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# THE ITALSAT EXPERIMENT

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## FOREWORD

This note gives some succint information on the ITALSAT millimetric waves propagation experiment, to be conducted with the ITALSAT satellite, whose launch is foreseen in the middle of 1990.

The main purpose of the ITALSAT project is the one of experimenting advanced technologies and techniques employing the 20/30 GHz bands in wideband telecommunications.

Among the most qualified features of this system there certainly are the multispot antenna (covering the Italian territory by six beams with full connectivity among them in the preoperational version) and the exchange function performed directly on board.

The preoperational version will also carry an advanced propagation payload allowing measurement in the 40 and 50 GHz bands. These beacons, in addition to the telemetry one at 20 GHz, are the ones which constitute the subject of the present note.

The satellite is owned by the Italian Research Council (CNR) and the management, originally committed to the Piano Spaziale Nazionale, has been passed today to a new body recently created, the Italian Space Agency (ASI), to which requests for further information can be addressed.

ITALSAT is being entirely developed and realized by SELENIA SPAZIO.

The scientific responsibility of the propagation experiment, lays, on behalf of ASI, under the author of the present note, who is also member of the Centro di Studio per le Telecomunicazioni Spaziali (a body of the CNR situated by the Politecnico di Milano), in which operates as a researcher.

## THE PROPAGATION EXPERIMENT

ITALSAT will allow propagation experiments in the 20-40 and 50 GHz frequency bands.

Remarkable characteristics of the satellite transmitter are the following:

-European antenna coverage

-long duration (5 years)

-high EIRP

-coherence among all the transmitted signals

-dual polarisation transmission at 50 GHz (commutation at 1KHz)

-angular modulation of the 40 GHz beacon (sidelines at +500Mhz from the central line)

Exploiting all the possibilities offered by the satellite it will be possible to achieve a very accurate and complete characterization of the radio channel practically up to the higher limit of the present frequency allocation recently established by the WARC.

Indeed, in addition to attenuation and depolarisation, measurable at all frequencies (only in North Europe the 20 GHz beacon is not available), the following activities will be possible:

-complete identification of the depolarising channel at 50 GHz (similarly to OLYMPUS at 20 GHz), which allows characterization in any polarisation;

-identification of the frequency response (amplitude and phase distortion) around 40 GHz by comparing the amplitude and phase of the sidelines;

-identification of the phase characteristic of the transfer channel across the entire band, by comparing the phase shifts of all the received signals (20,40 and 50 GHz);

-assessment of the dynamic characteristics of the received signal, including rapid variations (scintillations), owing to the high EIRP and phase stability of the on board source;

-assessment of the frequency scaling techniques, both long and short term, up to high attenuation levels;

-assessment of the incoherent scattering by water particles, even if only in particular meteorological conditions.

Naturally the value of the direct measurements can be strongly enhanced by associating to the beacon receivers some ancillary instruments such as one or more radiometers, rain-gauges, meteorological radars and other meteorological instruments. As well known, this allows determining the relation existing between directly measured and estimated attenuation and calibrating these "indirect" estimators for extensive measurements taken elsewhere. In addition the radiometer can "calibrate" the beacon itself by providing the correct zero reference.

By coordinating the measurements taken by various experimenters through Europe other fundamental achievments can be pursued. Among them it is worth reminding the climatological characterization of the European area and the large scale correlation of fading, recently recognized as a necessary input for the design of advanced satellite systems based on the "on-board resource sharing" philosophy.

As the past experience with SIRIO, OTS and COST 205 has shown, the significance of propagation experiments is dramatically increased if a good coordination level among the participants can be reached.

Moreover it is now evident that the coordination problems are enormously reduced if things are prepared well in advance.

Bringing ahead these previous experiences the OPEX (Olympus Propagation Experiment) group has been set up some years ago and has now reached an excellent level of coordination: procedures are being agreed and written within a common frame aiming at arriving to the complete interchangeability of all the data among experimenters and, more importantly, to the habit of putting and facing problems in a collective manner.

Of course we hope that this experience will be continued with ITALSAT, where, due to the new and perhaps more critical aspects being investigated, the coordination becomes a still more necessary prerequisite.

The long term scientific objectives that can be pursued with ITALSAT are very stimulating and perhaps hard foreseeing in their globality.

In the past, when the bands to be investigated were below 20 GHz, it was clear that attenuation by rain, specially convective rain, was the major problem to be tackled. The scientific comunity went far beyond this subject however! In fact the extraordinary collective effort of investigation throughout the world lead to significant achievments also in neighboring fields as meteorology, remote sensing and basic EM theory.

The attenuation measurements in itself were taken in a different way, enlarged and additioned with other measurements just as the requirements of the telecommunication engineering were pointed out. Along this line we have arrived to the threshold of the millimetric waves (30 GHz) which are going to be investigated with the forthcoming satellite OLYMPUS. At millimetric waves the new scenario for the propagation activity, to be performed with ITALSAT, will surely lead us to tackle different problems, most of them hard to be foreseen from the present standpoint.

The well established availability and quality objectives in the probability range 0.01-0.1 percent of time will probably lead to absolutely unfeasible system margins so that scaling rain attenuation up to the corresponding levels will probably constitute little more than a theoretical exercise.

On the other hand increasing the probability other phenomena become important, if not dominant in some cases (stratified rain, brightband, scintillation by irregularities of the refractive index, absorption by water vapour in gaseous or saturated form, depolarisation by ice needles,etc.).

For instance attenuation by clouds at 50 GHz is expected to be of the order of 1.5 dB in average, possibly much higher in extreme cases. Similarly scintillations of a 2-3 dB peak to peak should not be uncommon even for high elevation links.

From what precedes it seems that predictions will no more entirely based on rain gauge data but possibly on different meteorological data according to prediction rules still to be devised and tested.

In addition to these activities, somehow 'traditional' with respect to the technical objectives, one can consider the possibility of investigating on different and non-traditional areas (but perhaps important for the future systems as well) pertaining to the electromagnetic propagation basics: incoherent radiation, ray bending and multipath, which are probably of greater importance at 40/50 GHz and surely better observable with antenna systems of limited size.

## EXPERIMENT DEFINITION

The ITALSAT propagation meaurements are performed on down links at the three frequencies 20,40 and 50 GHz.

The payload characteristics are given in the additional material annexed, which gives the footprint of the onboard antennas, the EIRP values (with the associated fluctuations) and other various figures pertaining to the transmitter. It is important to remind that the three beacons are coherent to each other so that the receiver locking can be virtually based on the signal arriving at earth with greater strength at a particular instant.

The following paramaters can be directly measured:

1) CPA level at 20 GHz in vertical polarisation

2) CPA level at 40 GHz in circular polarisation

3) CPA level at 50 GHz in vertical and horizontal polarisations

4) XPD level and phase at 20 GHz

5) XPD level and phase at 40 GHz

5) XPD level and phase at 50 GHz

6) differential level and phase between the two polarisations at 50 GHz (fast commutated at 1 Khz rate)

7) differential phase shift between the sidelines and the carrier at 40 GHz (phase distortion)

8) differential amplitude between the sidelines at 40 GHz

9) differential phase between any pair of lines at 20,40 and 50 GHz

10) cross polar levels and phases of the sidelines at 40 GHz

Unfortunately the 20 GHz beacon is not visible from all sites in Europe as power budget constraints, due to the use as telemetry beacon, put an inferior limit to the antenna gain.

Reception of this frequency concurrently with the others is however extremely important both for the assessment of the frequency scaling technique down to the previously explored frequencies and for the possibility of simultaneous measurements with OLYMPUS (orbital diversity assessment).

In any case the coordination of the ITALSAT measurements with the OLYMPUS ones will offer the unique possibility of testing the effectiveness of the large scale diversity techniques at different frequencies, in addition to the more obvious, but all the same important, possibility of extending the number of points where measurements are taken, with benefit for climatology and modelling purposes.

In Italy three large stations are foreseen; one in Spino d'Adda, near Milan, menaged by the Centro di Studio per le Telecomunicazioni Spaziali of the Consiglio Nazionale delle Ricerche (CSTS/CNR), a second in the Rome managed by the Istituto Superiore delle Poste e Telecomunicazioni and Fondazione Ugo Bordoni (ISPT/FUB) and a third one in Turin, managed by the Centro Studi e Laboratori Telecomunicazioni (CSELT).

The link budget of the receiving stations, which will receive the three signals using a common phase locked source, is shown table 1.

With the margins reported, a worst case operativity of some 0.05% (in Italy) is foreseen (locking at 50 GHz); obviously this is expected to increase noticeably by exploiting the possibility to lock the lower frequency beacons. The table is all the same useful as reference for stand alone receivers.

TABLE 1

ITALSAT PROPAGATION EXPERIMENT LINK BUDGET

| | | | |
|---|---|---|---|
| Frequencies(GHz) | 20 | 40 | 50 |
| EIRP(dBW-mod. carriers) | 23.7 | 24.8 | 26.8 |
| Free space attn. (dB) | 209.6 | 215.6 | 217 5 |
| Antenna diameter(m) | 3.5 | 3.5 | 3.5 |
| Antenna gain (DB) | 55.1 | 60.6 | 62.3 |
| Receiver noise factor(dB) | 4 | 5 | 6 |
| Overall noise temp.(°K) | 728 | 917 | 1154 |
| G/T (dB) | 26.5 | 30.9 | 31.6 |
| C/N per Hertz (DB) | 69.3 | 68.7 | 69.5 |
| PLL bandwidth (dBHz) | 20 | 20 | 20 |
| C/N in 100 Hz (DB) | 49.3 | 48.7 | 49.5 |
| C/N limit (DB) | 7 | 7 | 7 |
| Dynamic range(dB) | 42.3 | 41.7 | 42.5 |

Additional information concerning the

ITALSAT PROPAGATION EXPERIMENT

## MAIN SATELLITE CHARACTERISTICS (prop. exp.)

EUROPEAN ANTENNA COVERAGE

LONG DURATION

HIGH EIRP

COHERENCE AMONG ALL THE TRANSMITTED SIGNALS

DUAL POLARISATION TRANSMISSION AT 50 GHz

ANGLE MODULATION OF THE 40 GHz BEACON

ITALIAN STATIONS FOR THE ITALSAT PROPAGATION EXPERIMENT:

| | | |
|---|---|---|
| SPINO D'ADDA | by | CNR/CSTS |
| ROMA | by | ISPT/FUB |
| TORINO | by | CSELT |

EXPERIMENTAL ACTIVITIES ALLOWED BY ITALSAT

PREDICTION OF PROPAGATION PARAMETERS FOR FUTURE SYSTEMS DESIGN (CPA, XPD, PHASE SHIFTS ETC.)

IDENTIFICATION OF THE EM CHANNEL PROPERTIES

ASSESSMENT OF METHODOLOGIES FOR INDIRECTLY ASSESSING PROPAGATION PARAMETERS (RADIOMETERS, RADARS)

CHARACTERIZATION OF WIDE AREAS WITH RESPECT TO THE STATISTICS OF VARIOUS PARAMETERS

DEVISING/ASSESSING OF PREDICTION METHODS FOR SINGLE AND MULTIPLE STATISTICS IN LITTLE KNOWN PROBABILITY RANGES

IDENTIFICATION OF THE DOMINATING MECHANISMS AFFECTING PROPAGATION AT MILLIMETER WAVES

ATMOSPHERE SOUNDING

SYSTEM-ORIENTED INVESTIGATIONS (small/large scale diversity, common on board resource systems up-path power control systems

PHYSICAL AND STATISTICAL MODELS

# RADIO MEASUREMENTS ALLOWED BY ITALSAT

ATTENUATION AT 20, 40 AND 50 GHZ

DEPOLARISATION AT 20, 40 AND 50 GHz

COMPLETE IDENTIFICATION OF THE DEPOLARIZING CHANNEL AT 50 GHz

IDENTIFICATION OF THE FREQUENCY RESPONSE (channel amplitude and phase distortion) AT 40 GHz

IDENTIFICATION OF THE PHASE CHARACTERISTIC OF THE TRANSFER CHANNEL ACROSS THE ENTIRE BAND

ASSESSMENT OF THE DYNAMIC CHARACTERISTICS OF THE RECEIVED SIGNALS (scintillations, fade duration and slopes etc.)

ASSESSMENT OF THE FREQUENCY SCALING TECHNIQUE

ASSESSMENT OF THE INCOHERENT SCATTERING BY WATER PARTICLES (even only in particular meteo. conditions)

## ELECTRICAL PARAMETERS MEASURABLE AT THE ITALSAT RECEIVER

CPA LEVEL AT 20 GHz IN VERTICAL POLARISATION

CPA LEVEL AT 40 GHz IN CIRCULAR POLARISATION

CPA LEVEL AT 50 GHz IN VERTICAL AND HORIZONTAL POL.

XPD LEVEL AND PHASE AT 20 GHz

XPD LEVEL AND PHASE AT 40 GHz

XPD LEVEL AND PHASE AT 50 GHz (both hor. and vert, pol)

DIFFERENTIAL LEVEL AND PHASE BETWEEN THE TWO POLARISATIONS AT 50 GHz (fast commutated at 1KHz)

DIFFERENTIAL PHASE SHIFT BETWEEN THE SIDELINES AND THE CARRIER AT 40 GHz (phase distortion)

DIFFERENTIAL AMPLITUDE BETWEEN THE SIDELINES AT 40 GHz)

DIFFERENTIAL PHASE BETWEEN ANY PAIR OF LINES AT 20,40 AND 50GHz

CROSS POLAR LEVELS AND PHASES OF THE SIDELINES AT 40 GHz

UNUSUAL MEASUREMENT OF PROBABLE INTEREST AT MILLIMETRIC WAVES

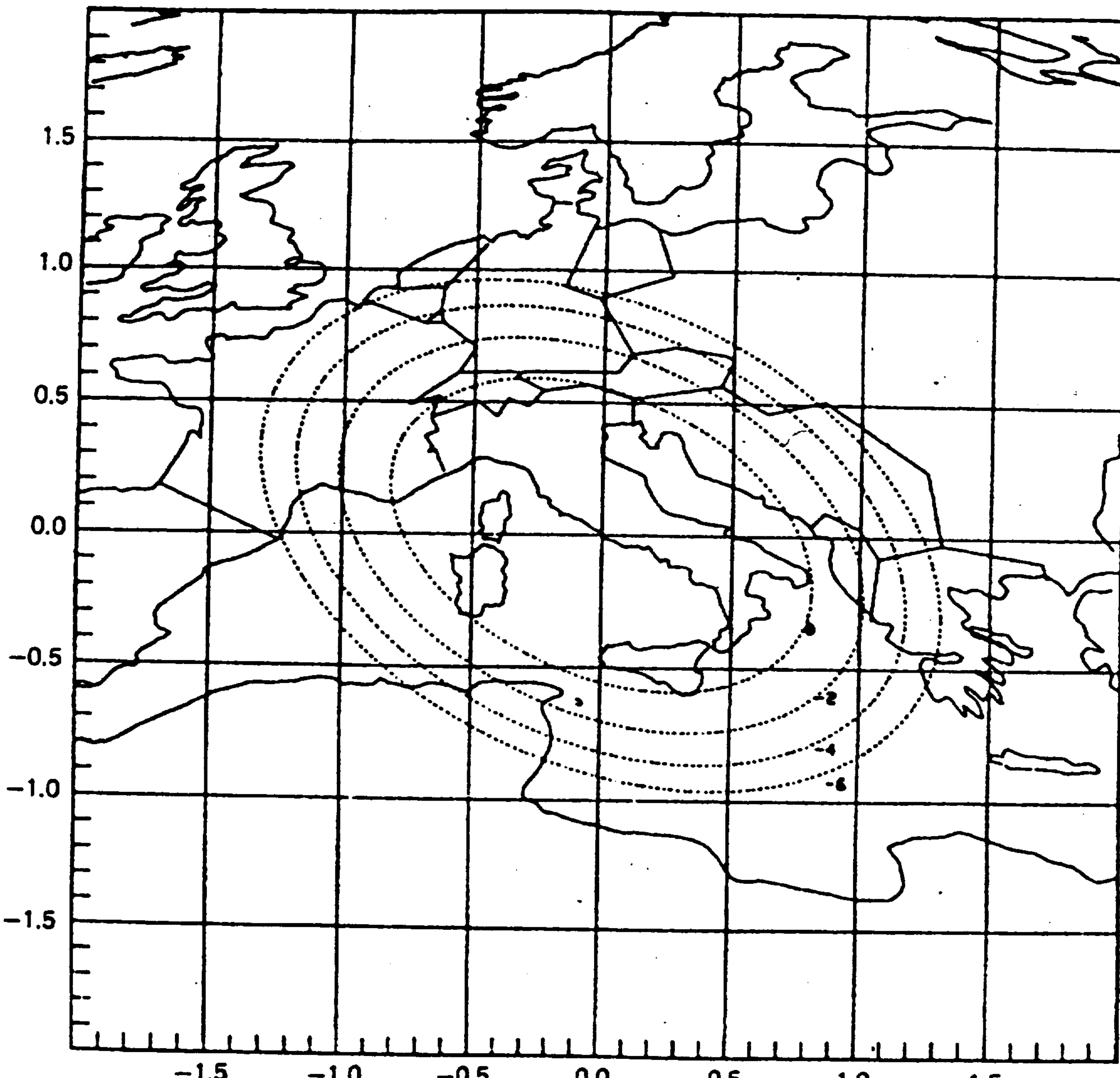
INCOHERENT RADIATION

RAY BENDING

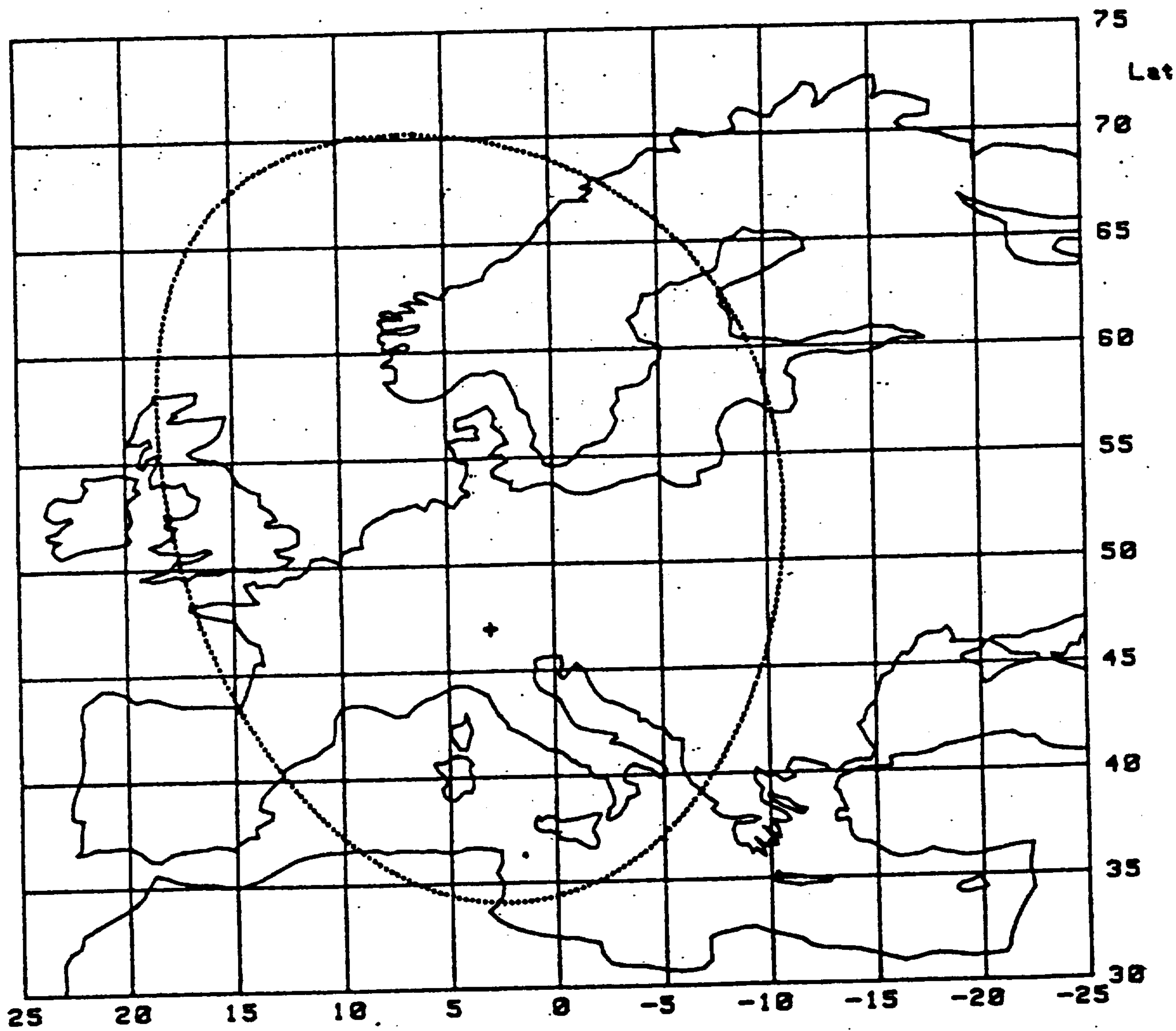
MULTIPATH (?)

ITALSAT PROPAGATION EXPERIMENT
LINK BUDGET (italian stations)

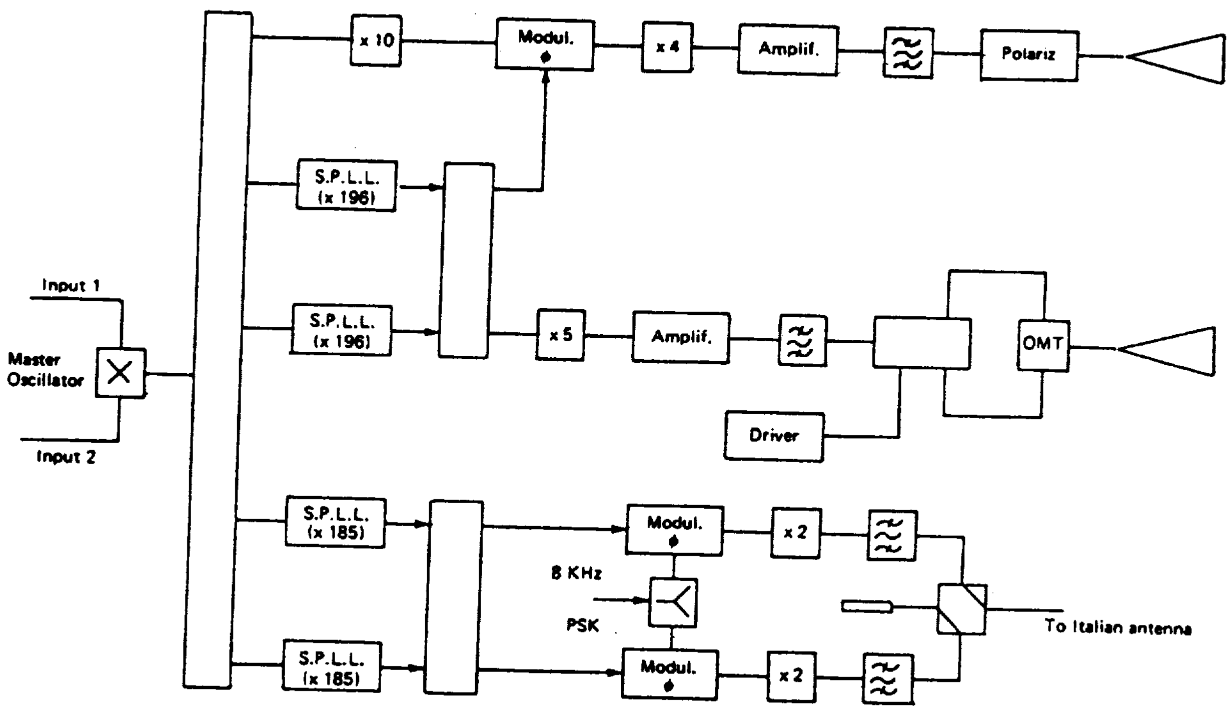
| | | | |
|---|---|---|---|
| frequencies | 20 | 40 | 50 |
| EIRP | 23.7 | 24.8 | 26.8 |
| fr.sp. attn. | 209.6 | 215.6 | 217.5 |
| antenna diam. | 3.5 | 3.5 | 3.5 |
| antenna gain | 55.1 | 60.6 | 62.3 |
| noise fact. | 4 | 5 | 6 |
| temperature | 728 | 917 | 1154 |
| G/T | 26.5 | 30.9 | 31.6 |
| C/N per Hz | 69.3 | 68.7 | 69.5 |
| PLL bandw.dB | 20 | 20 | 20 |
| C/N in 100 Hz | 49.3 | 48.7 | 49.5 |
| C/N limit | 7 | 7 | 7 |
| dynamic range | 42.3 | 41.7 | 42.5 |




20 GHz beacon coverage




40/50 GHz beacon coverage




Synthesis of the ITALSAT beacon frequencies

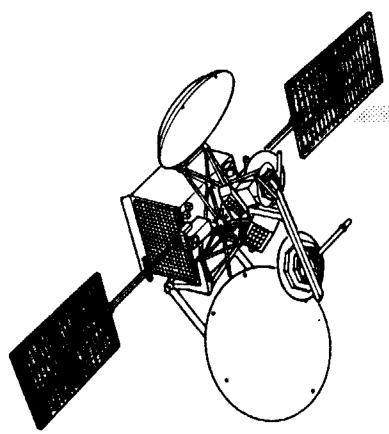
Session 3

# ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE

Chairman:

Dr. Faramaz Davarian
Jet Propulsion Laboratory

# ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS) PROGRAM



Presentation to:

NAPEX

Dean A. Olmstead

NASA Headquaters

June 30, 1989

ACTS

NASA

# ACTS

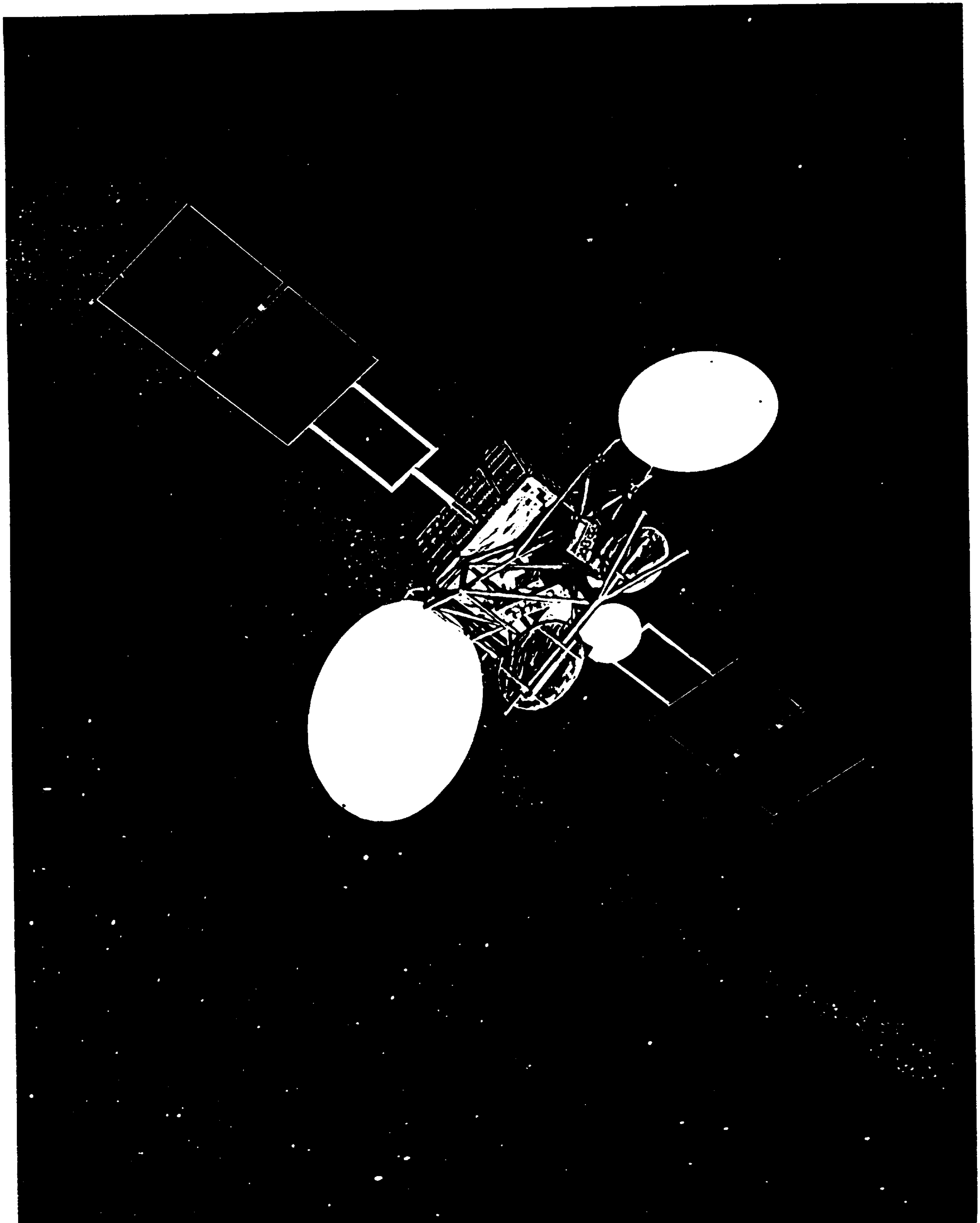
# PROGRAM OVERVIEW

# WHAT IS ACTS?

- ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)
- AN EXPERIMENTAL SATELLITE SPONSORED BY NASA TO PAVE THE WAY FOR NEXT GENERATION COMMUNICATION SATELLITE
- INCORPORATE ADVANCED CONCEPTS
  - ELECTRONICALLY HOPPING SPOT-BEAM ANTENNAS
  - ONBOARD PROCESSING AND SWITCHING
  - KA-BAND TRANSMISSION
- REDUCE RISK SUFFICIENTLY TO STIMULATE COMMERCIAL USE OF TECHNOLOGIES
- TARGET LAUNCH DATE: MAY. 1992
- MISSION LIFE: 2-4 YEARS

# OBJECTIVES OF ACTS PROGRAM

- Maintain U.S. Position of Preeminence in the World's Communications Satellite Market in the Face of Strong Foreign Competition
  - — Balance of Trade
- Develop Advanced High Risk Technologies Which Fall Outside Sponsorship Capability of the Private Sector
- Encourage Widest Possible Participation by all U.S. Institutions in the Program (Private, Government, DOD, Academia)
- Improve Productivity of Future NASA Missions Through Technology Advances in Communications



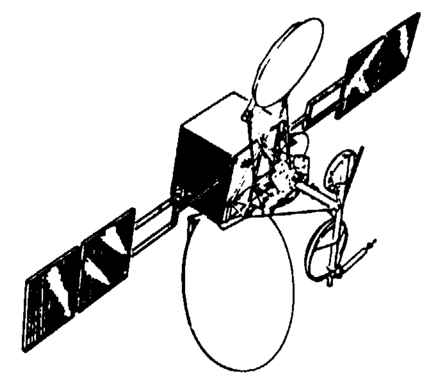
NASA

ACTS ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE

## NASA HEADQUARTERS

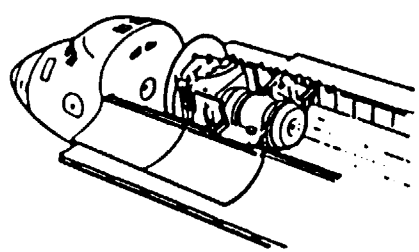
- OFFICE OF SPACE SCIENCE AND APPLICATIONS
  Dr. L.A. Fisk
- DIRECTOR OF COMMUNICATIONS & INFORMATION SYSTEMS DIVISION
  Ray J. Arnold

ACTS PROGRAM MANAGER
Dean A. Olmstead
DEPUTY PROGRAM MANAGER
William T. Kondik
PROGRAM EXPERIMENTS MANAGER
William T. Kondik (Acting)



## NASA LEWIS RESEARCH CENTER

- SPACE FLIGHT SYSTEMS DIRECTORATE
  Vernon J. Weyers

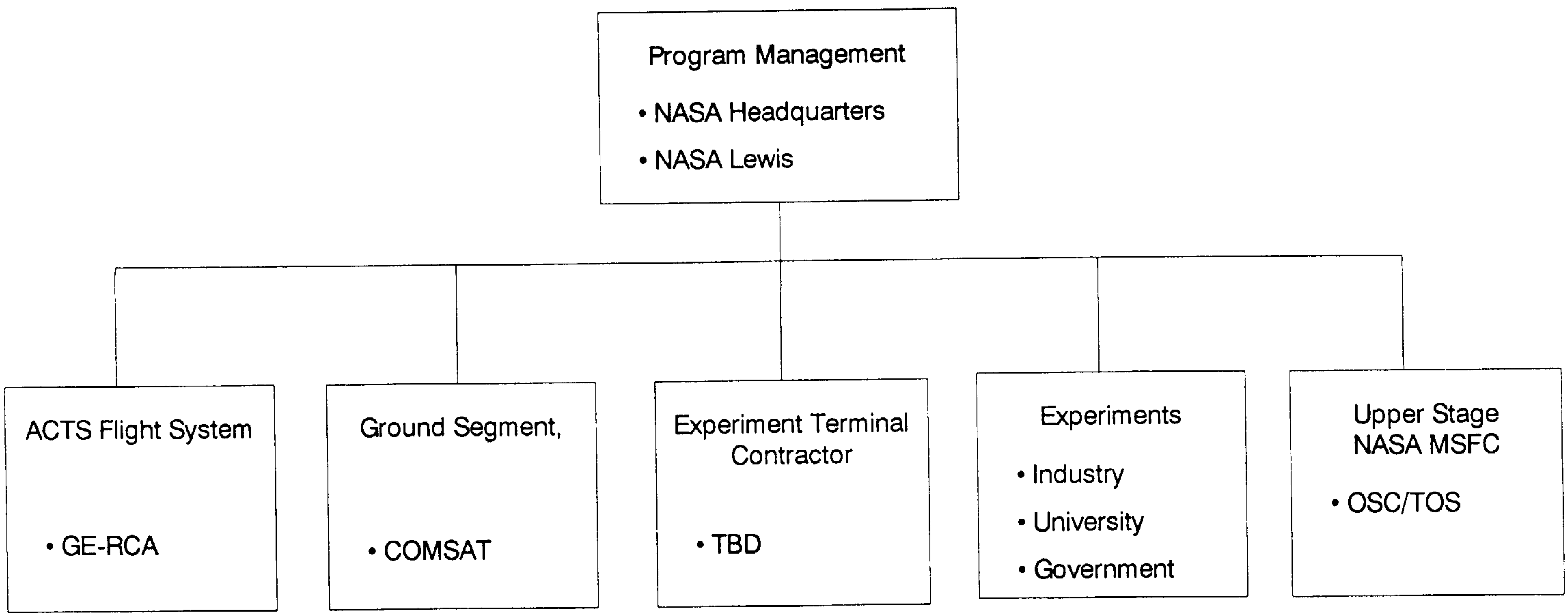


ACTS PROJECT OFFICE

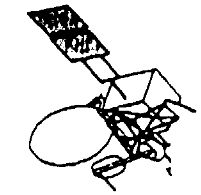
PROJECT MANAGER
Dr. Richard T. Gedney
PROJECT EXPERIMENTS MANAGER
Ronald J. Schertler

EC89-305(1)
1-26-89

# ACTS Team

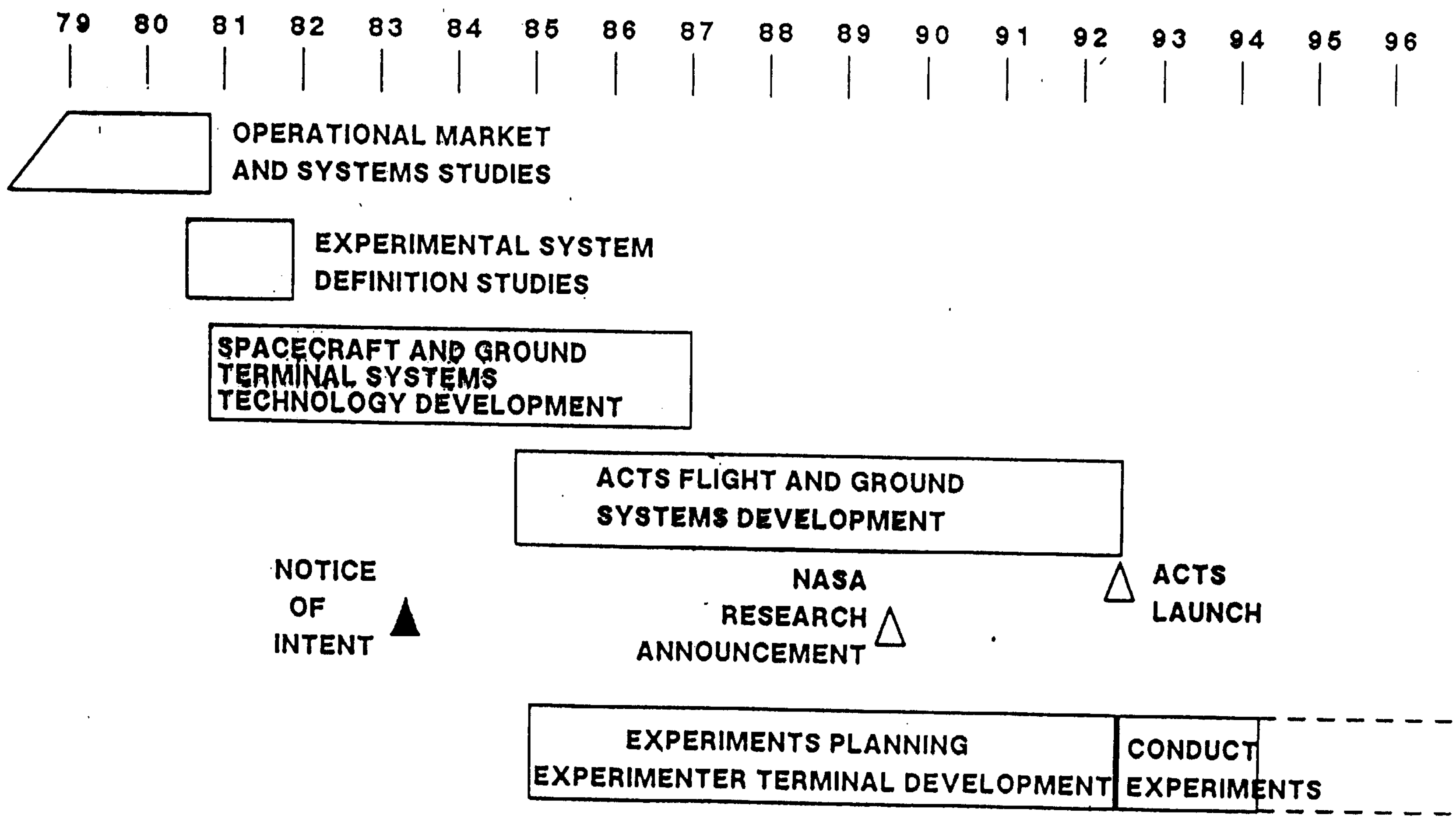

Program Management
• NASA Headquarters
• NASA Lewis
ACTS Flight System
• GE-RCA
Ground Segment,
• COMSAT
Experiment Terminal Contractor
• TBD
Experiments
• Industry
• University
• Government
Upper Stage NASA MSFC
• OSC/TOS

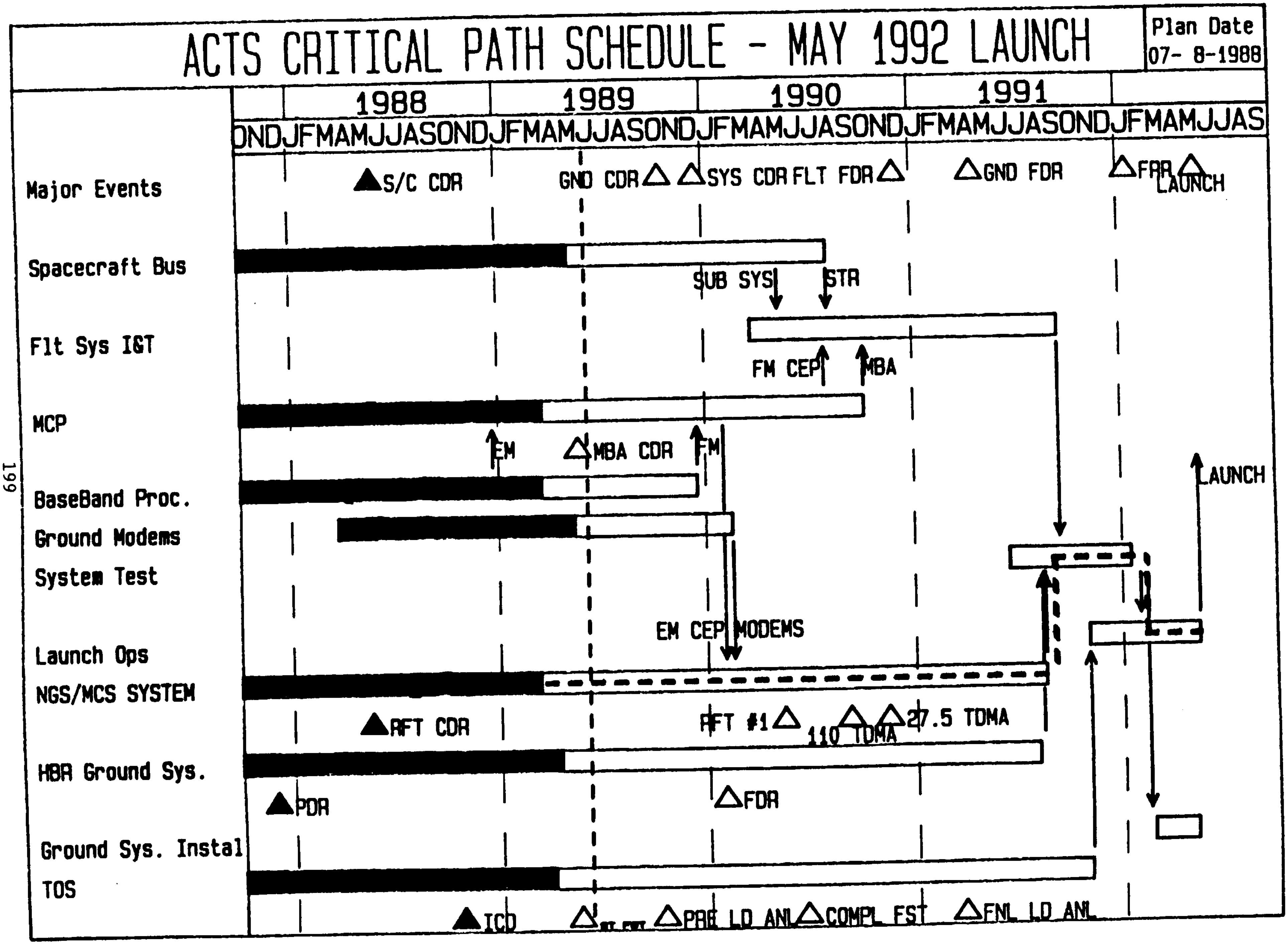
## NASA ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)



### MAJOR PROGRAM ELEMENTS

CY'S




ACTS CRITICAL PATH SCHEDULE - MAY 1992 LAUNCH
Plan Date
07- 8-1988
1988
1989
1990
1991
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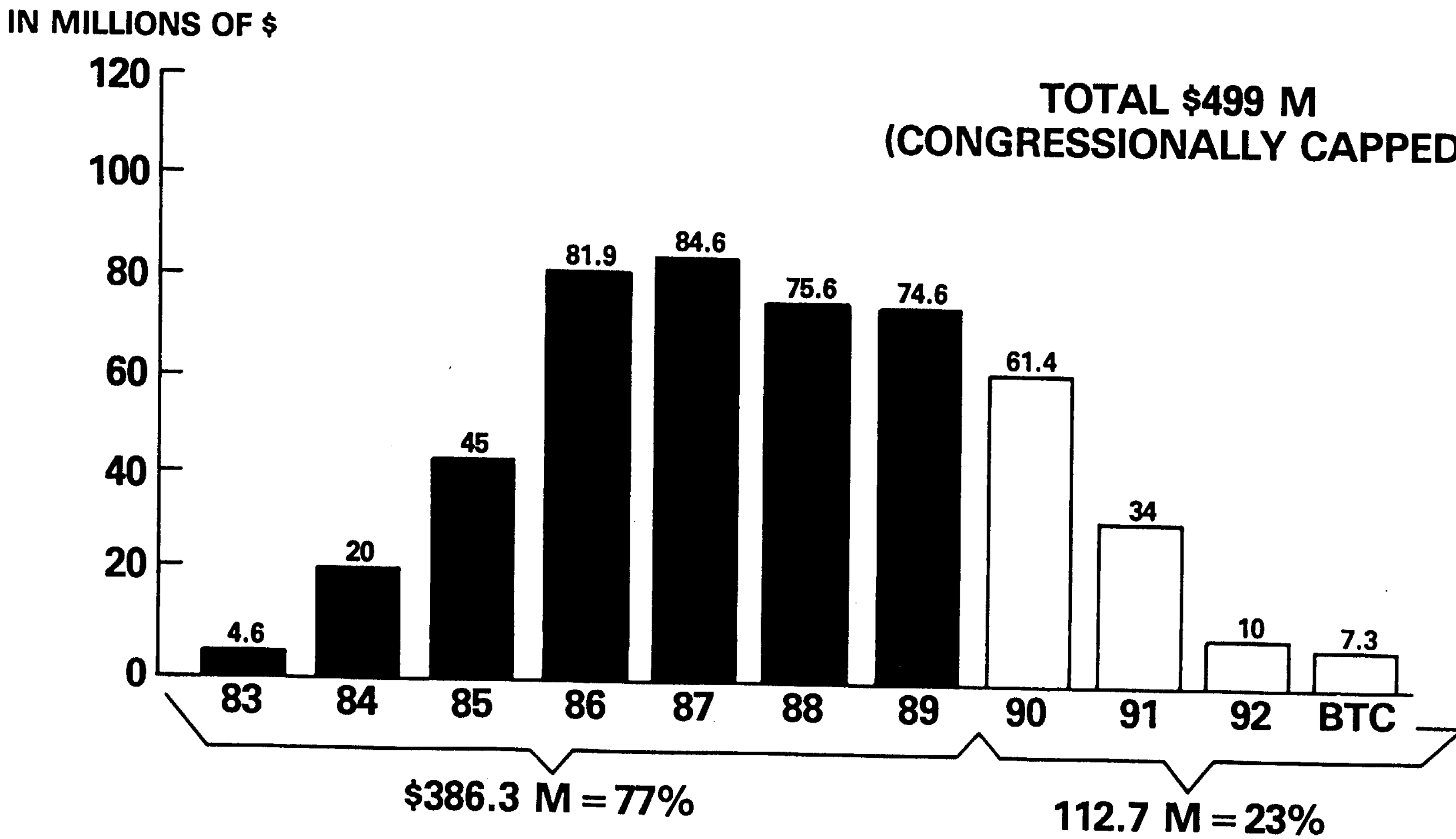
Major Events
Spacecraft Bus
Flt Sys I&T
MCP
BaseBand Proc.
Ground Modems
System Test
Launch Ops
NGS/MCS SYSTEM
HBR Ground Sys.
Ground Sys. Instal
TOS
S/C CDR
GND CDR
SYS CDR
FLT FDR
GND FDR
FRR
LAUNCH
SUB SYS
STR
FM CEP
MBA
EM
MBA CDR
FM
EM CEP
MODEMS
RFT CDR
RFT #1
110 TDMA
27.5 TDMA
PDR
FDR
ICD
PRE LD ANL
COMPL FST
FNL LD ANL

# ACTS PROGRAM NEARLY 3/4 COMPLETED

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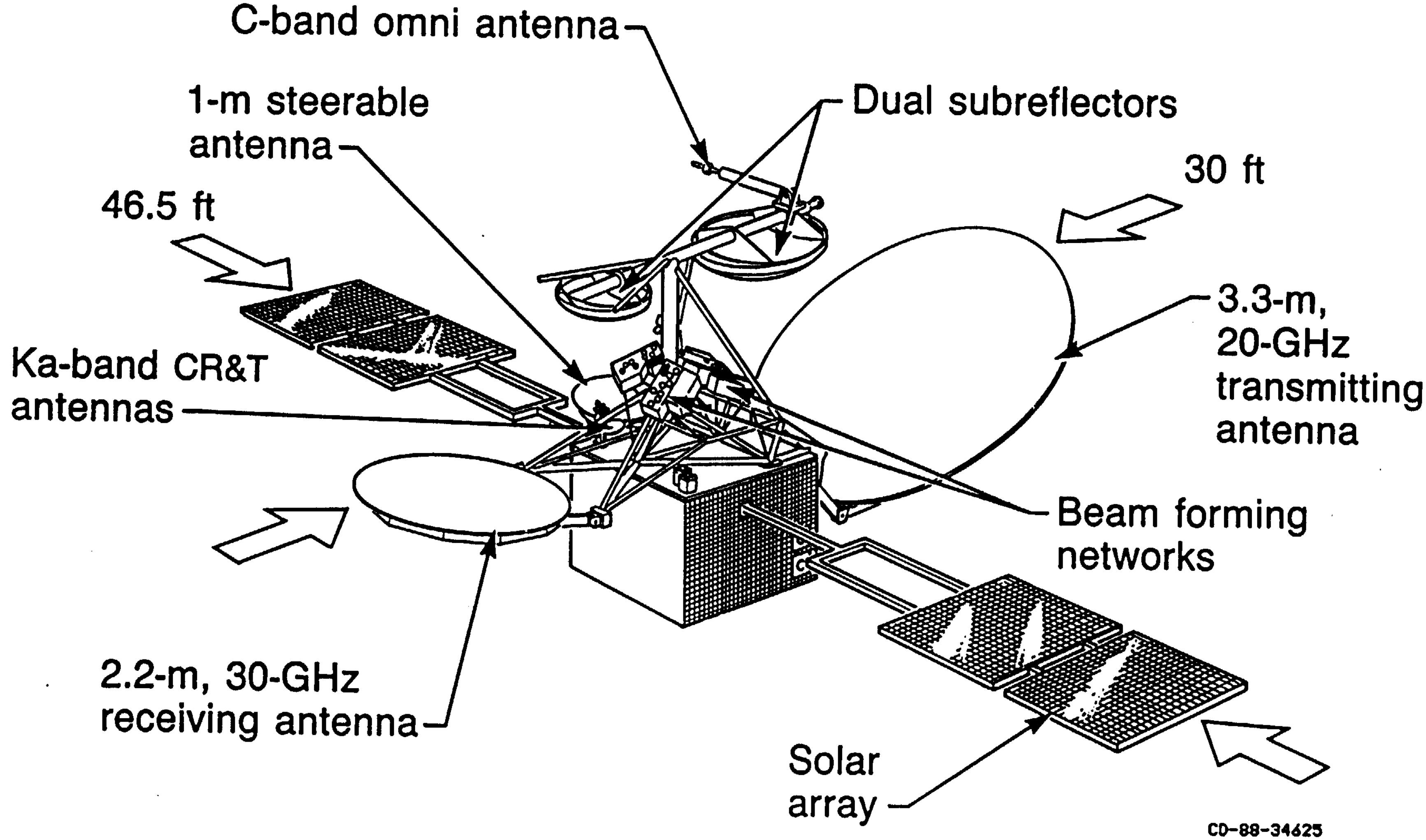
1-26-89

# ACTS

# SYSTEM DESCRIPTION

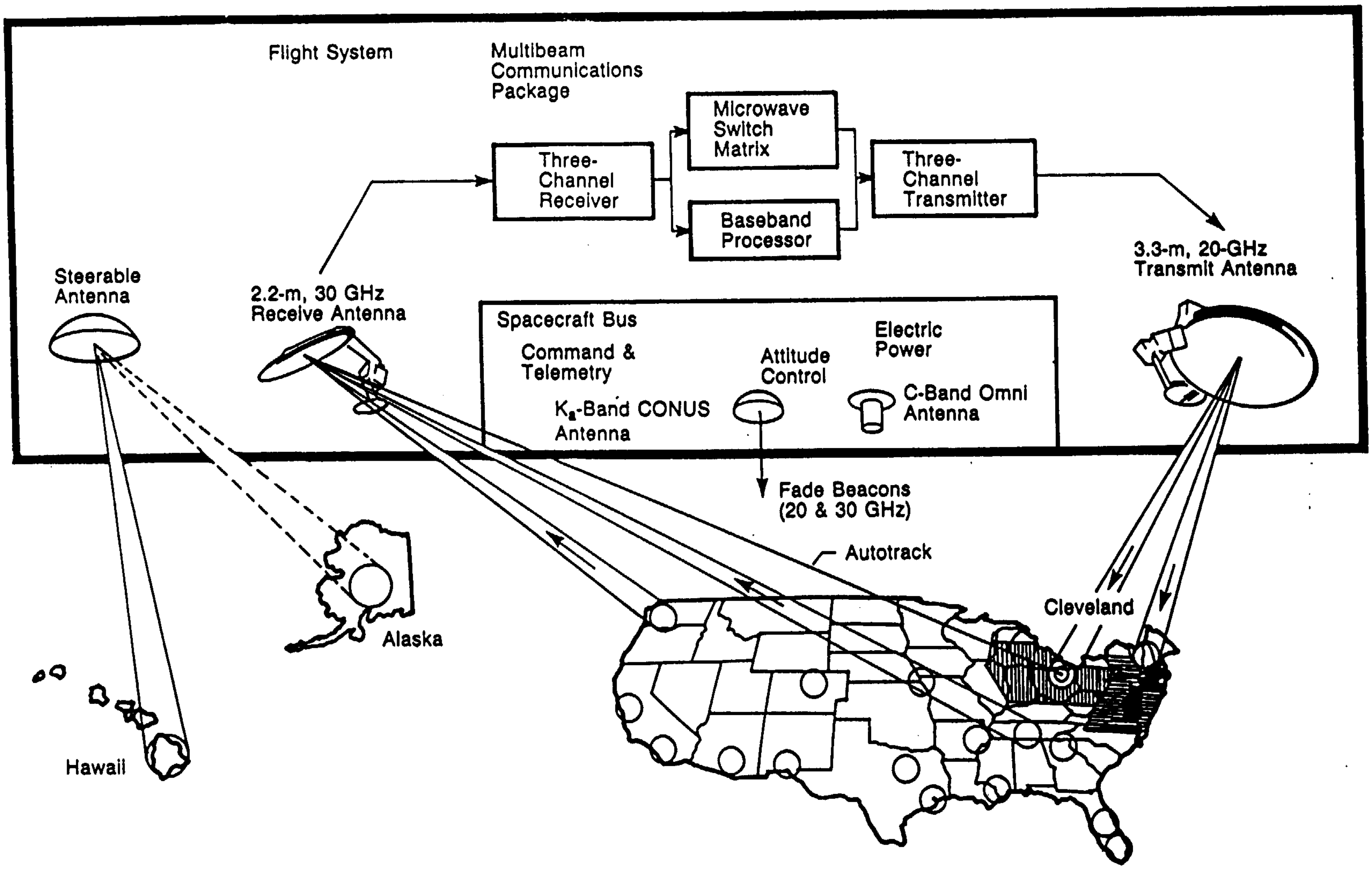
# Spacecraft Configuration



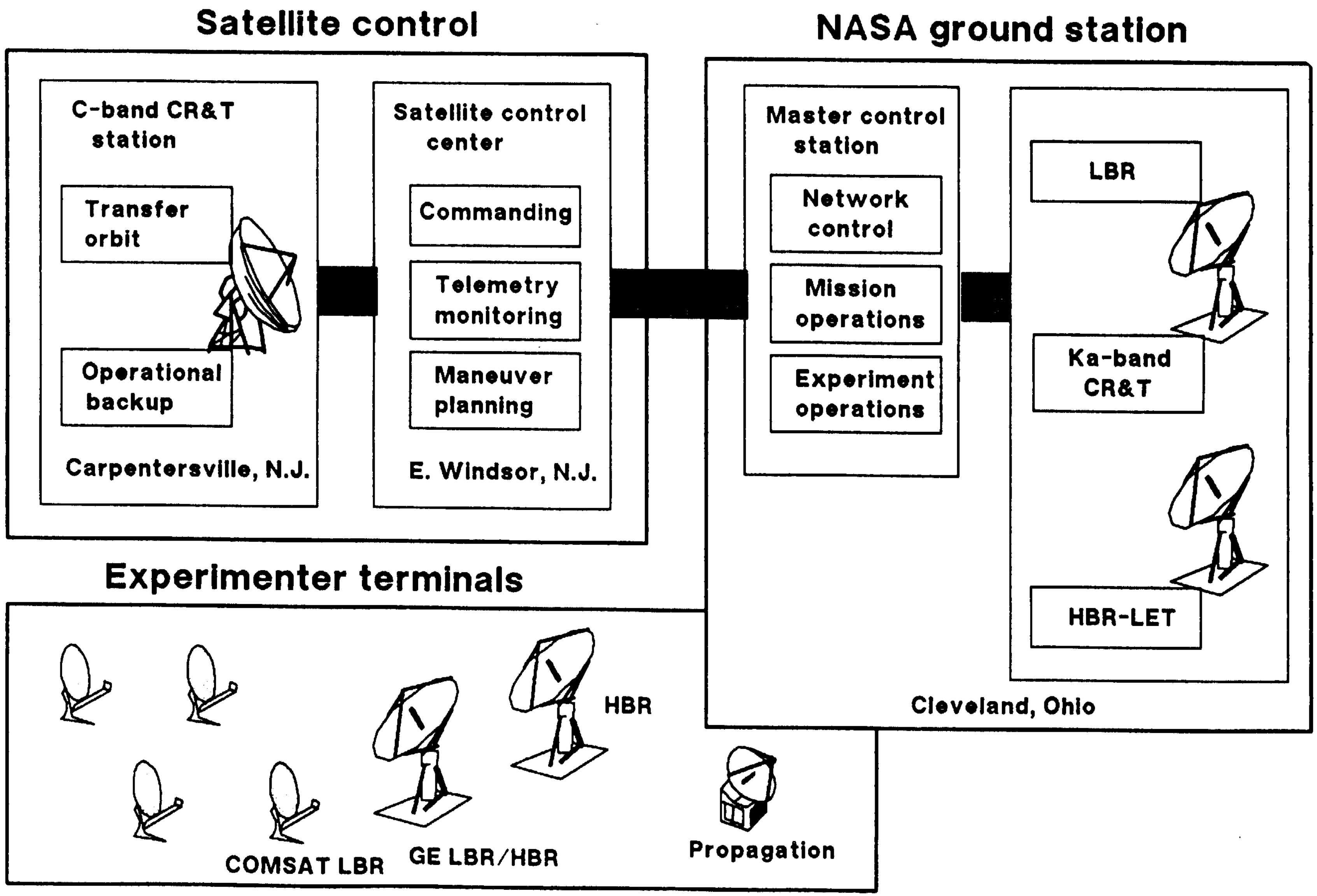

ACTS

NASA

# FUNCTIONAL OVERVIEW OF ACTS FLIGHT SEGMENT

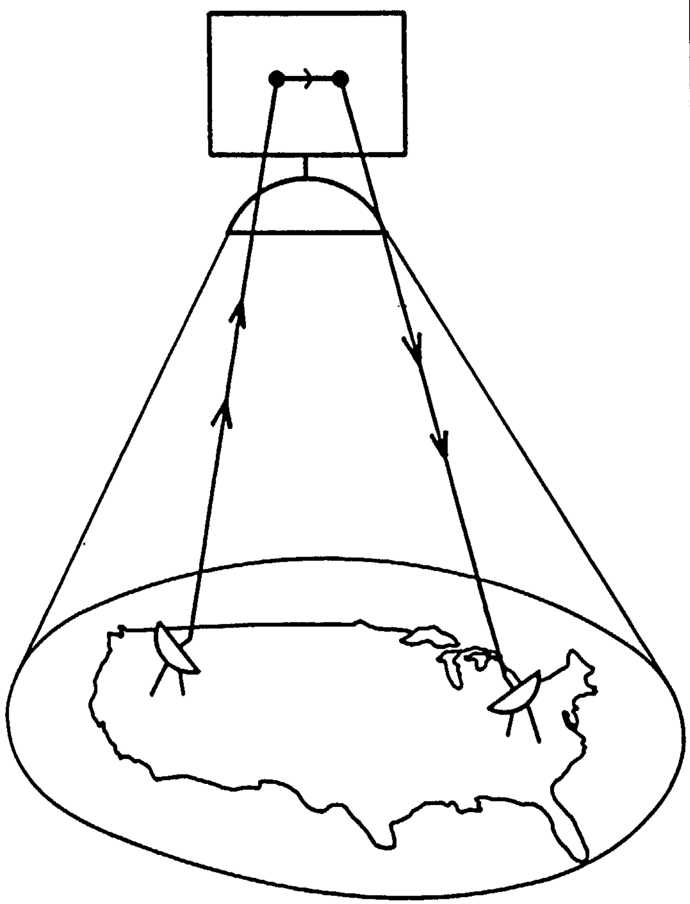


# FUNCTIONAL OVERVIEW OF THE ACTS GROUND SYSTEM

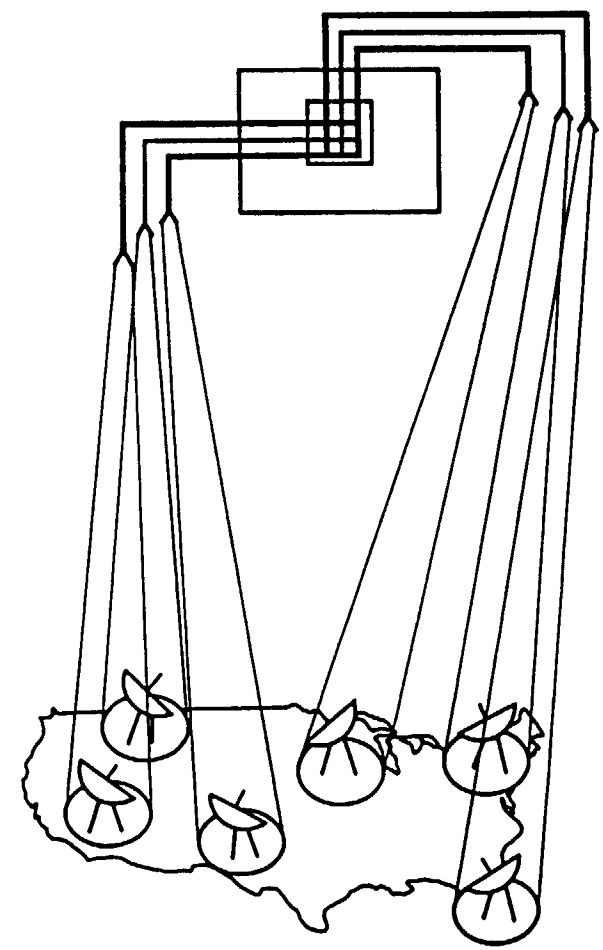


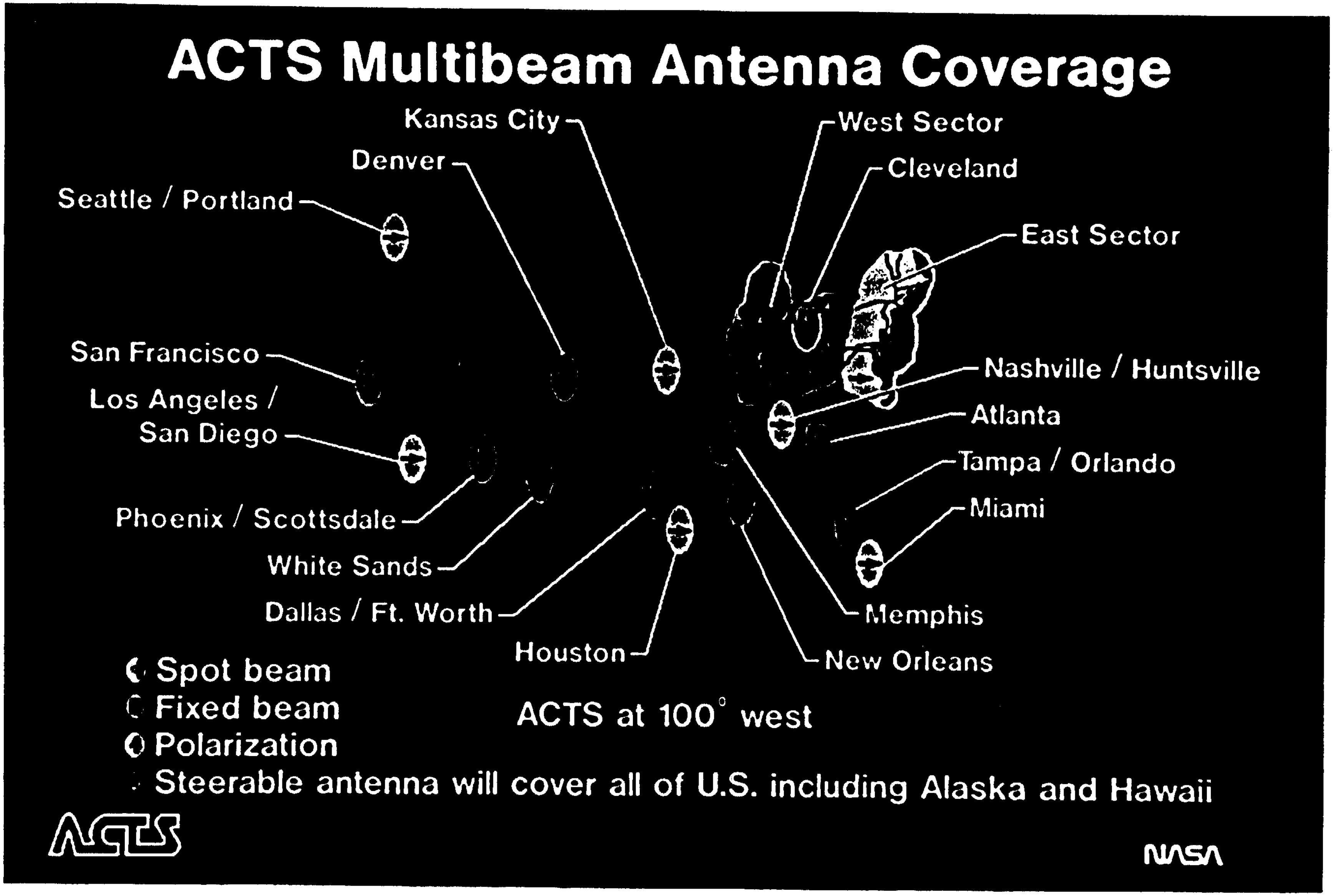
# BENT PIPE vs SWITCHING SATELLITE

SINGLE-BEAM BENT PIPE
SATELLITE

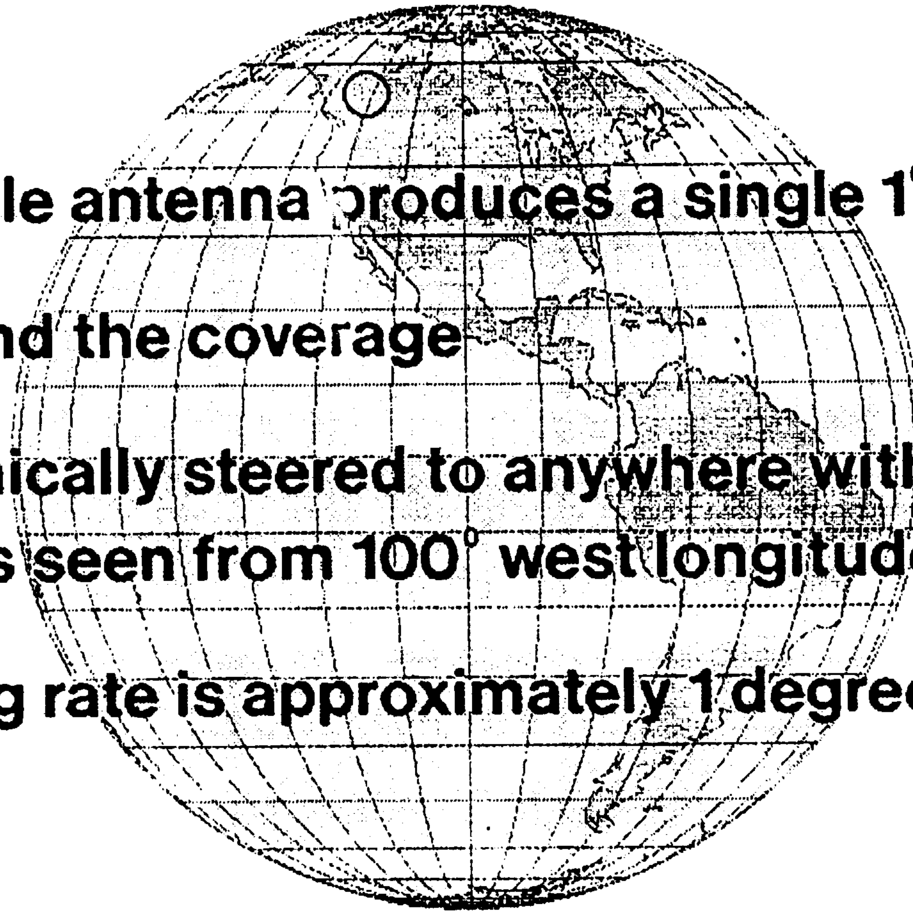


MULTIPLE BEAM SWITCHING
SATELLITE




ACTS Multibeam Antenna Coverage
Kansas City
Denver
Seattle / Portland
San Francisco
Los Angeles / San Diego
Phoenix / Scottsdale
White Sands
Dallas / Ft. Worth
Houston
West Sector
Cleveland
East Sector
Nashville / Huntsville
Atlanta
Tampa / Orlando
Miami
Memphis
New Orleans
Spot beam
Fixed beam
Polarization
Steerable antenna will cover all of U.S. including Alaska and Hawaii
ACTS at 100° west
ACTS
NASA

# ACTS Mechanically Steerable Beam Antenna Coverage



Steerable antenna produces a single 1° beam

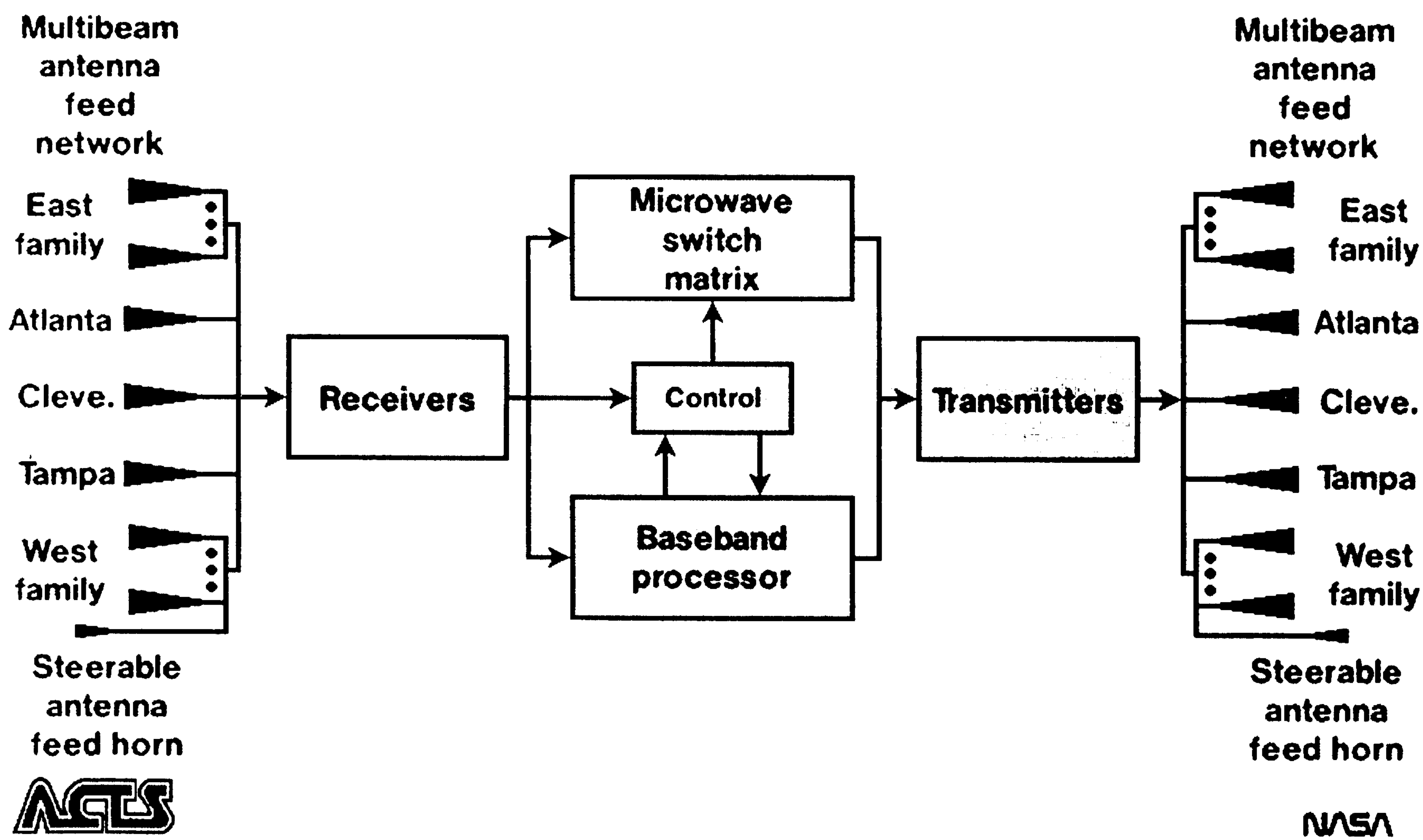
To extend the coverage

Mechanically steered to anywhere within disk of earth as seen from 100° west longitude

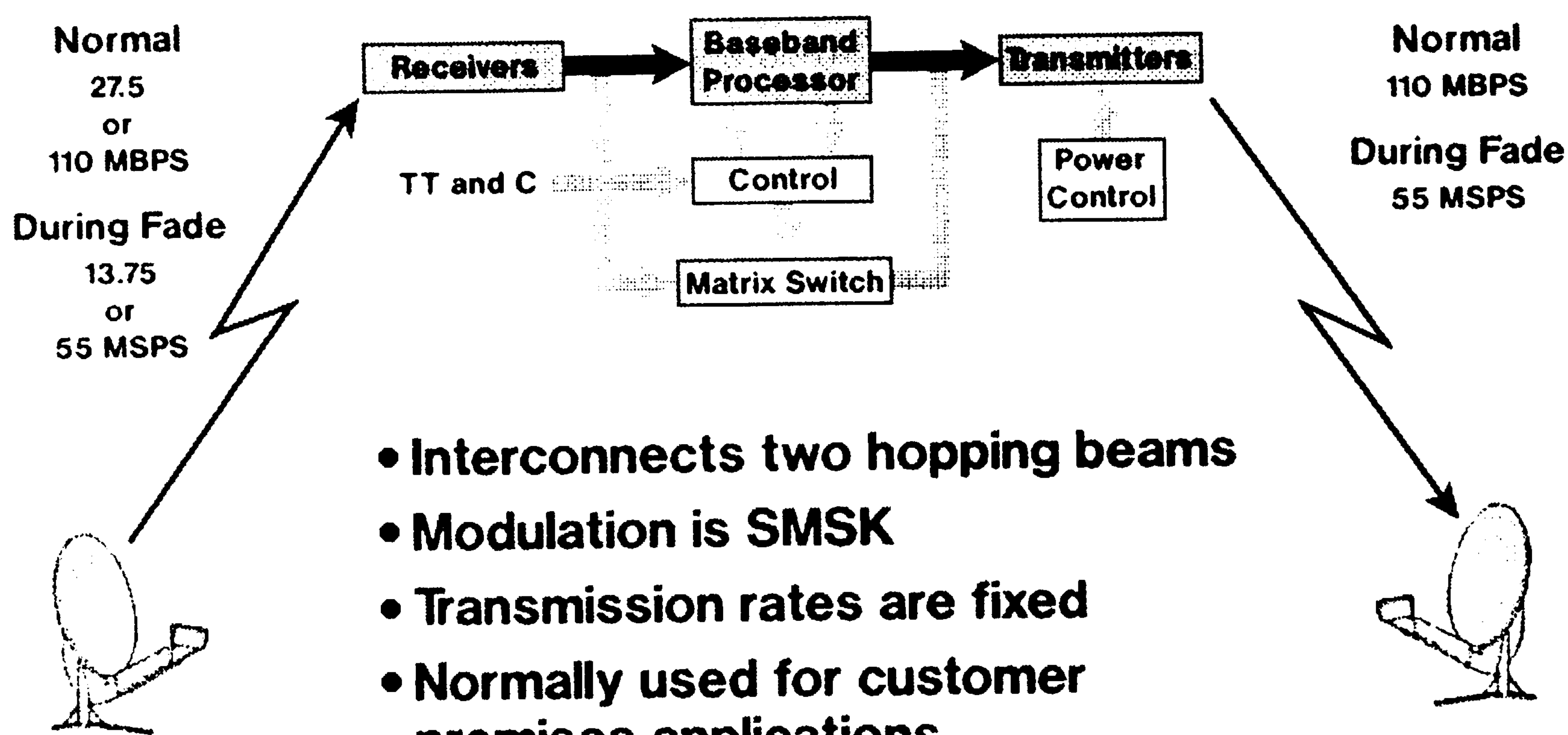
Steering rate is approximately 1 degree / minute

CD-30157

# ACTS Communications System



# Baseband Processor Mode
## (OSBS-TDMA)

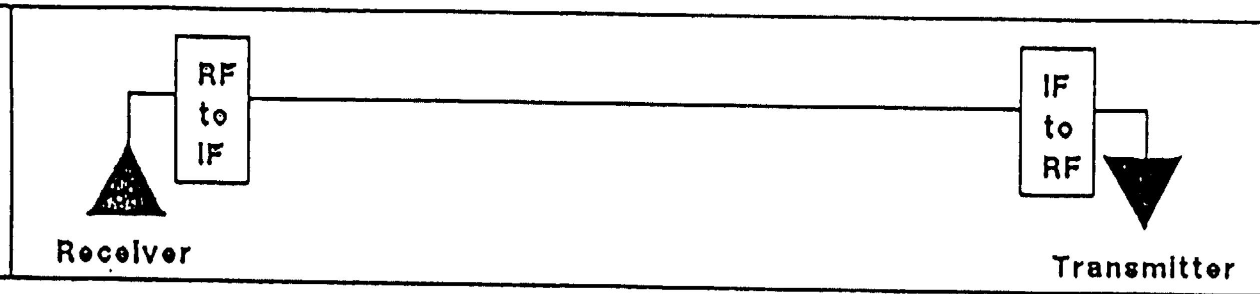



- Interconnects two hopping beams
- Modulation is SMSK
- Transmission rates are fixed
- Normally used for customer premises applications

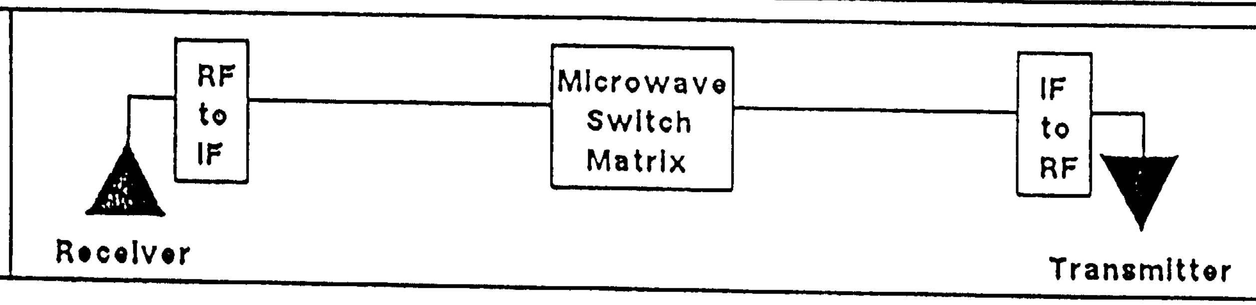
ACTS NASA

# Satellite Switching: What is on the Horizon?

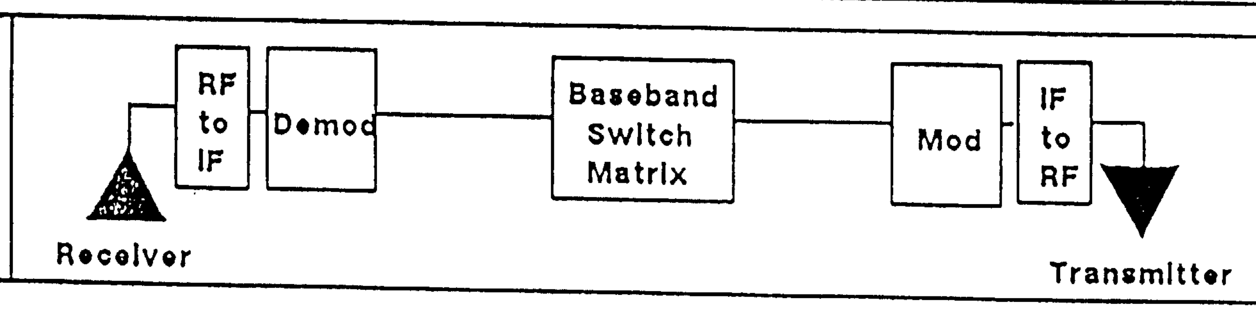
- Bent pipe (no switching)
- All commercial satellites currently in orbit



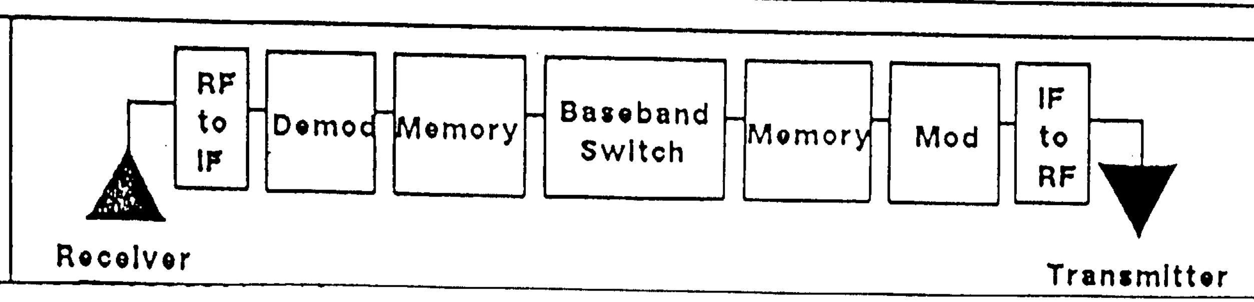

- Satellite switched TDMA (SS/TDMA)
- INTELSAT VI (1989)



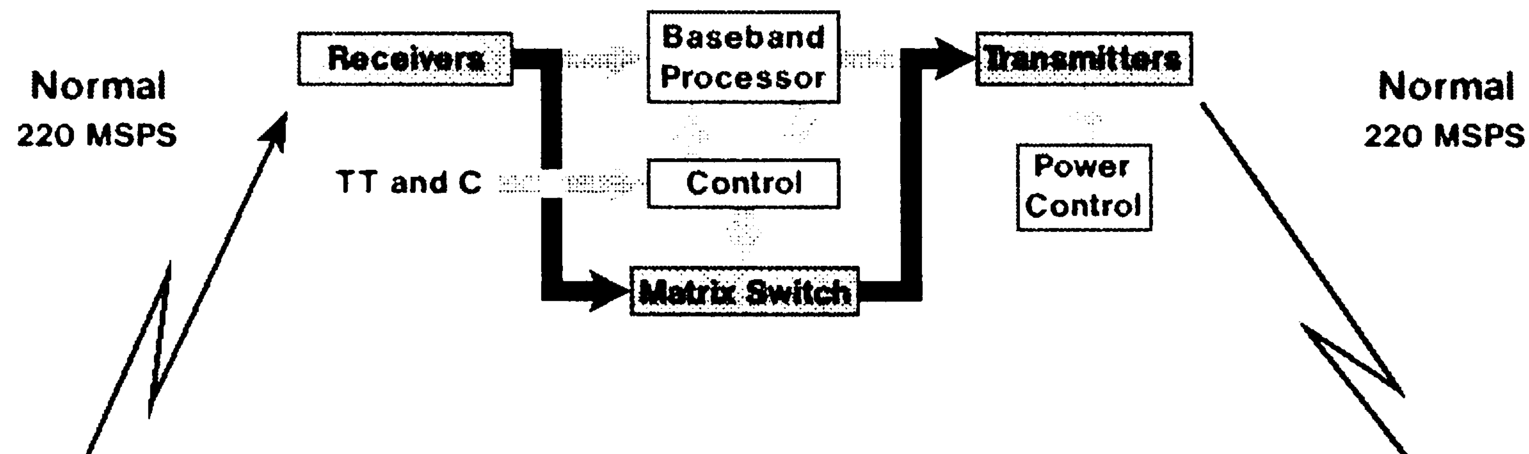

- Baseband switched TDMA (BBS/TDMA)
- ITALSAT (1991)

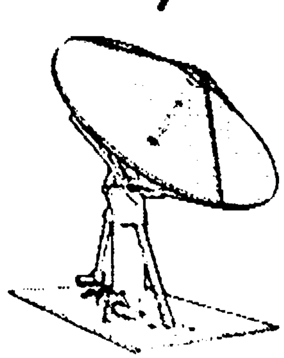


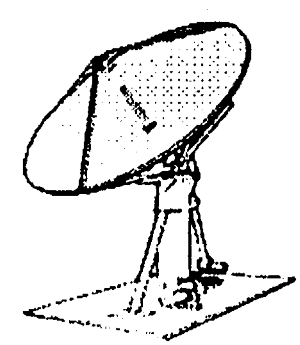

- Onboard stored baseband switched TDMA (OSBS/TDMA)
- ACTS (1992)



# Microwave Switch Matrix Mode
## (SS-TDMA)





- Interconnects three stationary beams
- No restriction on modulation
- No restriction on transmission rate
- Normally for wideband trunked applications

# ACTS

# EXPERIMENTS PROGRAM

# PROGRAM GOALS

| | GOAL | APPROACH |
|---|---|---|
| ACTS Overall Program | • Support Continued U.S. Industry Leadership In The World Communications Satellite Market | – Develop Advanced Technologies<br>– Use Technologies In An Experiment Program |
| ACTS Experiments Program | • Stimulate Commercial Use of ACTS Technologies | – Demonstrate Technical Feasibility *Through Technical Performance Evaluation Experiments*<br>– Demonstrate Applications *Through Applications Experiments*<br>– Encourage Widest Possible Participation by All U.S. Institutions in the Program (Private, Government, DOD, Academia) |

# SUPPORT TO NON-NASA EXPERIMENTS

- NASA PROVIDES:
  - Spacecraft Time During Experiment Period
  - Master Control Station Operations
  - Experiment Planning and Technical Support as Requested
  - Access to NASA Facilities for Cooperative Experiments
  - Engineering Measurements Aboard Spacecraft and at Master Control Station (MCS)
  - Industry Source for Experimenter Ground Terminals
- EXPERIMENTERS PROVIDE:
  - Experiment Definition and Design
  - Experimenter Working Group Support
  - Special User Equipment
  - Experiment Operations
  - Analysis of Experiment Results
  - User Charges for Ground Terminals