	UHF to 12.7	4	13,000 to 42,000	<6,000	28 to 106	12 to 743	Yes	3	Wide user range, good multi-purpose concept (high volume)
E	0***	1	0	UHF only	1	9,800	570	14.6	30	Yes	5	Antenna too large, volume too small
F	9	11	4	UHF to 12.7	6	12,000 to 42,000	<6,000	18 to 88	14 to 245,000	Yes	1	Satisfies wide user range

*Concept was first or second choice
**Size insufficient for all systems considered
***Applicable only at UHF, which is not optimum frequency

6

CONCLUSIONS AND RECOMMENDATIONS

A review of the Television Broadcast Satellite Study, in terms of the study goals shown in Table 6-1, shows these have been met and, for the most part, exceeded.

Table 6-1. TVBS Study Goals

- Ascertain real TVBS user requirements.
- Develop systhesis computer program
  - Minimum total costs
  - System sensitivities
- Develop Saturn V class TVBS configurations.
- Determine critical technologies.
- Select "best" user/system application.
- Refine selected system(s).

6.1 CONCLUSIONS

User Requirements

A wide range of potential users was contacted. From these contacts the following general conclusions have been derived:

- Ground facility coverage is not adequate for users in western areas, Alaska and U.S. Pacific territories.
- Special interest groups, even in urban areas, are not adequately covered: AMA, institutional interconnections, parochial schools and others.
- Interaction/2-way/talk-back, are prime objectives for most telecommunications systems.
- International users are primarily in the classification of "underdeveloped" nations.
- Consensus is that satellites have an important role to play in future telecommunications systems, particularly for education & low coverage areas.

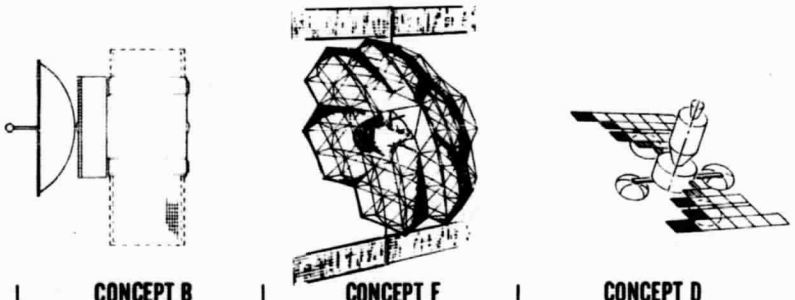
Synthesis Program

A most comprehensive synthesis program has been developed. It addresses the entire system — uplink systems, propagation characteristics, satellite and downlink systems (either Direct or Redistribution facilities) and derives a minimum total cost solution by performing the system and subsystem tradeoffs.

This same technique can be applied to any type of satellite payload if sufficient information can be derived to define the payload parametrically.

Saturn V Configurations

A series of 6 basic satellite configurations was derived to be compatible not only with the Saturn V in single and multiple payloads, but also with smaller launch vehicles as single payloads. Variations were introduced on two of these to provide a working group of 8 concepts. These were exercised through the synthesis program for each set of user requirements. The conclusion is that the 3 concepts shown in Figure 6-1 form the best foundation for continued analysis and definition.



	CONCEPT B	CONCEPT F	CONCEPT D
SIZE	TO 5,000 LB. 262 CU. FT.	42,000 LB. 6,000 CU. FT.	42,000 LB. 6,000 CU. FT.
BEAMS	1 OR 2 MAX.	6 TO 12 MAX.	4 TO 8 MAX.
POWER	5 KW MAX.	ABOUT 50 KW MAX.	ABOUT 100 KW MAX.
FREQUENCY	2.5 TO 12.7 GHz	800 MHz TO 12.7 GHz	2.5 GHz TO 12.7 GHz
MANNED	NO	YES	YES

Figure 6-1. Selected Concepts

Critical Technologies

Candidate missions and associated key satellite parameters are summarized in Table 6-2. The areas in which technology developments are required are also noted.

1. General. Some of the systems require wideband transmissions to accommodate multiple TV channels. The availability of spectrum space at the optimum frequencies is dubious. These systems may be forced to higher frequencies — e.g., 11.7 - 12.7 GHz or above.

Table 6-2. Mission Groups and Key Satellite Parameters.

Mission/User System	Satellite Parameters						Areas for Technology Development
	No. Beams	No. Channels	Prime Power (KW)	RF Power* (W)	Frequency Band (GHz)	Antenna Size (Ft.)	
	(1)	(2)	(3)	(4)	(5)	(6)	
1. U.S. Armed Forces Radio and Television	2	5	10	542	0.8	29.7	1,3,4,6
2. U.S. Parochial Schools	2	2	1.5	31	0.8	29 x 57	1,6
3. U.S. Biomedical Network	1	3	2	35	2.5	9 x 18	6
4. India ETV - Direct	1	1	7	1,512	0.8	27	3,4,6
5. U.S. ETV - Distribution	4	8	1.5	22	2.5	9 x 18	1,6
6. Mexican ETV - Direct	2	4-8	23	840	0.8	33.1	1,3,4,6
7. Mexican ITV - Direct	2	4-8	3	36	0.8	33.1	1,6
8. U.S. ITV - Distribution	8	4-24	87	1,380	2.5	11.4	1,3,4
9. U.S. ETV - Direct	6	2-12	100	2,490	0.8	29 x 57	1,3,4,6
10. U.S. ITV - Direct	8	4-32	5	256	2.5	9 x 18	1,6

*RF Power per TV Channel

Not specifically shown in Table 6-2, but of concern is the effect of the long life requirement of most systems on the attitude control and stationkeeping system. Ion propulsion is the most cost-effective system for these purposes at lifetimes greater than 5 years. This is particularly true when considering high-powered systems requiring tri-axial stabilization. Considerable effort beyond that so far expended on the SERT systems needs to be put into the development of a family of thrusters with an appropriate range of impulse.

2. Multiple Beams. Eight of the missions require multiple beams for providing coverage to specified geographic areas (e.g., 4 time zones in U.S.). The multiple beams can be implemented by means of multiple antennas, multiple feeds per antenna or phased arrays. Of these, only the multiple antenna approach has been considered for operation in space (Intelsat IV). Proposed phased array are for narrow-band systems. Their operation in wideband systems is questionable in terms of phasing characteristics and frequency response over the total bandwidth.

3. Prime Power. While solar array systems have been proposed for power levels up to 50 KW none have flown at power levels in excess of 5 KW. As noted in Table 6-2 seven of the systems require more than 5 KW and two of them require up to 100 KW. If solar arrays continue to be the workhorse for the earth orbiting missions advanced array, along with their system accessories (transfer mechanisms, control units, conditioning, etc.), must be developed. Alternatively, development must be initiated on appropriate SNAP isotope or reactor systems to provide this power.

4. RF Power Components. Considerable work has been undertaken by NASA in the development of "multi-kilowatt transmitters" at UHF. This needs to be extended to the higher frequency ranges to be compatible with future mission requirements.

5. Antenna Size. Development of erectable antennas has been underway for several years. The LMSC antenna, previously flown at approximately 20 ft. diameter on a USAF mission, has been selected for the ATS-F (30-ft. diameter). Present indications are that the diameter requirement has been reduced to be compatible with the previous flight unit. This requires further development to be undertaken to meet the large (and shaped) sizes shown in Table 6-2.

6. Ground Terminals. Most of the systems identified so far in the study have a large population of potential users. Furthermore, in most of these systems, more than 50% of the total system cost is attributable to the procurement, operation and maintenance of the ground terminals — uplink as well as downlink. This is an area that could benefit greatly by the development of low-cost, high-reliability and easily-operated ground terminals. A significant start has been made by NASA for low-cost direct receiving systems. Other options should be reviewed and accommodated.

6.2 RECOMMENDATIONS

1. Continue the planning and system development activities to establish a position of technological readiness for the implementation of the selected and similar missions.

2. Undertake detailed study of the selected missions:

   a. Armed Forces Radio and Television Services

   b. Combined Educational and Instructional TV Services for the U. S.

   c. Television Services for Alaska and the Western States

3. In recognition of the present plan to terminate production of the Saturn V launch vehicle, it is recommended that the alternative Space Shuttle/Orbit-Orbit Shuttle combination be investigated as the primary booster and final orbiter. This offers the further potential advantage of performing manned aspects of the missions at lower altitudes before final placement in the geostationary orbit.