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ANTENNA TECHNOLOGY SHUTTLE EXPERIMENT (ATSE)

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ATSE PROJECT OBJECTIVES

Numerous space applications of the future will require mesh deployable antennas of 15 meters in diameter or greater for frequencies up to 20 GHz. These applications include mobile communications satellites, orbiting very long baseline interferometry (VLBI) astrophysics missions, and Earth remote sensing missions. Ground testing of these antenna systems is extremely difficult and expensive, and the results can be of questionable value. A flight test of the entire antenna system would greatly reduce the risk and uncertainty of launching such an antenna and would at the same time validate ground test procedures for future antenna systems. The NASA STS is ideally suited for performing the majority of 0 g, dynamic, and thermal tests required to space qualify this type of antenna system.

- GENERAL
  - REDUCE RISK IN UTILIZING LARGE DEPLOYABLE ANTENNAS, THEREBY ENABLING APPLICATIONS SUCH AS
    - 2nd GENERATION MSAT
    - ORBITING VLBI
    - REMOTE SENSING
- SPECIFIC
  - DEMONSTRATE CRITICAL TECHNOLOGIES AND VERIFY IN-FLIGHT PERFORMANCE OF AN ANTENNA SYSTEM REPRESENTATIVE OF ABOVE APPLICATIONS
  - DEMONSTRATE IN-FLIGHT MEASUREMENT OF LARGE SPACE ANTENNAS

ANTENNA CHARACTERISTICS FOR CANDIDATE APPLICATIONS

Listed below are some of the characteristics for candidate applications: second and third generation mobile communications satellites (MSAT), orbiting VLBI (such as the proposed QUASAT mission), and a general range of Earth remote sensing missions.

	FREQ (GHZ)	DIAM (M)	CONFIG	FEATURES	SURFACE ACCURACY
MSAT - 2ND GEN	1.6	15-20	OFFSET	MULTI-BEAM LOW SIDELOBES	3 mm (1.6 GHz)
MSAT - 3RD GEN	1.6	25-35	OFFSET	MULTI-BEAM LOW SIDELOBES	(AS ABOVE)
ORBITING VLBI	1.4-22	15-20	AXI-SYM	MULTI-FREQ HIGH GAIN	0.8 mm (22 GHz)
REMOTE SENSING	1-20	10-100	AXI-SYM & OFFSET	HIGH GAIN LOW SIDELOBES	$\lambda/30$

SPECIFICATIONS FOR LOCKHEED TEST ANTENNA

For the purposes of this study, a Lockheed wrap-rib antenna was used as the test article. Based on the requirements for the various applications in the 20 meter antenna class, a candidate test antenna was specified as outlined in the list below.

The offset configuration was chosen for the MSAT applications and is considered to be more demanding than the axisymmetric feed configuration. The 3mm surface accuracy will satisfy the MSAT L-band requirements while the 0.8 mm accuracy of the inner 10 meters will satisfy the 22 GHz requirements of the orbiting VLBI missions, such as QUASAT.

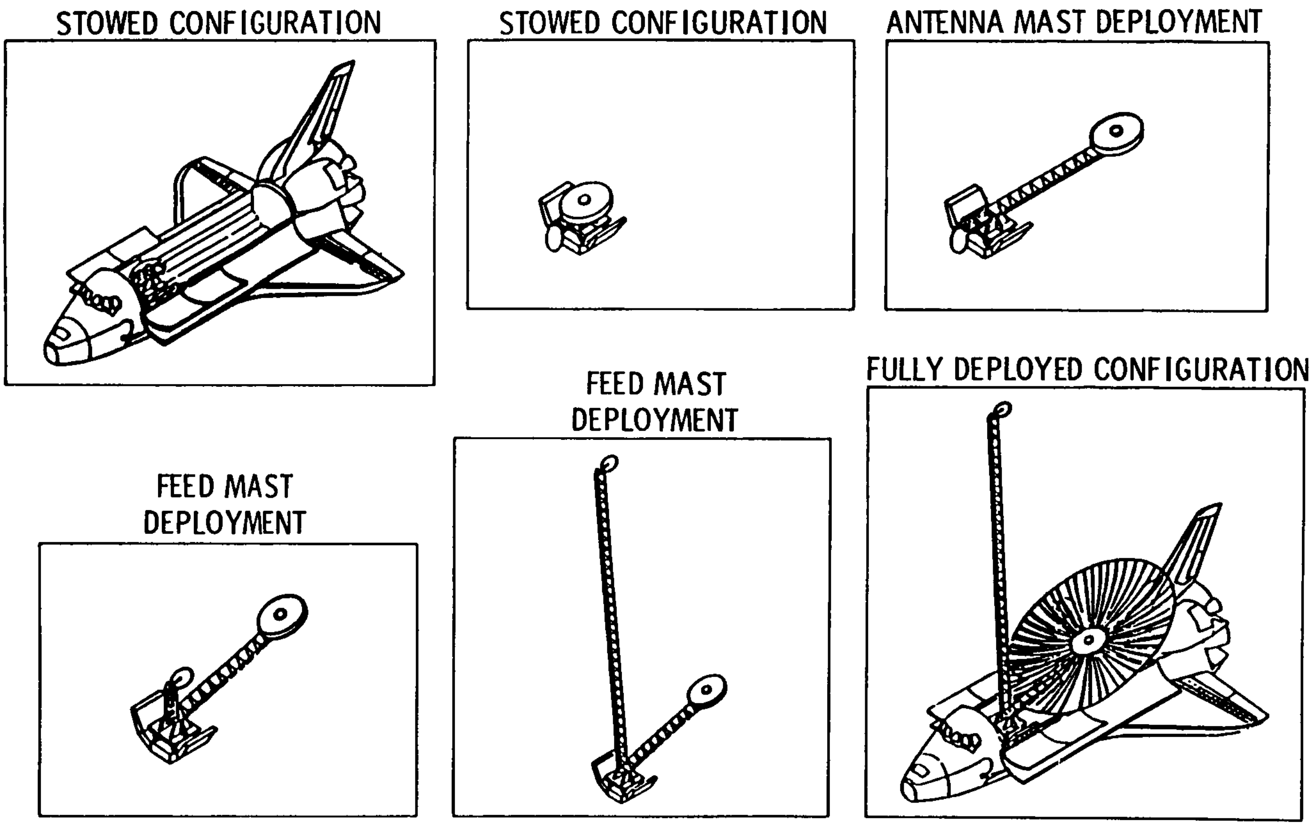
REFLECTOR TYPE	WRAP-RIB AUTOMATIC DEPLOYMENT/ REFURLMENT
REFLECTOR DIAMETER	20 METERS
CONFIGURATION	OFFSET FED
MAST TYPES	TETRAHEDRAL TRUSS MANUAL DEPLOYMENT/ REFURLMENT
FOCAL LENGTH/ DIAMETER	1.5
RMS SURFACE ERROR	3 mm (ENTIRE SURFACE) 0.8 mm (INNER 10 METERS)
FEED ALIGNMENT ERROR	5 mm

EXPERIMENT OBJECTIVES

Based on the project objectives the following list of experiment objectives was defined. These experiment objectives cover a broad range of structural, control, and RF discipline objectives which, if fulfilled in total, would greatly reduce the risk of employing these antenna systems in future space applications.

1. DEMONSTRATE THE RELIABLE DEPLOYMENT OF THE ANTENNA STRUCTURE (REFLECTOR, MASTS, AND FEEDS)
2. VERIFY PREDICTED REFLECTOR SURFACE PRECISION AND THE FEED/REFLECTOR ALIGNMENT IN ZERO G
3. MEASURE THE THERMAL STRUCTURAL CHARACTERISTICS OF THE REFLECTOR AND MASTS
4. MEASURE THE DYNAMIC STRUCTURAL CHARACTERISTICS OF THE REFLECTOR AND MASTS
5. VERIFY RF PERFORMANCE WITH:
    - SIMPLE RF FOCAL POINT FEED
    - FEED SCANNED OFF AXIS (SIMULATED MULTIPLE BEAM)
    - MULTIPLE BEAM FEED AT 0.9 OR 1.6 GHZ
6. DEMONSTRATE THE FEASIBILITY OF IN-FLIGHT SHAPE SENSING AND CONTROL
7. DEMONSTRATE ANTENNA POINTING STABILITY/JITTER CONTROL
8. VERIFY DEPLOYMENT REPEATABILITY OF SURFACE CONTOUR
9. DEMONSTRATE ASTRONAUT IN-FLIGHT ASSEMBLY
10. SCIENTIFIC AND ENGINEERING DEMONSTRATIONS OF THE ANTENNA SYSTEM (E.G., ORBITING VLBI, RADIOMETRY, ETC)

The figures show the stowed experiment package and the sequence of the deployment of the antenna system. The entire experiment package is mounted on the NASA Langley developed STEP pallet which contains the mechanical and electrical interfaces to the Shuttle. When fully deployed, the antenna feed is in the offset configuration and is located at the top of the feed mast tower. The boresight of the RF pattern is perpendicular to the roll axis of the shuttle.

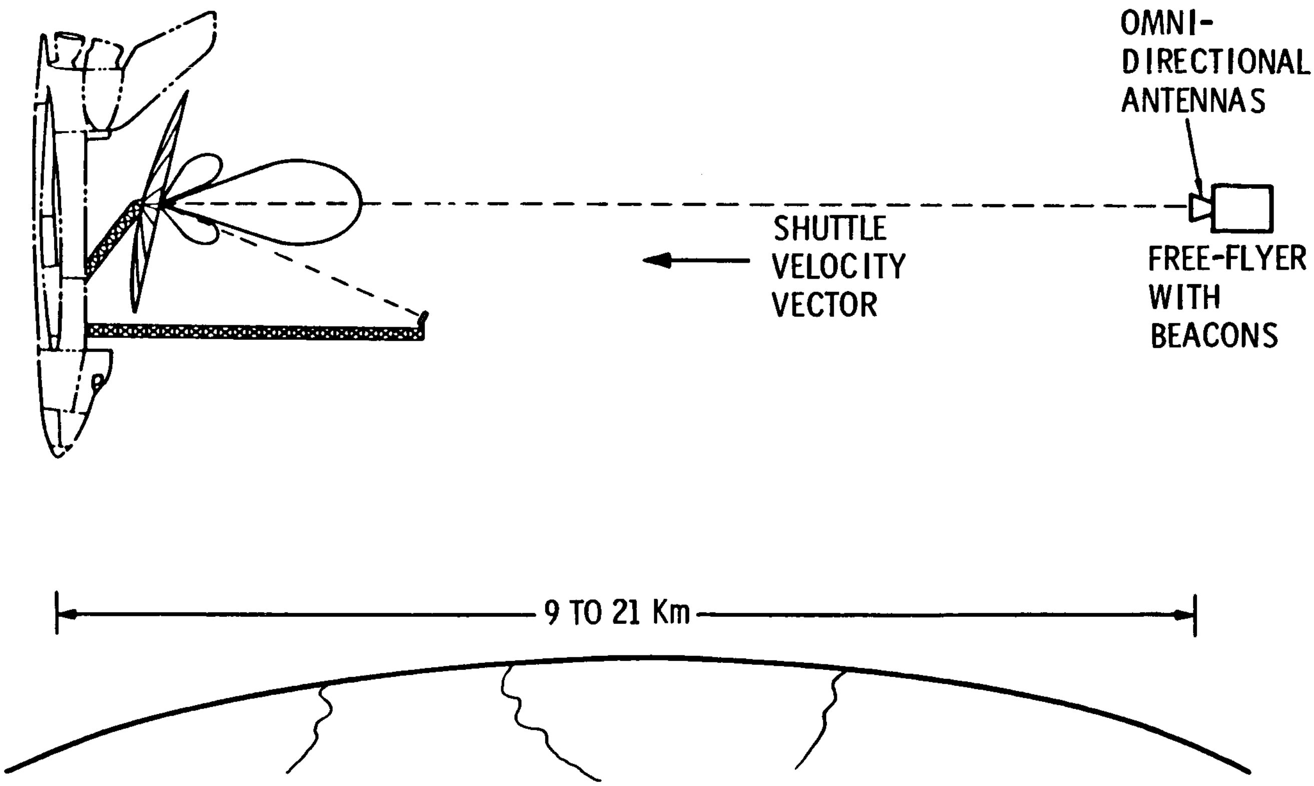


SPARTAN/SHUTTLE OBSERVATION

The RF pattern of the antenna is measured in the far field by employing an RF beacon on a derivative of the Spartan retrievable spacecraft. The Spartan is deployed and checked out prior to the deployment of the wrap-rib antenna and is subsequently retrieved after the wrap-rib antenna has been refurled.

The operational configuration will be with the Shuttle in a gravity gradient orientation (nose toward Earth) and its minus Z-axis aligned with the velocity vector. This orientation will allow the antenna to be in the Shuttle wake region and will minimize the interaction of free-stream oxygen with the reflector and mast structures.

The SPARTAN, equipped with an omni-directional antenna and beacon transmitter, will trail the Shuttle at a distance that places it in the far field of the test antenna. The upper limit is chosen to keep the power requirements on the SPARTAN to a reasonable level.



MISSION DESCRIPTION

In the baseline scenario, the experiment will be conducted in a 28.5^{o}, 250 N.M. orbit. Such an orbit affords the opportunity to conduct the antenna experiment during a flight in which other payloads are carried. Other (e.g., high inclination, high-altitude) orbits have also been studied. Some high inclination orbits afford opportunities for full illumination (constant thermal input) slowly precessing into orbits with varying shadowing. Higher altitudes minimize the deleterious effects of atomic oxygen on the antenna. Unfortunately, both of these orbit types imply less payload mass in orbit thus reducing the possibility of a multi-payload flight.

After launch and deployment of the other payloads, the SPARTAN will be checked out and deployed. The operational configuration will be attained. Then the various antenna structures will be deployed and aligned with EVA astronauts assisting.

- LAUNCH INTO 28.5^{0}, 250 N.M. ORBIT
- DEPLOY OTHER PAYLOADS
- CHECKOUT AND DEPLOY SPARTAN
- SEPARATE FROM SPARTAN 9-21 km
- ROTATE TO G-G ATTITUDE
- DO EVA DEPLOYMENT OF ANTENNA BOOM, FEED BOOM, ANTENNA REFLECTOR
- DO COARSE AND FINE ALIGNMENTS OF ANTENNA STRUCTURES

MISSION DESCRIPTION (Cont'd)

After calibrations are performed, the antenna undergoes passive characterization. The RF patterns will be traced by performing attitude maneuvers using the Shuttle VRCs. This is done manually by an astronaut who is observing the SPARTAN optical beacon via a sensor mounted on the hub of the antenna. Several scenarios for the attitude maneuvers have been proposed. These include a roster scan pattern that requires frequent motion reversals with antenna settling time required after the corresponding accelerations. One alternative scheme is a continuous roll (barbecue mode) with a slow pitch maneuver superimposed on it.

Throughout the experiment, it will probably be necessary to perform periodic Shuttle propulsive maneuvers to remove the effects of differential atmospheric drag on the Shuttle and SPARTAN thus maintaining the desired relative range between the two objects. The Shuttle in g-g mode and the SPARTAN have similar ballistic coefficients, thus station keeping maneuvers may need to be performed relatively infrequently, perhaps no more than once per day.

Significant parts of the controls experiment can be performed independently of the RF characterization and may even be performed during astronaut sleep periods. The final part of the experiment will be a test of antenna surface repeatability performed by unlatching and relatching the antenna mesh and measuring the antenna surface.

Finally, the antenna is stowed by the astronauts and the SPARTAN is recaptured.

- PERFORM CALIBRATIONS AND PASSIVE CHARACTERIZATION OF ANTENNA
- PERFORM RF PATTERN TRACING VIA MANUAL STS VRCS TURNS
- PERIODICALLY CORRECT SPARTAN RELATIVE RANGE VIA VRCS OR PRCS
- PERFORM SOME OBSERVATIONS (CONTROLS AND STRUCTURES) DURING SLEEP PERIODS
- PERFORM ANTENNA SURFACE REPEATABILITY TESTS
- DO EVA STOW OF ANTENNA STRUCTURES
- RECAPTURE SPARTAN

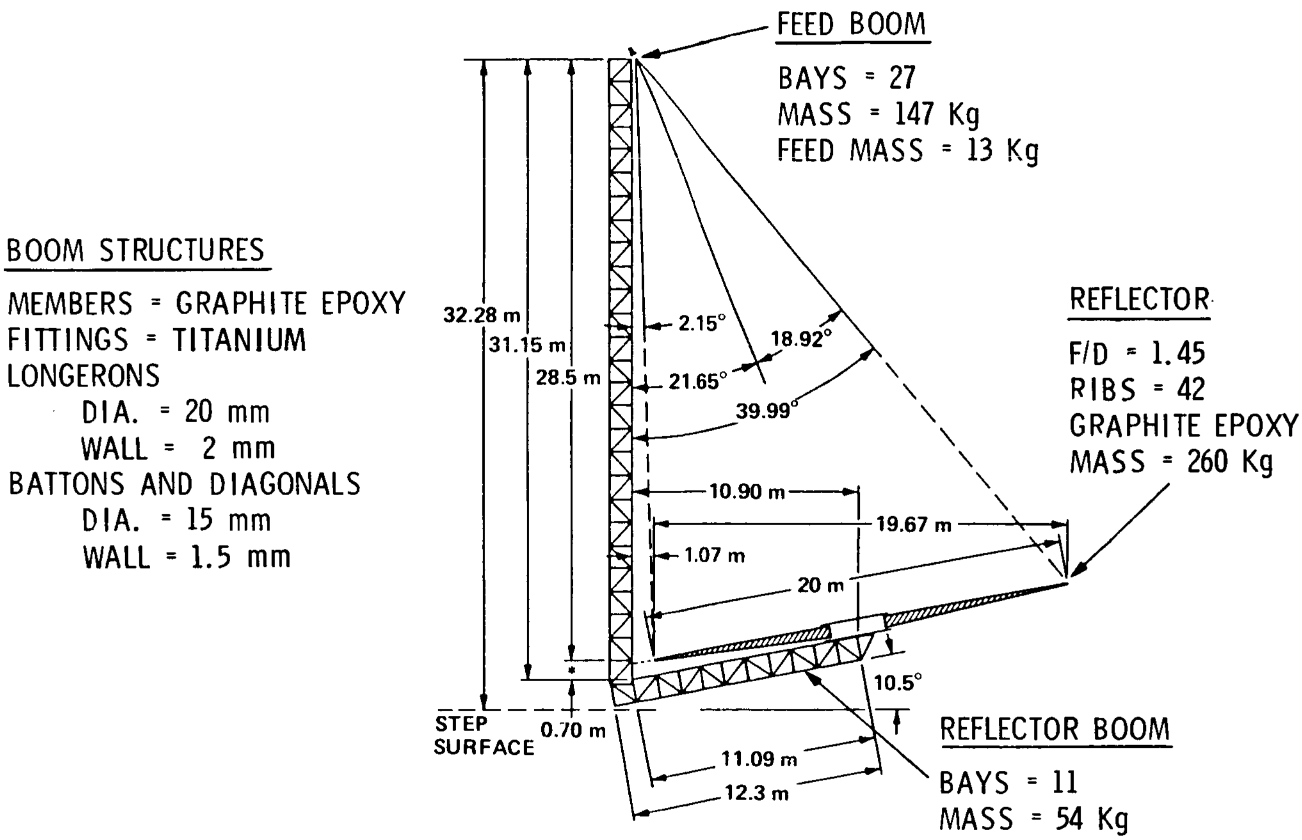
ATSE STRUCTURAL SYSTEM EXPERIMENT
OBJECTIVES

The structural experiment objectives are to demonstrate reflector kinematic deployment reliability and the capability for man to assist the deployment of a high precision feed support structure. Repeated partial restowing and then complete deployment is expected to help characterize the reflector initial position variations. Direct measurement of aperture precision and fee structure alignment is required to validate the mechanical design. Measurements of structural thermal distortions are required for design verification, but distortions and actual temperature distributions are needed for comparison with analytical models. Measurements of a few fundamental mode shapes, natural frequencies and associated damping are needed for characterizing the structural design and correlating analytical models.

- DEMONSTRATE LARGE ANTENNA DEPLOYMENT IN ZERO-G
  - 20 METER ANTENNA
  - PARTIALLY MAN ASSISTED
- CHARACTERIZE DEPLOYMENT INITIAL POSITION VARIATION
- MEASURE APERTURE PRECISION AND FEED STRUCTURE ALIGNMENT
- MEASURE THERMAL DISTORTIONS AND TEMPERATURE DISTRIBUTIONS
  - REFLECTOR
  - FEED STRUCTURE
- MEASURE FREQUENCIES, MODE SHAPES, AND DAMPING
- VALIDATE AND REFINE THERMAL AND STRUCTURAL ANALYTICAL MODELS

ATSE ANTENNA STRUCTURE CONFIGURATION DESIGN

The antenna structure configuration design is based on an advanced version of the Lockheed wrap-rib system developed by the NASA sponsored Large Space System Technology Program. The offset reflector is a segment of the parent paraboloid with an F/D of 1.5. There are 42 graphite-epoxy lenticular ribs. The RF reflective mesh is made from 1.2 mil diameter, gold-plated molybdenum wire. It is a tricot knit with 4 cells per inch. Rib deployment is accomplished by controlling the strain energy with a mechanism on each rib. The baseline deployable booms are based on a 3 longeron Astro Industries configuration design. The longerons, battons, and diagonals are based on graphite-epoxy tubes that interface with titanium fittings. Graphite-aluminum metal matrix composite tubes are also under consideration as an alternate to graphite-epoxy. The boom configuration designs lend themselves to astronaut assisted deployment.



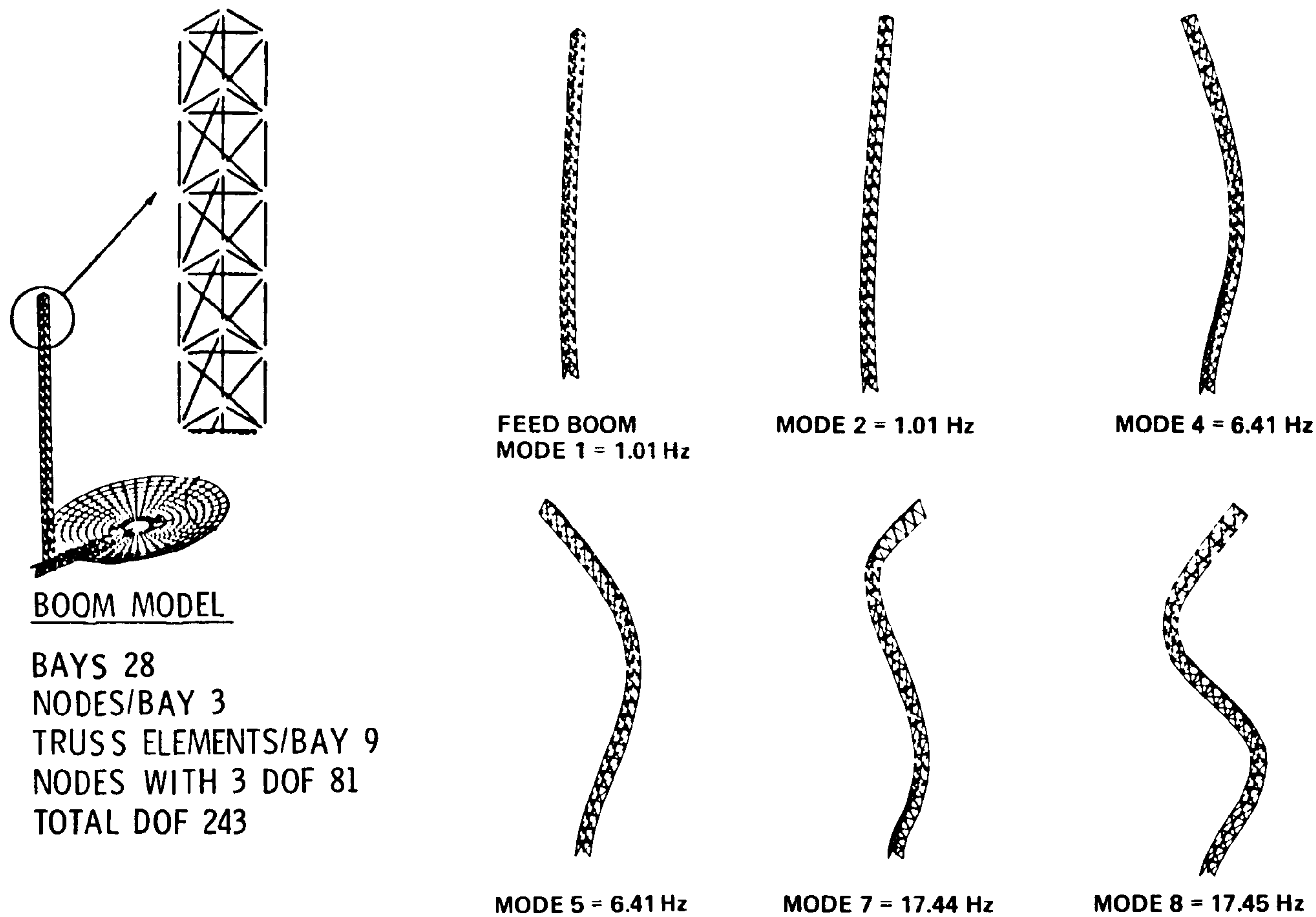
MESH DEPLOYABLE ANTENNA REFLECTOR ERROR SOURCES

There are a number of sources of error that must be considered when designing a reflector to a specified level of precision. The concept approximation error for the wrap rib antenna is the mesh flats between the ribs. Because of the difference between the radial and circumferential tensions in the mesh, there is a low amplitude pillowing of the mesh between the ribs. Component and assembly tolerances usually result in a randomly distributed surface error. Deployment dimensional repeatability results from the variations of surface initial position each time a complex structure is deployed. Thermal distortion is a function of the antenna configuration, material properties, internal heat sources and orbit. Since a large part of the antenna structure is made from graphite-epoxy, the long-term dimensional stability of this material must be considered.

- CONCEPT APPROXIMATION ERROR
- MESH PILLOWING
- COMPONENT TOLERANCES
- ASSEMBLY TOLERANCES
- DEPLOYMENT DIMENSIONAL REPEATABILITY
- THERMAL DISTORTION
- LONG-TERM MATERIAL DIMENSIONAL STABILITY

ATSE FEED BOOM STRUCTURAL ANALYTICAL MODEL

The 28 bay feed support structure has 9 truss members and 3 nodes per bay. This results in 81 nodes with 3 degrees of freedom for a model with a total of 243 degrees of freedom. Since the base of the feed support structure is supported directly by the STEP, the resulting modes are similar to those of a cantilever beam.



STRUCTURAL DYNAMICS IDENTIFICATION EXPERIMENT

The structural dynamics identification experiment is based on measuring the response of the antenna structure resulting from excitations produced by Shuttle thruster firings and proof mass dampers located on both boom structures. Dynamic response will be measured with accelerometers. Near real-time and post-flight data analysis will be utilized.

OBJECTIVE: CHARACTERIZE STRUCTURAL DYNAMICS OF REFLECTOR BOOM, FEED BOOM, AND REFLECTOR.

REQUIREMENTS: CHARACTERIZE SELECTED MODAL FREQUENCIES, DAMPING, AND MODE SHAPES FOR CORRELATION WITH ANALYTICAL MODELS.

APPROACH: MEASURE STRUCTURAL DYNAMIC RESPONSE TO DESIGNED EXCITATION SEQUENCES.

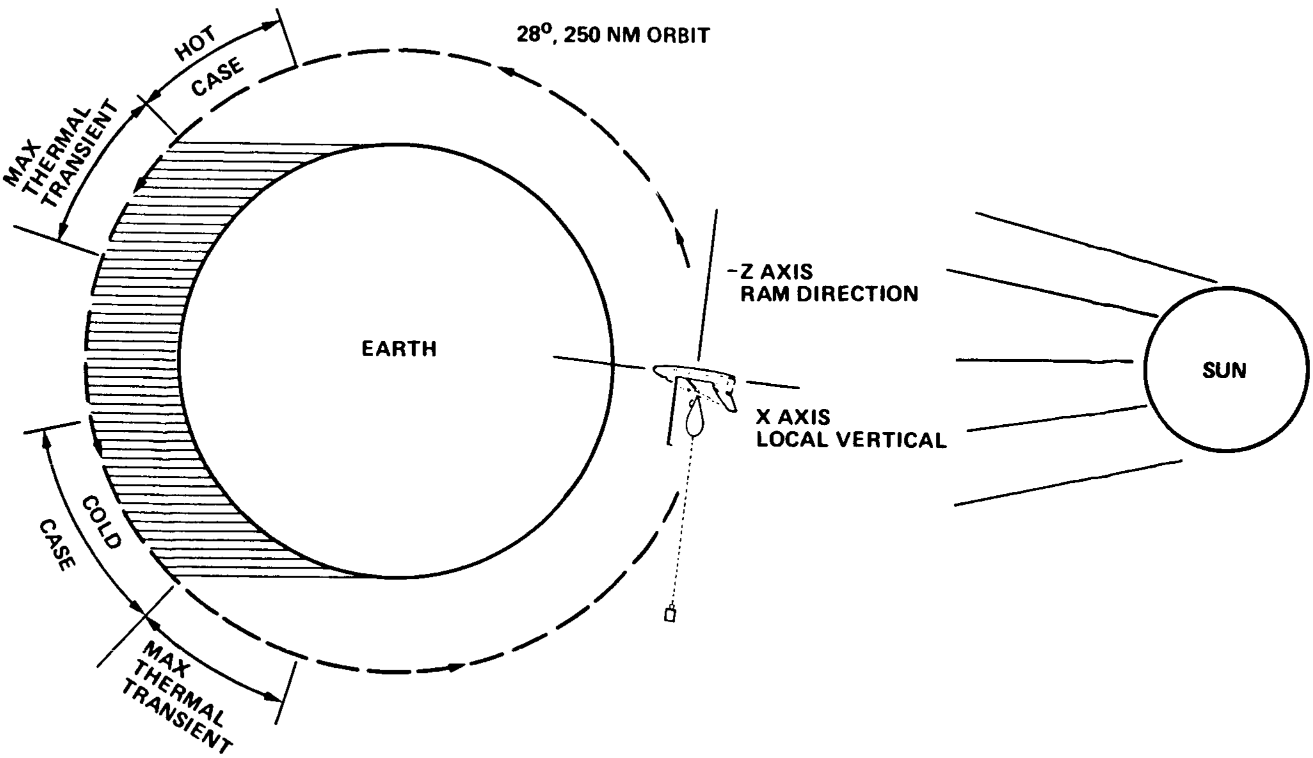
- IDENTIFY SIGNIFICANT PARAMETERS THROUGH GROUND BASED DATA PROCESSING.
- EXCITATIONS INCLUDE STS THRUSTER FIRING AND INPUT FROM PROOF MASS ACTUATORS.
- RESPONSES MEASURED BY ACCELEROMETERS
- QUICK SURVEY, NEAR REAL TIME, AND POST-FLIGHT PROCESSING.

METHOD: INPUT EXCITATION

- SHUTTLE THRUSTER FIRING SEQUENCES (IMPULSIVE INPUT)

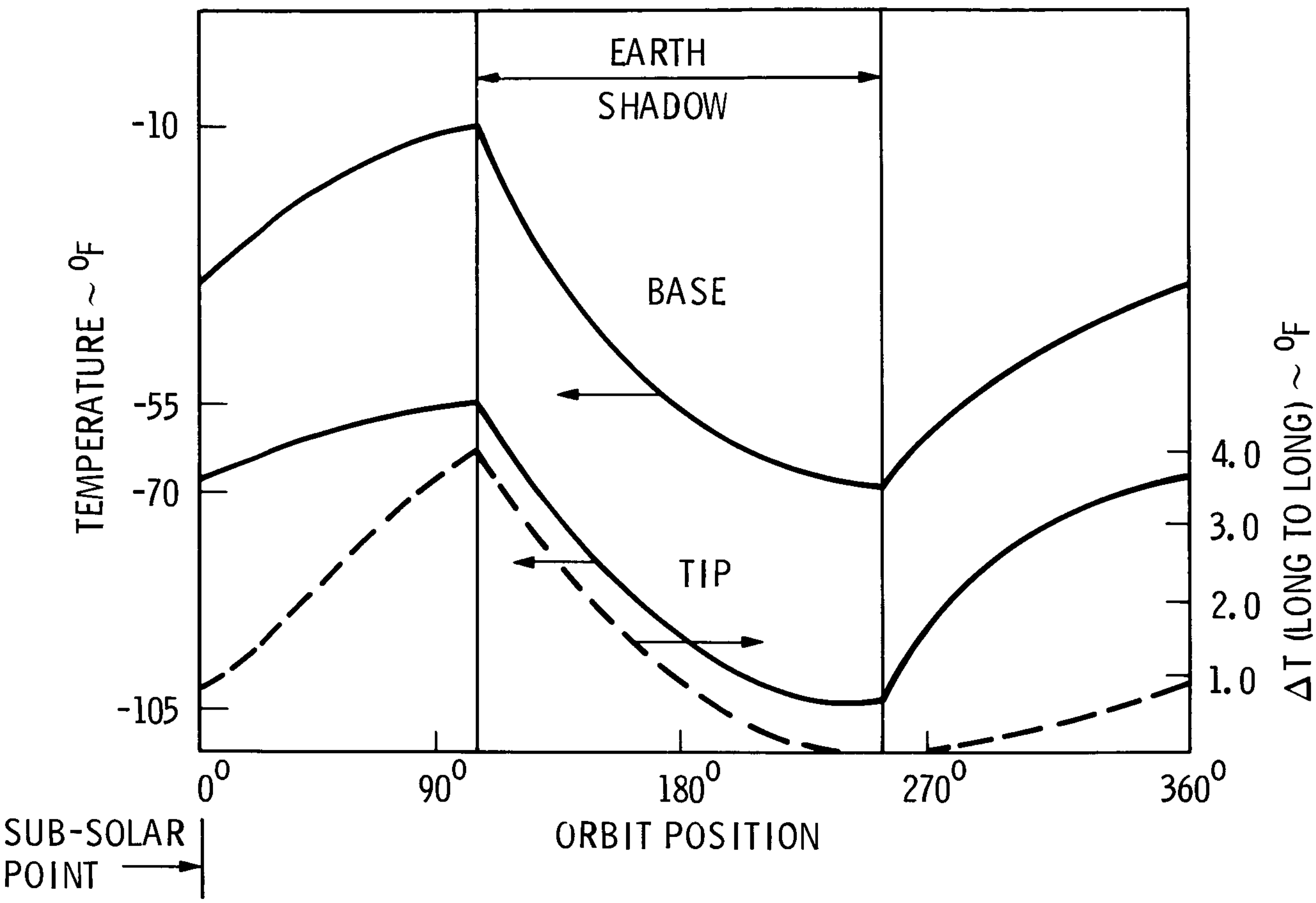
ATSE ORBITAL THERMAL REGIONS

The ATSE orbit consists of regions of solar illumination and Earth shadow. The maximum thermal transient occurs when the structure first enters Earth shadow or solar illumination. The extreme temperature cases for the test structure, both hot and cold, occur at the terminator portions of each thermal region.



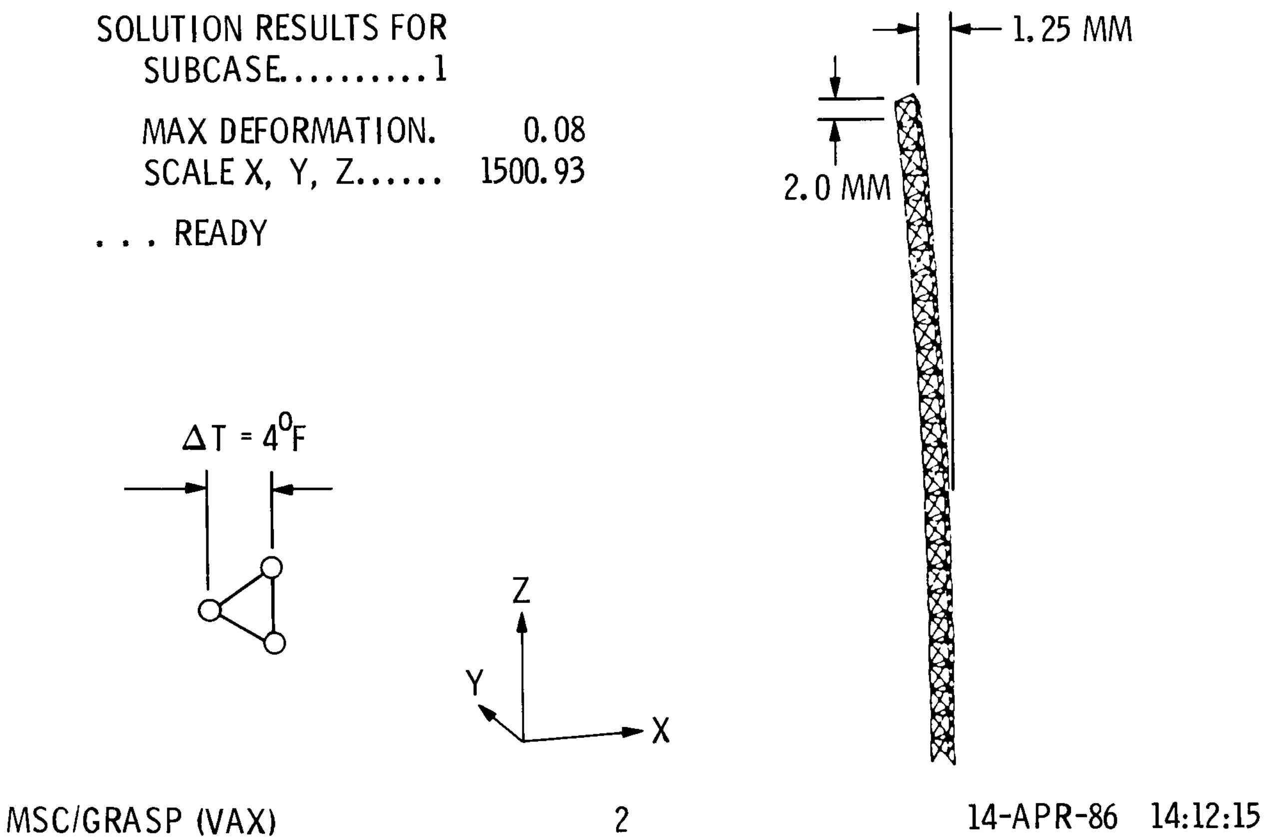
ATSE ANTENNA FEED BOOM THERMAL CHARACTERISTICS

The temperature of the base of the boom is relatively higher than at the tip because it is closer to the Shuttle. During solar illumination, there is a lot of reflected energy from the Shuttle. In Earth shadow, there is heat radiating from the Shuttle and a smaller view to space than at the tip of the boom. Even though there are significant temperature variations at each point along the boom as a function of orbit position, the temperature differences between the longerons, at equal distances along the boom, is very small.



ATSE ANTENNA FEED BOOM THERMAL DISTORTION

The "hot case" portion of the thermal orbit produces the maximum temperature changes and differentials for the structure. The large temperature change from ambient to orbital results in an axial deformation of 2.0 millimeters. Since the graphite-epoxy boom has a negative coefficient of thermal expansion, there is a decrease in the length of the boom. This change in length is fairly constant with respect to orbital position because the differences in temperature between the tip and base of the structure are also fairly constant. The lateral thermal distortion results from differences in temperature of the longerons. This difference in temperature varies from 0 to a maximum of 4^{o}F, as a function of orbital position, and produces a lateral deformation of 1.25 millimeters.



THERMAL SYSTEM IDENTIFICATION REQUIREMENTS

Results of the thermal modeling of the ATSE provide temperature distributions as a function of orbital position. These results when used in conjunction with the structural analytical model provide estimates of actual thermal deformation. Consequently, measurement of temperature and deflection are required for model validation. The number and location of sensors for characterizing temperature distributions represent the minimal accompaniment for obtaining temperature magnitudes and differentials. Similarly, the quasi-static instrument requirements reflect characterization of the most significant structural deformations.

	QUASI-STATIC DEFL.		TEMP. DISTRIBUTIONS	
STRUCTURE	LOCATION	DIRECTION	LOCATION	POSITION
FEED BOOM	3 ALONG BOOM	2 LATERAL 1 AXIAL	3 ALONG BOOM	1/LONGERON
REFLECTOR BOOM	2 ALONG BOOM	2 LATERAL 1 AXIAL	2 ALONG BOOM	1/LONGERON
REFLECTOR RIB	1 TIP 1 INTERMEDIATE EACH RIB	OUT OF PLANE	20 ON TBD RIBS	TOP & BOTTOM
MESH GORES	TBD/GORE ALL GORES	OUT OF PLANE	--	--

STRUCTURE/ENVIRONMENT INTERACTION EXPERIMENT IMPACT

Detailed contamination analysis has shown that a number of combinations of aft PRCS engines in operation simultaneously could result in permanent damage to significant portions of the antenna mesh. However, preferentially selected and operated PRCS in a pulse mode will preclude a problem.

Analysis results indicate that deposition of mass from the forward PRCS firings will change the thermal radiative properties of the forward portion of the thermal surfaces of the feed tower. This could significantly increase the thermal distortion of this structure. This problem could be somewhat minimized by preferential use of the forward engines.

Portions of the ATSE structures will be exposed to direct impact from atomic oxygen for the duration of the experiment. Exposure of the unprotected graphite-epoxy, as proposed for the test structure, would result in unacceptable damage. However, this type of material, when covered with the appropriate thermal control paint or multilayer insulation, will have no problem with the environment.

- MESH WILL BE DAMAGED UNLESS PRCS ENGINES ARE PREFERENTIALLY SELECTED AND OPERATED IN A PULSE MODE.
- POTENTIAL TOWER/FEED THERMAL DISTORTIONS DUE TO EXCESSIVE CONTAMINATION FROM FORWARD ENGINES.
- ATOMIC OXYGEN EROSION A NON-ISSUE AS LONG AS GRAPHITE/EPOXY STRUCTURES ARE OVERCOATED (PAINT OR MLI).

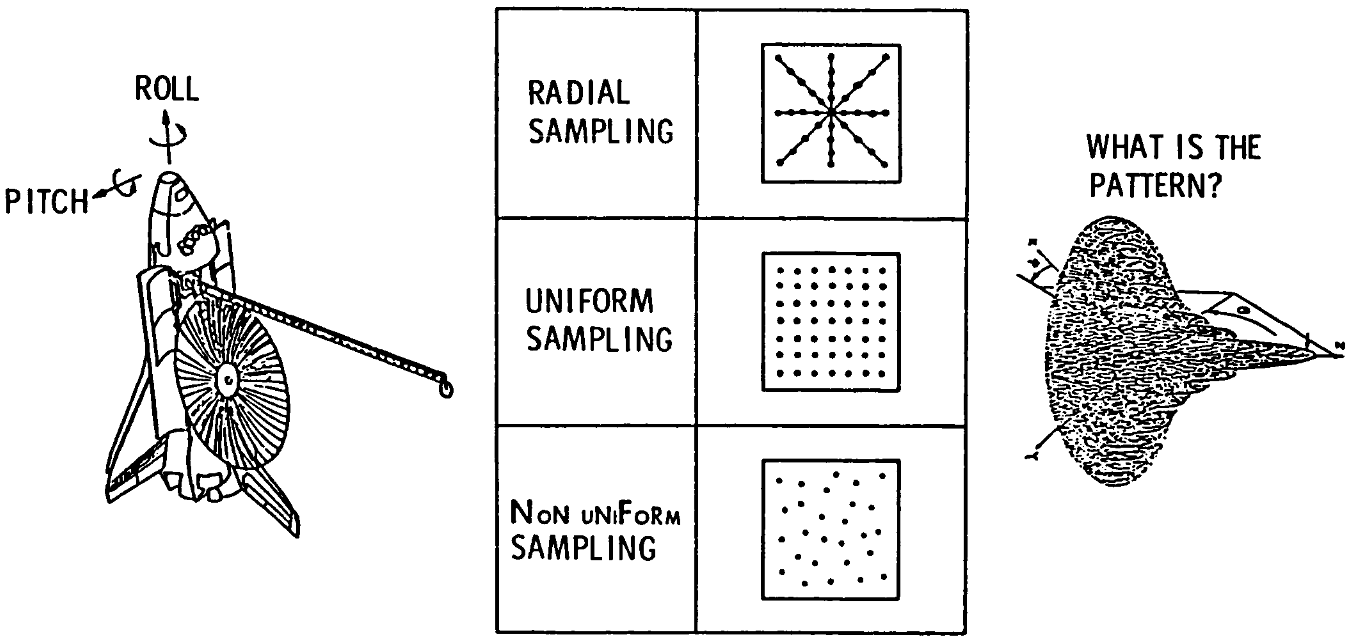
RADIO FREQUENCY EXPERIMENT

Since RF pattern measurements will provide the ultimate characterization of the antenna performance, a series of RF measurements are planned with the following objectives: (a) to demonstrate and develop the technological capabilities to measure large space antennas in space; (b) to measure the on-axis and off-axis beam patterns under various thermal conditions and after on-orbit surface and feed adjustment; (c) to correlate the measured RF performance with the measured surface and feed alignment; (d) to verify and update the mathematical and computer models of RF performance analysis and prediction; and (e) to project the RF performance of an operational system. These kind of data should establish an acceptable level of confidence considering large antennas for commercial and scientific applications.

- DEMONSTRATE THE ABILITY TO MEASURE (RF) LARGE SPACE ANTENNAS
- MEASURE ANTENNA BEAM PATTERNS
  - VARYING THERMAL CONDITIONS
  - VARYING SURFACE AND FEED
- CORRELATE ANTENNA BEAM PATTERNS WITH
  - MEASURED SURFACE
  - MEASURED FEED ALIGNMENT
- VERIFY AND REFINE RF MODELS
- PROJECT THE RF PERFORMANCE OF AN OPERATIONAL SYSTEM

CANDIDATE SCAN OPTIONS

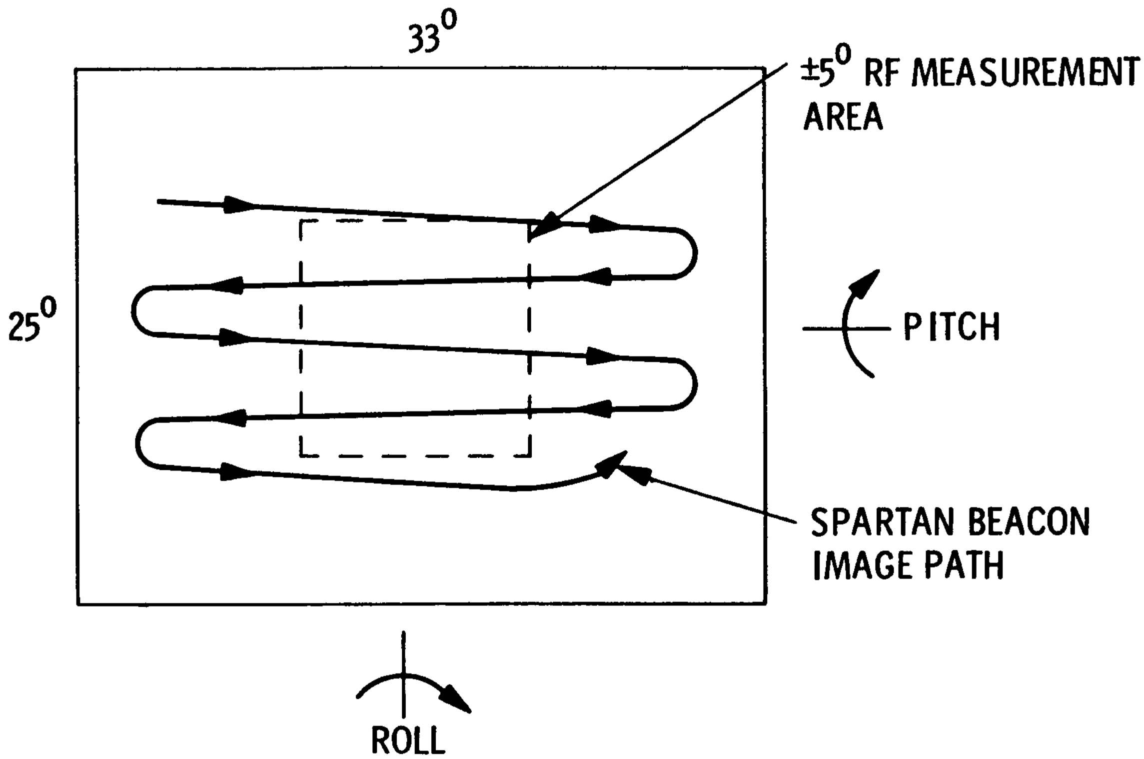
To characterize an antenna far-field pattern, one typically displays the far-field amplitude distribution as a function of polar angle theta versus the azimuthal angle phi. This representation is shown for several values of phi which are called far-field pattern cuts. Clearly, the simplest way to achieve these representations is to move the antenna in a fixed phi cut and then measure the far-field variation as a function of theta. This data taking approach is called radial sampling. It is clear that such a sampling can be achieved only when the antenna motion with respect to the illuminating source is controlled with a precision gimbal mechanism aboard the Shuttle. This, however, could lead to a very costly system. An alternative approach would be to measure antenna far-field amplitude and phase at uniform sample points and then determine the standard far-field cuts from them. This scheme would also necessitate application of a gimbal mechanism which again could be very costly. Ultimately, it would be desirable to utilize a nonuniform sampling algorithm which would allow application of measured amplitude and phase data points on nonuniform sample points which could result from relative motions of the shuttle and the free-flyer (SPARTAN). Such an algorithm has recently been developed and tested, and it believed that it can enhance the capability of in-space measurement without the utilization of a gimbal mechanism.



- WE MUST BE PREPARED TO USE ANY OF THE ABOVE OPTIONS BASED ON THE ACHIEVABLE SHUTTLE AND FREE-FLIER MANEUVERS

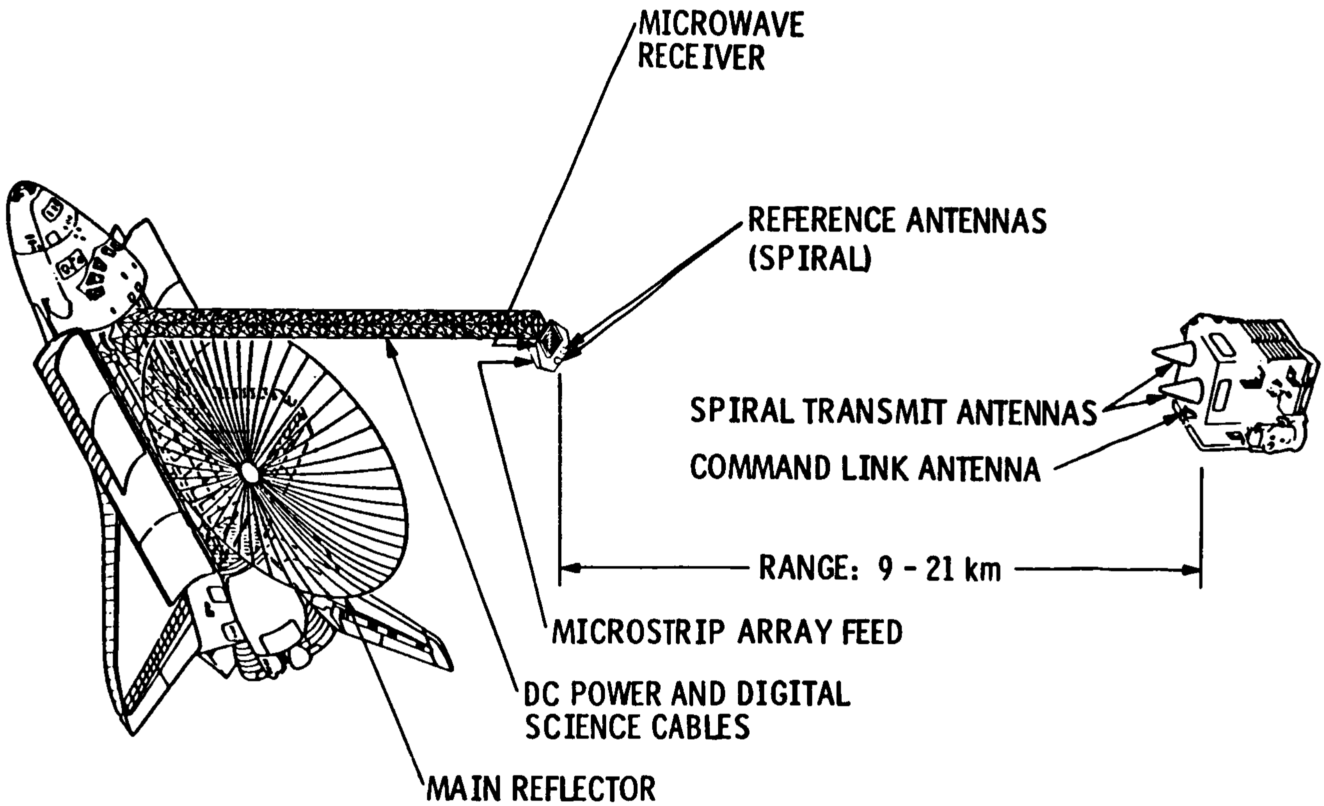
SPARTAN LOCATION IMAGE

Since the test antenna operates in the receive mode and the RF illumination is performed by the radiating antennas aboard the free-flyer (SPARTAN), one has to determine the relative location of the SPARTAN with respect to the test antenna as the Shuttle maneuvers on its roll and pitch axes. This relative location determination is achieved by utilizing an optical sensor which allows a precise evaluation of the location of the SPARTAN at the instant when the RF signal is measured. Based on the achievable maneuvering dynamics of the Shuttle and the SPARTAN, an image window, as depicted in the figure, could be traced which provides the nonuniform sampling data distribution.



RF MEASUREMENT SYSTEM

In order to satisfy the required far-field distance criterion, a minimum separation of 9 km between the test antenna aboard the Shuttle and the SPARTAN will be needed at the operating frequency (L-band). However, in order to meet the link budget requirements based on the available radiating power from the radiating antennas aboard the SPARTAN, the maximum separation must be kept under 21 km. Since the utilization of the nonuniform sampling algorithm demands the measurements of both the amplitude and phase of the received signal, the RF measurement system will consist of the following subsystems: (a) test antenna and its feed array; (b) reference antenna for the amplitude and phase measurements; (c) calibrated microwave receiver; (d) dc power and digital science cables for data recording; (e) transmitter unit and antennas aboard the SPARTAN and (f) command link antennas and units.



REFLECTOR SHAPE, POINTING AND VIBRATION CONTROL EXPERIMENTS

The control system experiments take place after the completion of the RF pattern measurements. The control system tests consist of evaluating the performance of different types of dynamics identification and control algorithms. For each set of software, the response of the antenna to commanded structural excitation via the RCS, VRCS and proof mass actuators will be measured and evaluated.

The objectives of the reflector shape, pointing and vibration control experiments are to:

1. Demonstrate on-orbit shape and alignment sensing and control technology in order to measure the overall antenna shape (ribs, mesh and feed misalignments) to an accuracy of 0.3 mm root-mean-squared (rms) knowledge, and to control it with actuators (rib-root and feed) to an accuracy of 1.0 mm rms.

2. Validate the control design methodology used to design the initial control system and the process of in-flight updates of the control parameters based upon on-orbit dynamic identification.

3. Demonstrate active line-of-sight pointing and vibration control design to show stability improvement over a passive system and demonstrate antenna boresight pointing stability performance of 0.01 degrees.

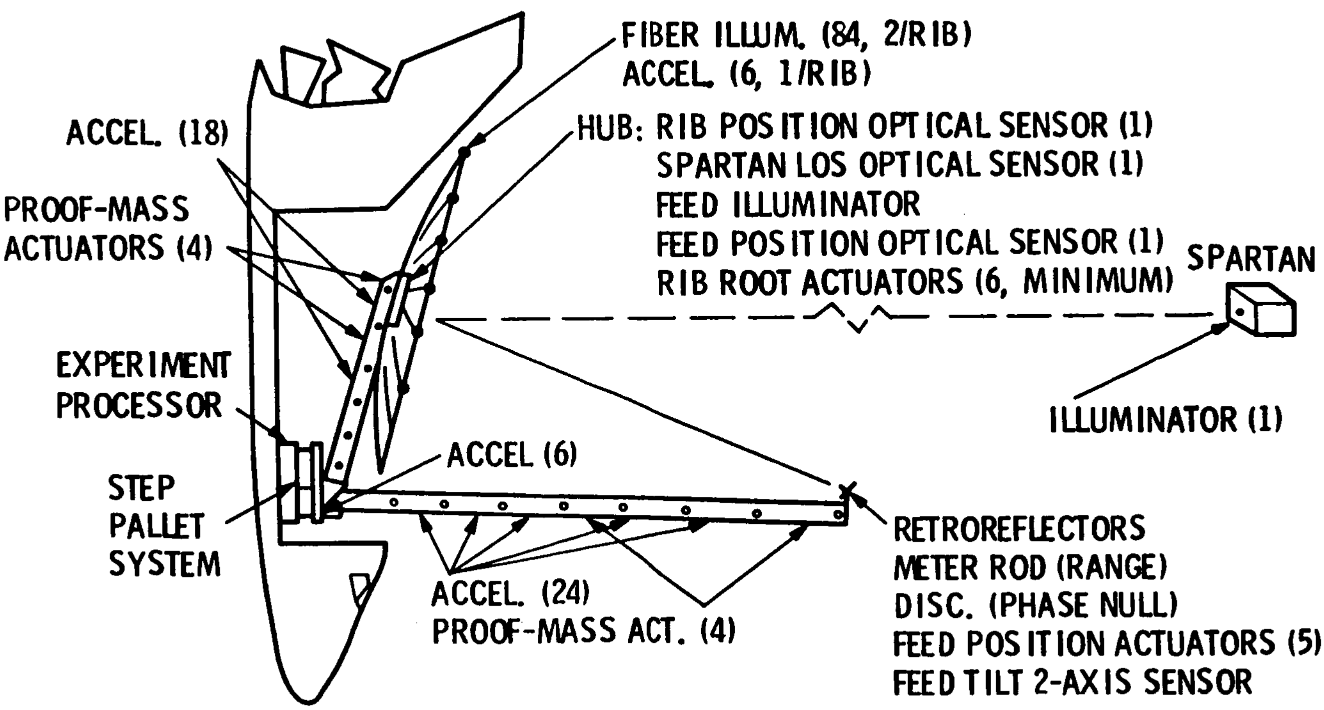
4. Update and refine analytical tools and prediction models with the test data base.

- DEMONSTRATE ON ORBIT SHAPE AND ALIGNMENT SENSING AND CONTROL
- VALIDATE CONTROL DESIGN METHODOLOGY
  - INITIAL CONTROL SYSTEM
  - ON-ORBIT DYNAMIC IDENTIFICATION
  - IN-FLIGHT UPDATES OF CONTROL PARAMETERS
- DEMONSTRATE ACTIVE CONTROL
  - LINE-OF-SIGHT POINTING
  - VIBRATION
- UPDATE AND REFINE ANALYTICAL TOOLS AND MODELS

CONTROL EXPERIMENT HARDWARE ARCHITECTURE

The antenna control system functions consist of RF feed and antenna position sensing, rib root and feed plane actuation, and feed and dish boom active dynamic control. The angular position of the RF feed will be determined in real time by viewing the tracking beacon(s) on the SPARTAN via a CCD sensor. This sensor and associated electronics will be located on the hub of the reflector and be aligned along the antenna boresight. The position sensing function will determine in real time the angular location of the reflector ribs, the location and orientation of the feed, and the position of the feed mast with respect to the reflector hub. This information is necessary for static control of the reflector and the feed. In general both range and orientation information will be determined via a CCD sensor in combination with point light sources and retroreflectors.

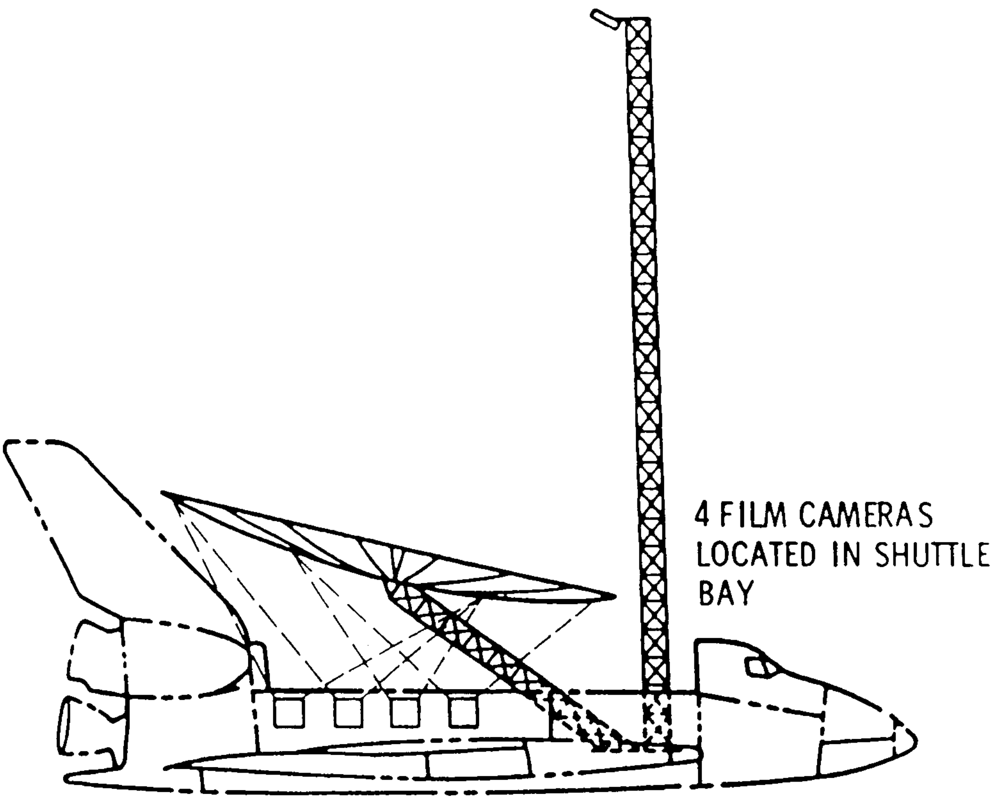
Attached at the root of a subset of the reflector ribs will be a micromotor driven, screw-type actuator. These actuators will be used collectively to adjust the rib positions and thus the reflector shape. They will be capable of single DOF rotation of the rib-root so as to cause translation of the rib tip in the direction perpendicular to the plane of the reflector surface. Attached to the feed plane will be translational and rotational actuators to control the feed position in three DOF and the orientation in two DOF. These actuators will be used for static control of the position and orientation of the feed relative to the reflector hub after the fee mast is deployed. Attached to the feed and dish booms at the appropriate locations will be accelerometers and proof mass actuators. The accelerometers, along with the control algorithms, will provide the commands to drive the proof mass actuators for dynamic control of the feed-hub line-of-sight jitter.



PHOTOGRAMMETRY

The purpose of the photogrammetry subsystem is to characterize the reflector static shape. The subsystem will locate a large number of points on the mesh and ribs defined by a retroreflective target attached to that point. The number of points that can be measured is limited by the range of change in position resulting from shape distortion. The envelope of possible locations of one point must not enter the envelope of adjacent points. An additional limit to the number of measurement points may be the available mesh packing volume to handle the retroflector array.

Three film cameras located in the Shuttle bay will be mounted in position to measure the underside of the reflector (mesh, ribs, and hub) to cover the central 10 meters. An additional camera is required to measure the full 20 meters to the desired accuracy. Approximately 130 frames of film are available per camera. The film is processed post-flight to yield approximately 1500 points on the antenna mesh to a location accuracy of 0.2 mm rms.

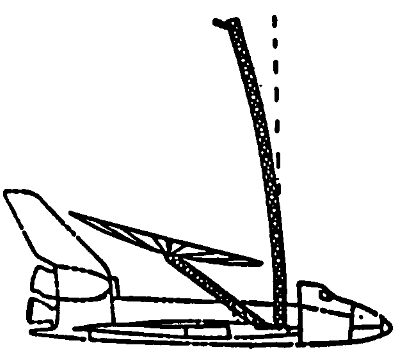


PHOTOGRAMMETRY SUBSYSTEM

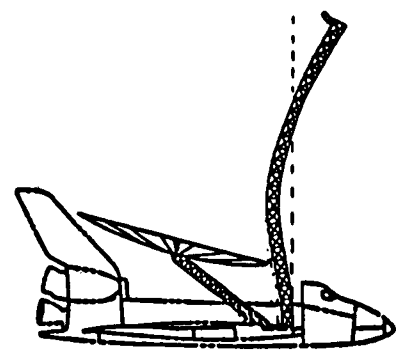
STRUCTURE CONTROL DYNAMICS IDENTIFICATION

Dynamics Identification: An initial wideband characterization of the antenna system dynamic response to induced disturbances will be performed after the passive behavior of the antenna has been measured and analyzed (to first order). Induced impulsive disturbances, encompassing the range expected during the period of the experiment, will be made utilizing controlled VRCS and/or RCS thruster firings. Measurement of the antenna dynamic response will be made via accelerometers placed at the appropriate locations on the feed and reflector booms to determine the nominal, modal frequencies and damping. The wideband data will be used to initialize more precise narrowband excitation using proof-mass actuators located on the antenna and feed booms. Results of the narrowband-frequency-domain modal estimates and transfer functions will be used to optimize the subsequent inputs for recursive-time-domain algorithms, and for data-block-MIMO identification methods such as Maximum Likelihood Estimation. Data processing will be done by the ground payload operations control, with parameter updates transmitted to on-board controllers.

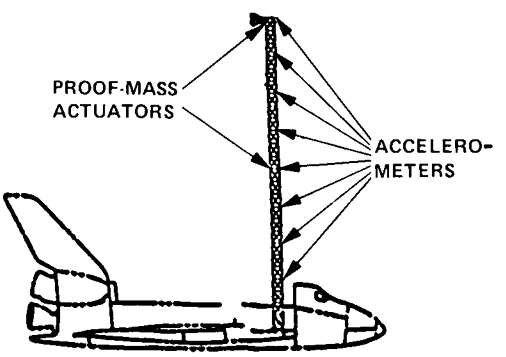
Pointing and Vibration Damping Control: The purpose of this experiment is to demonstrate that the feed-reflector alignment can be actively controlled to reduce inherent perturbations. This will be accomplished using proof mass actuators on the feed and dish booms to control the structure's oscillations and the feed plane actuators to control the feed-hub line-of-sight position. Data obtained from the characterization experiment may be evaluated in mission time and used to adjust and tune the onboard control models. A series of active pointing and jitter suppression experiments will be performed that include both regulation and tracking control laws.



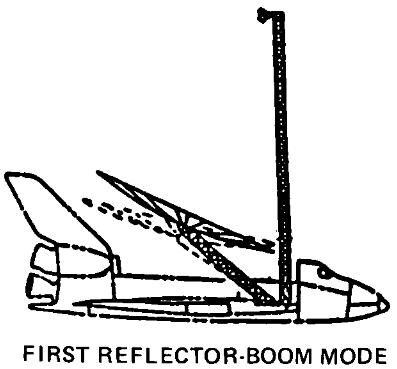
FIRST FEED-BOOM MODE (1.01 HZ)



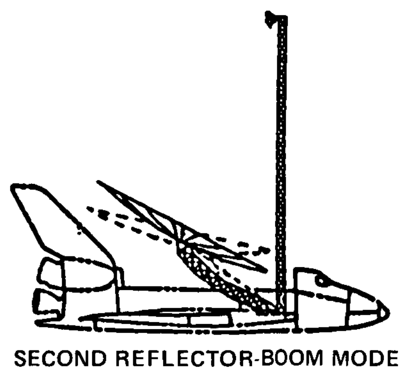
SECOND FEED-BOOM MODE (6.60 HZ)



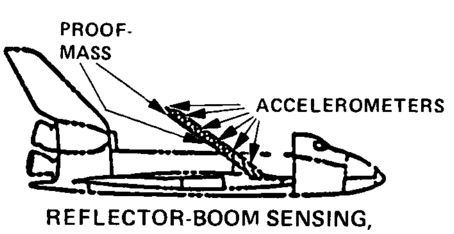
FEED BOOM SENSING, ACTUATION



FIRST REFLECTOR-BOOM MODE
(2.26 HZ)



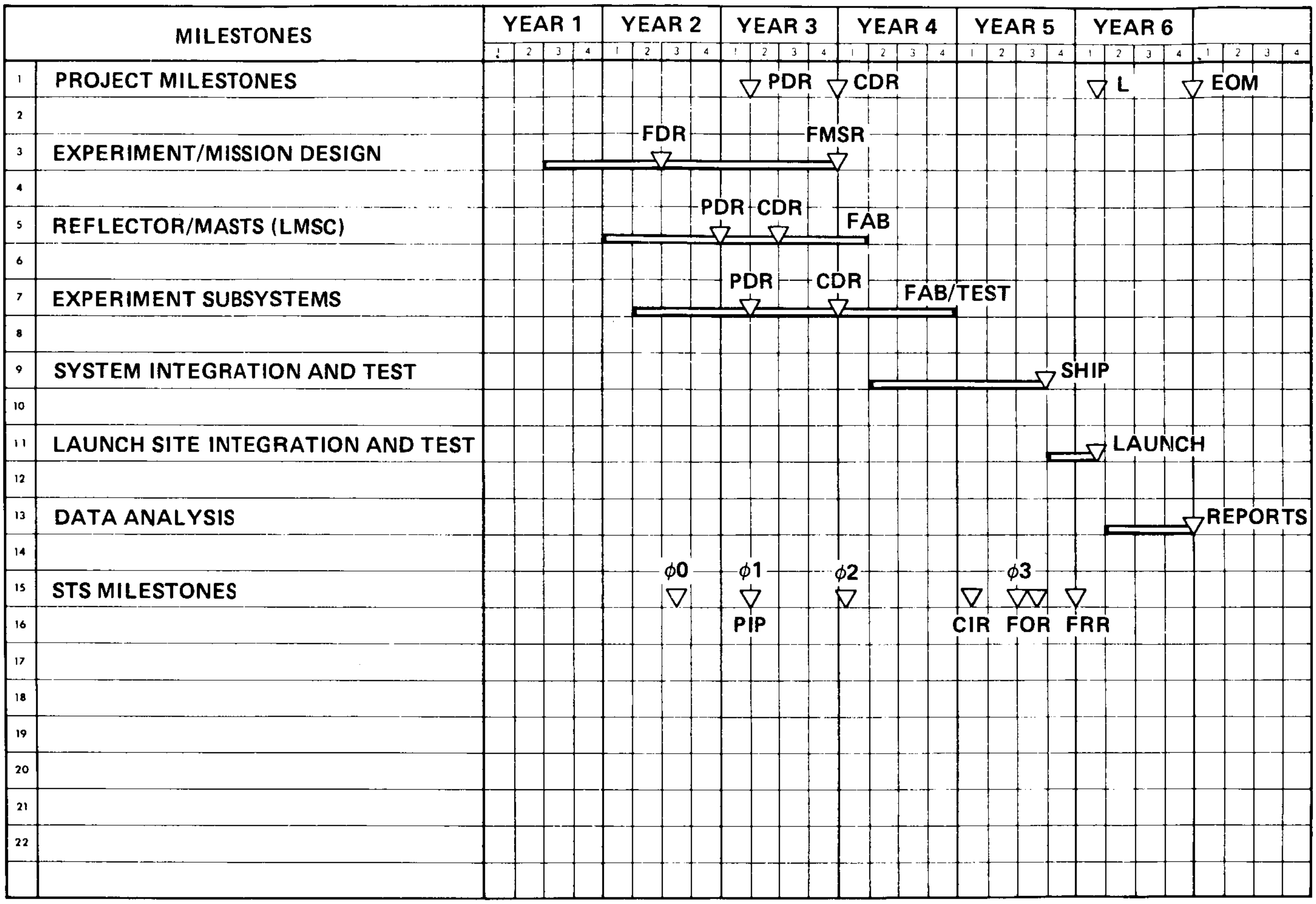
SECOND REFLECTOR-BOOM MODE
(9.52 HZ)



REFLECTOR-BOOM SENSING,
ACTUATION

PROJECT MASTER SCHEDULE

The master schedule for this flight experiment shows that Year 1 would consist of preproject studies and analyses followed by a project start in Year 2. The project would take roughly four years to the launch and flight experiment in Year 6. A significant amount of data analysis and modeling would follow the experiment itself.



CONCLUSIONS FROM THE FY '86 ATSE STUDIES

The studies conducted at JPL and Lockheed over the past year have concluded that a flight experiment of a relatively large mesh deployable reflector is achievable with no major technological or cost drivers. The test article and the instrumentation are all within the state of the art and in most cases rely on proven flight hardware. Every effort was made during the course of the studies to design the experiments for low cost, either through hardware inheritance or design simplicity. The net result is an experiment design which is relatively low in cost yet achieves the global objectives of the project, which were to enable new applications of large deployable space antennas and to advance the state of the art in the structural, control, and RF aspects of these antenna systems.

- ANTENNA EXPERIMENT IS TECHNICALLY FEASIBLE
  - NO TECHNICAL "SHOW-STOPPERS"
  - EXPERIMENT WOULD ENABLE NEW APPLICATIONS
  - EXPERIMENT WOULD ADVANCE TECHNOLOGY STATE OF THE ART