JPL ANALYTICAL PERFORMANCE PREDICTION CAPABILITY

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JPL Analytical Performance Prediction Capability

OBJECTIVES

The basic long term objective of this task is for JPL to develop simplified analytical capability for the simulation and prediction of performance for large deployable antenna structures. This capability, in the form of a computer code, is expected to account for all phases of hardware use, i.e., ground handling, boost, deployment, on-orbit station keeping, and transfer from LEO to GEO, if applicable. In addition to accounting for static and dynamic loading of the basic structure, the variation in the precision of the reflector surface and the alignment of the feed support structure as a function orbit must be understood and quantified to accommodate electromagnetic analysis.

This development activity is expected to involve the application of the state-of-the-art analysis capability, modification of this capability, the development of entirely new capability and the application of the subject technology by specific antenna structures.

JPL ANALYTICAL PERFORMANCE PREDICTION CAPABILITY
OBJECTIVES

LONG TERM

TO DEVELOP SIMPLIFIED ANALYTICAL CAPABILITY
FOR THE SIMULATION AND PREDICTION OF PERFORMANCE
FOR LARGE DEPLOYABLE ANTENNA STRUCTURES

FY 79

TO DEVELOP ANALYTICAL APPROACHES AND TO INITIATE
THE DEVELOPMENT OF A SIMPLIFIED INTERACTIVE PROGRAM
FOR LARGE DEPLOYABLE ANTENNA STRUCTURES

Specific Tasks

Five tasks were established at the beginning of FY'79 as guidelines for accomplishing objectives.

A. The task involves identifying antenna structures and environment based upon results of recent NASA mission model studies and the specific antennas selected for development from the Wrap-Rib and Precision Deployable Conceptual Development Studies.

B. Construct models to demonstrate computer code capabilities, new capability required, and to establish bases for integrated analysis studies.

C. Investig te different modes for accomplishing structural/thermal coupling based on dissimilar requirements on models used for structural and thermal analyses.

D. Supply dynamic models describing typical modal data to Controls Division to establish interdisciplinary dialogue between Structures and Controls engineers.

E. Determine structural, thermal and dynamic response in terms of structural loading and reflector surface distortion.

SPECIFIC TASKS

A. IDENTIFY CHARACTERISTIC ANTENNA STRUCTURES AND APPLICATIONS

B. DEVELOP ANALYTICAL MODELS

C. DEVELOP APPROACH FOR STRUCTURAL/THERMAL COUPLING CAPABILITY

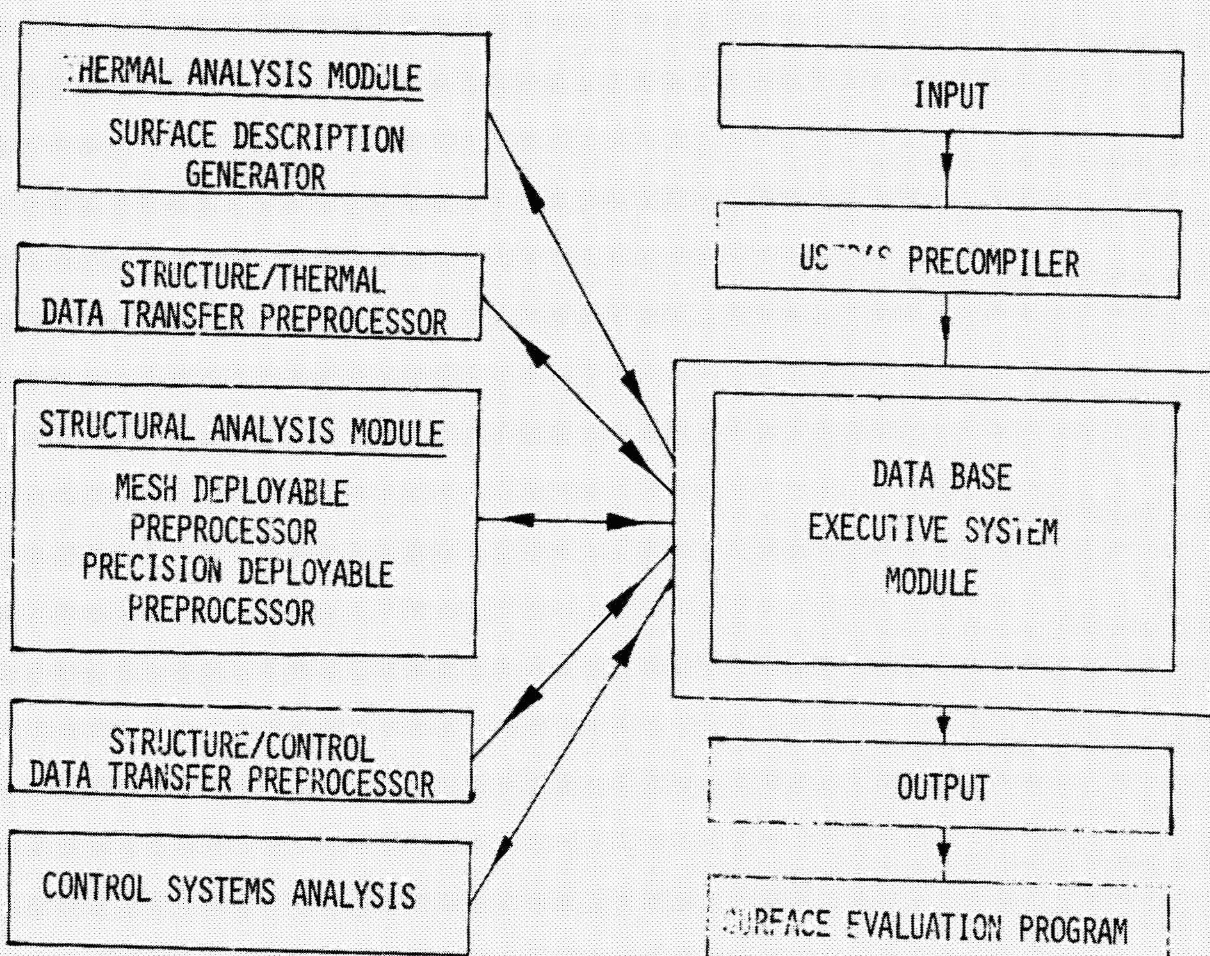
D. DEVELOP APPROACH FOR STRUCTURAL/CONTROL COUPLING CAPABILITY

E. CHARACTERIZE AND DETERMINE IMPACT OF EXTERNAL DISTURBANCES

Preliminary Plans

A preliminary plan for an analytical program resulting in mid-FY'79 features a centralized data base executive system to be commanded by the user using a precompiler signaled from input information. The data base executive system is capable of storing, managing, indexing, and recalling large amounts of data connecting and sequencing the required analysis tools of various disciplines for proper execution. This feature stresses versatility as well as flexibility in handling interactive analyses for varieties of LSST systems.

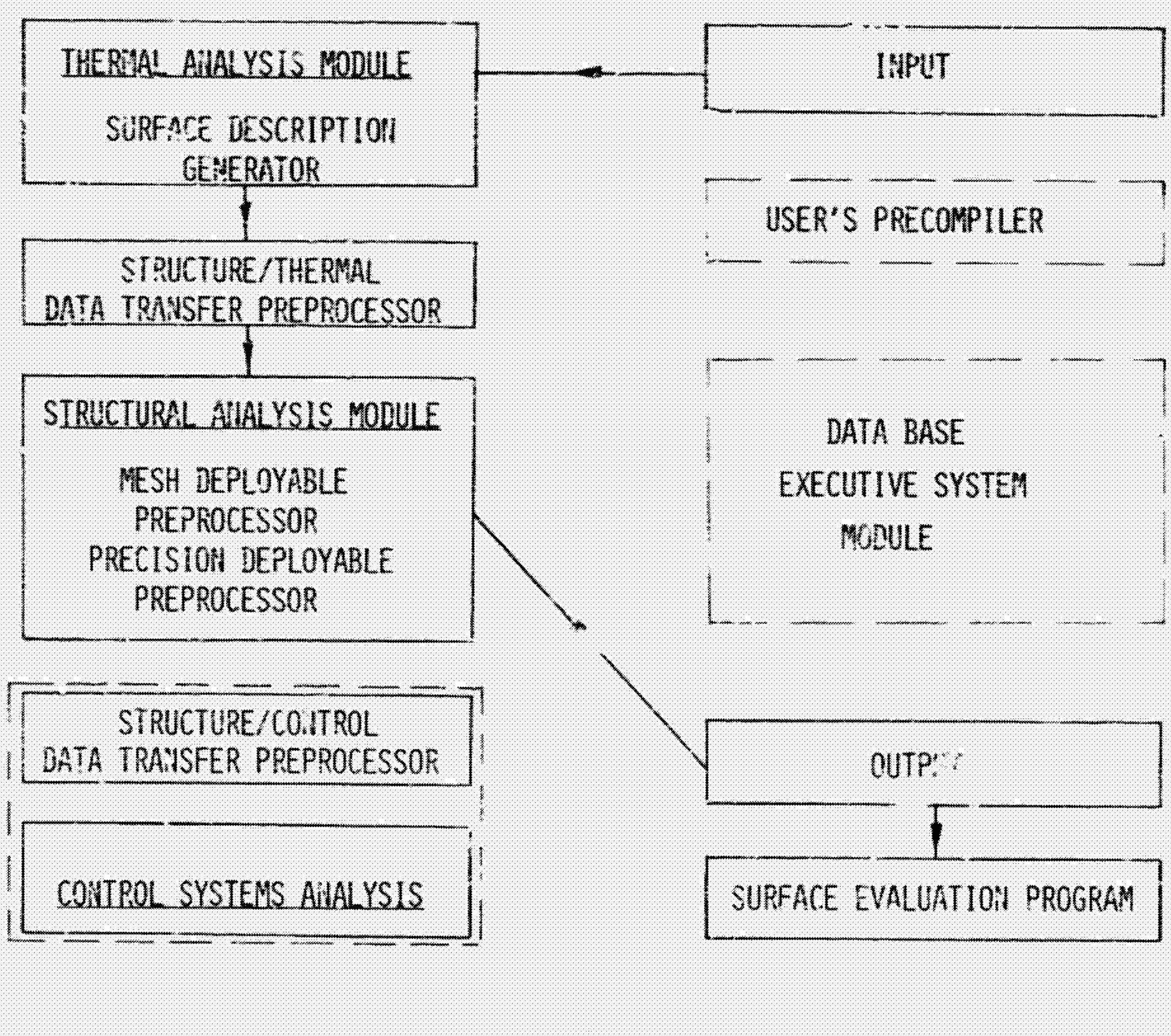
LSST - STRUCTURAL CONCEPT - DEPLOYABLE REFLECTORS
SIMPLIFIED INTERACTIVE ANALYSIS COMPUTER PROGRAM



Near Term Plan

The near term (FY'80) objective for implementation of the proposed approach is described in the following figure. The current plan is to develop a thermal/structural analysis capability specifically tailored for the wrap-rib deployable antenna since development of precision deployable antenna has been terminated. In this plan the approach for the structural/controls integrated analysis will be completed in FY'80. Since the analytical capability will be focused only on the mesh deployable antenna, a data base management system is not required here.

NEAR TERM PLAN



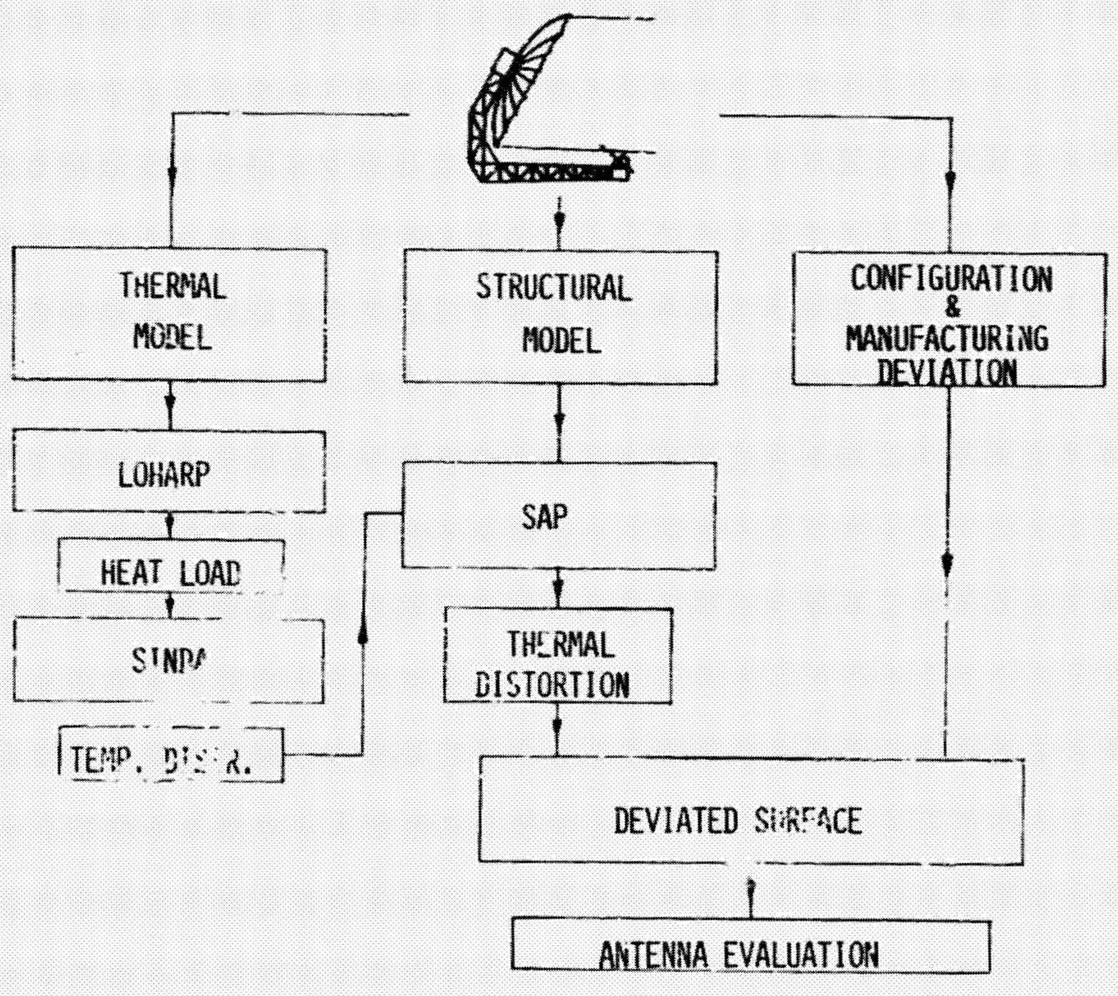
Thermal/Structural Analysis Computer Program

The computer program for the evaluation of thermally distorted wrap-rib antenna consisted of the following main components:

1. LOHARP code to compute heat load input.
2. SINDA code to compute temperature distribution.
3. SAP finite element program to compute thermal/structural distortion.
4. JPL RMS program to compute the total surface RMS deviation to be used in Ruze's formula for evaluation.

Necessary modifications to these programs are to be shown on the following figures.

MESH DEPLOYABLE ANTENNA THERMAL/STRUCTURAL COMPUTER PROGRAM



Mesh Deployable Antenna Thermal Analyzer

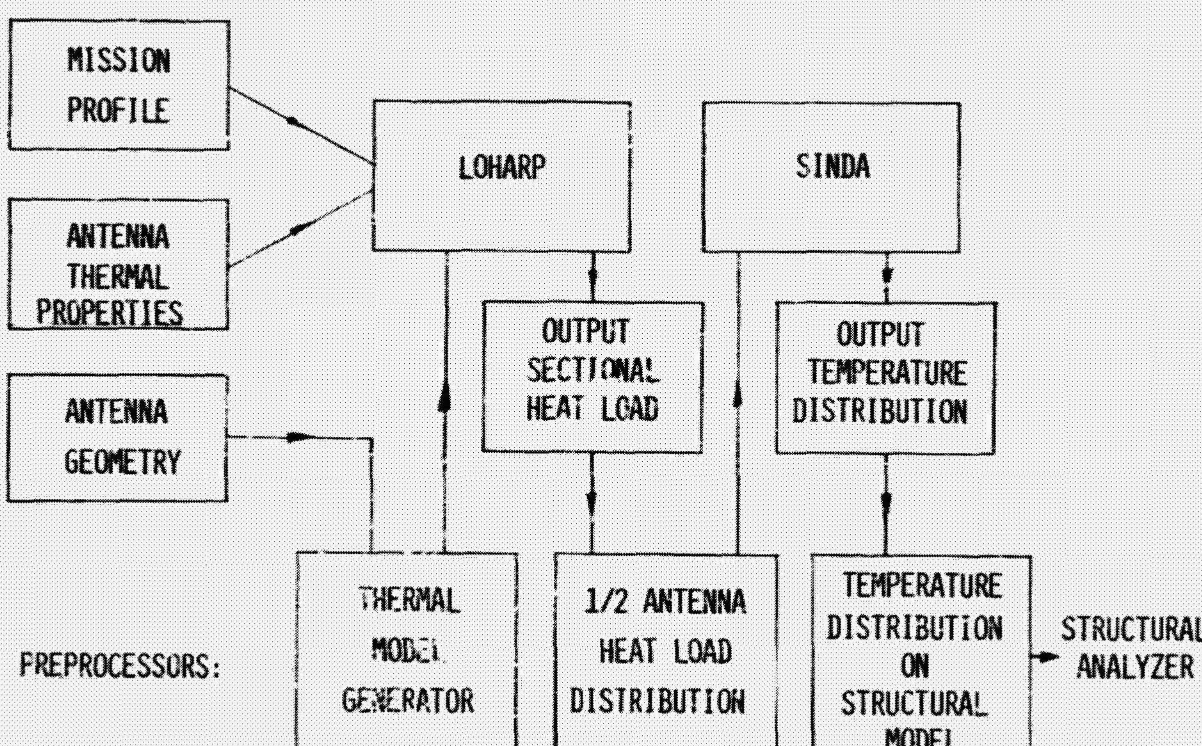
Three main preprocessors are required to integrate the input information and the computer codes:

1. A preprocessor to generate all surface descriptions of a wrap-rib paraboloid antenna surface. Because of the LOHARP code core limitation, the surface view factors and the radiation exchange factors and therefore the heat loads will be computed on sections of antenna only.

2. A preprocessor to collate the sectional heat loads and compiles the results to yield heat load distribution on a half antenna for use of SINDA code.

3. A preprocessor to transfer temperature distribution information on thermal model to appropriate nodal points of the structural model for use of the structural analyzer.

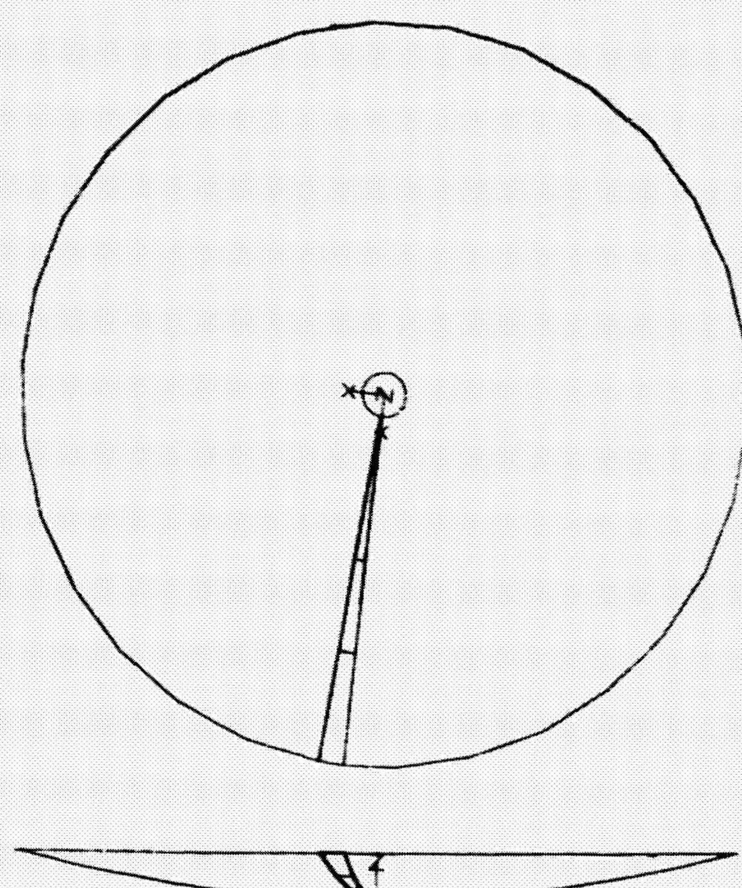
MESH DEPLOYABLE ANTENNA THERMAL ANALYZER



Thermal Model

This figure illustrates a plane and side view of the thermal model of wrap-rib mesh deployable antenna used to find solar and planetary induced heat loads on rib and mesh nodes. As may be seen, only two ribs and included mesh are modeled at one time. The mesh of the rest of the antenna is included for shading purposes only. Heat loads on all other pairs of ribs are found by mathematically rotating the structure shown about the axis by an amount equal to the angle between ribs.

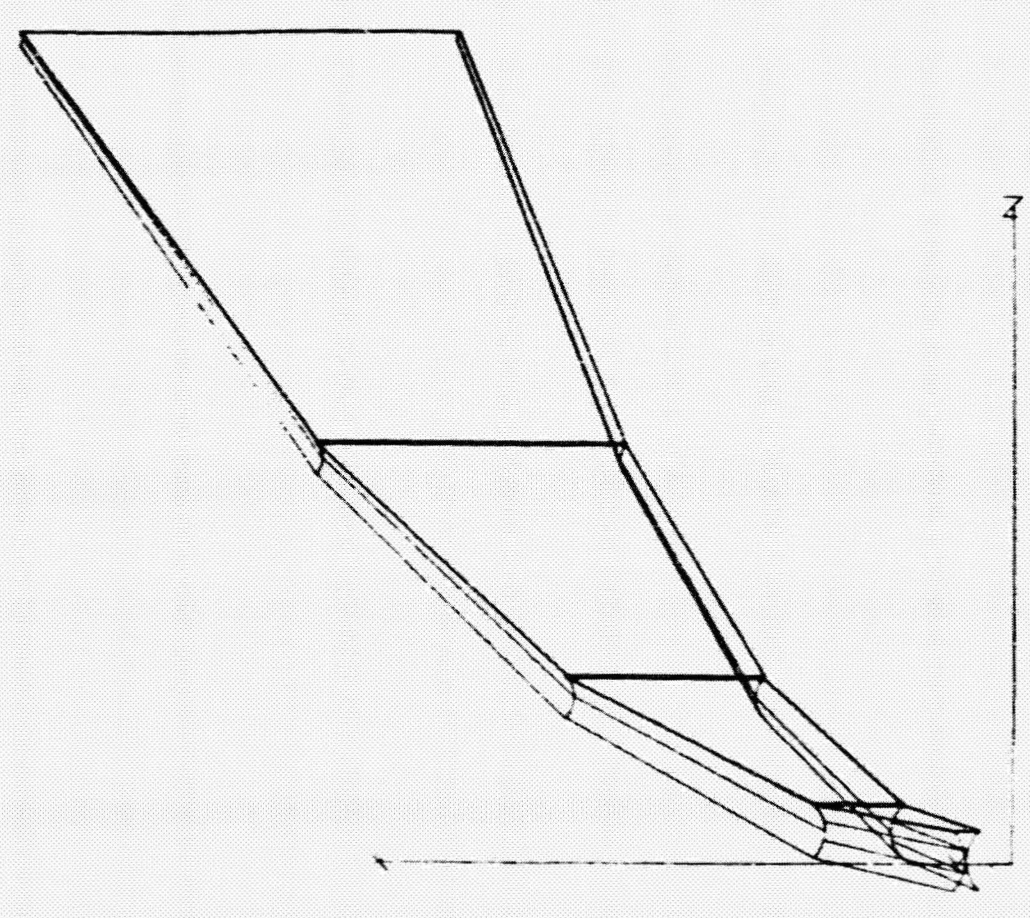
THERMAL MODEL



Thermal Model of Outside of Two Adjacent Ribs and Included Mesh

This figure is a close up of the adjacent rib sections appearing in the previous figure. The section shown here is an accurate representation of the actual rib and included mesh surface for a particular set of geometric parameters, and was automatically generated by the preprocessor program given minimal input. View factors and radiant energy interchange factors between the exterior surfaces of adjacent ribs are computed once and subsequently used for all pairs of adjacent ribs.

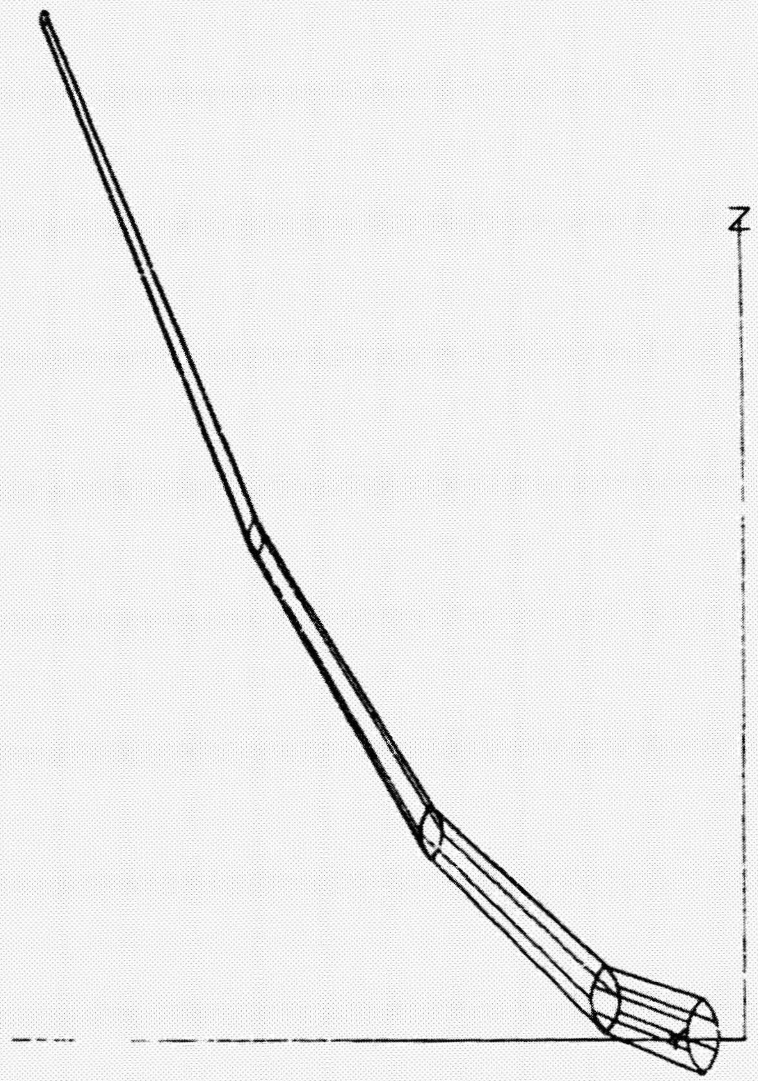
THERMAL MODEL OF OUTSIDE OF
TWO ADJACENT RIBS & INCLUDED MESH



Thermal Model of the Inside of A Single Rib

This figure illustrates the thermal model of one single complete rib and is used to determine view factors and radiant energy interchange factors for intrarib heat transfer. The mathematical model of the single rib is also automatically generated by the preprocessor code. Solar and planetary heat loads do not impinge on the interior surfaces of the rib due to the opaqueness of the rib and multi-layer thermal blanket.

THERMAL MODEL OF THE INSIDE OF A SINGLE RIB

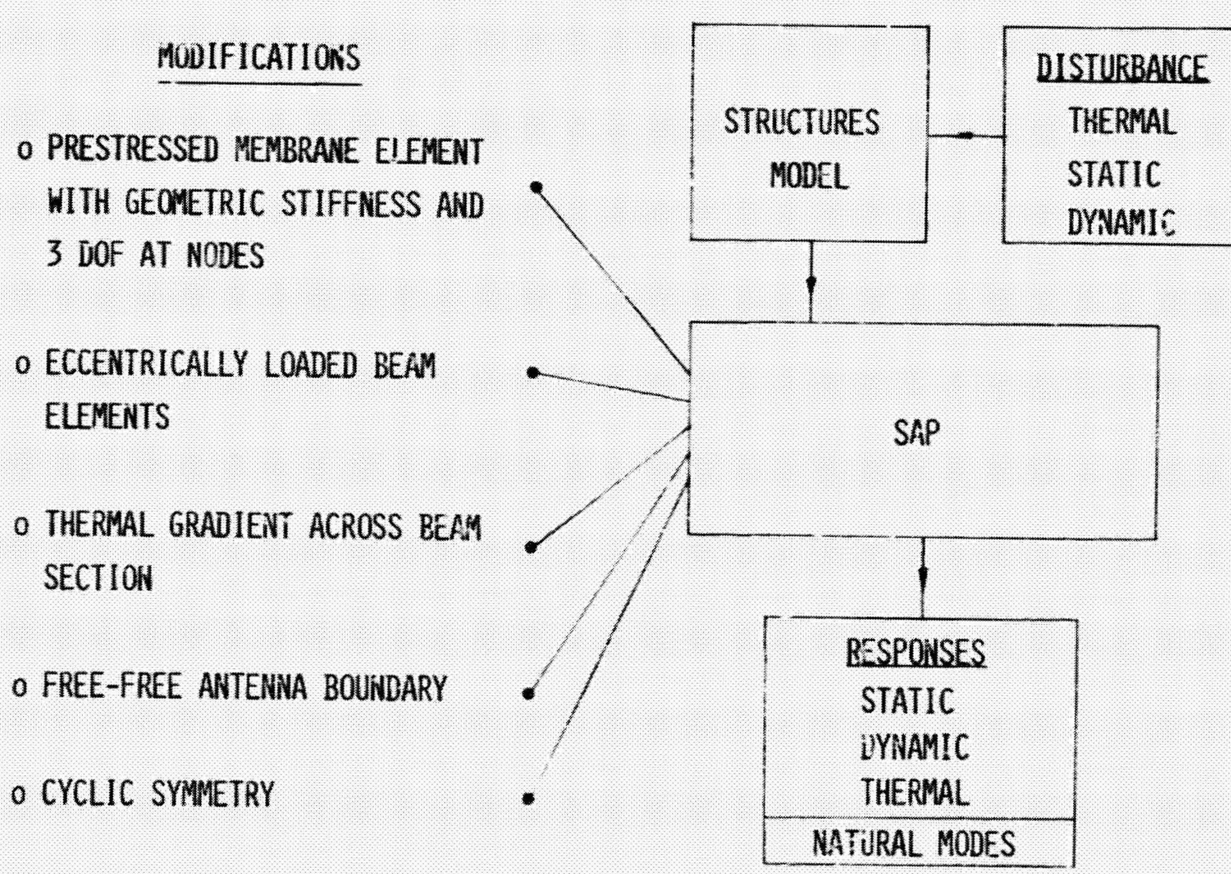


Deployable Reflector Structural Analyzer

Deployable reflectors employ tension type structural components which are in general made from materials having nonlinear elastic properties. For a practical and simplified tool, tension only membrane element is developed by modifying bending elements in the SAP finite element code. The nonlinear behavior of the membrane element is simulated using the perturbation method based upon small linear changes from the undisturbed configuration, the undisturbed configuration being the initial state where the mesh is stretched at the designed pre-stress. The result is a stretched membrane that has a geometric stiffness which gives additional out-of-plane rigidity resulting from the inplane tensile stress.

Other modifications to the structures code include adding capabilities to handle thermal gradients across the rib cross sections, eccentrically applied rib loads, vibrations of the freely supported reflectors, and a cyclic symmetric feature for reducing model size and therefore the computer running time.

MESH DEPLOYABLE REFLECTOR STRUCTURAL ANALYZER



Structural Model 30 Meter Precision Deployable Antenna

A NASTRAN structural model using the 30-m diameter advanced Sunflower antenna concept was constructed. This model was used primarily to obtain samples of structural dynamic characteristics for investigating controls requirements on this type of antennas.

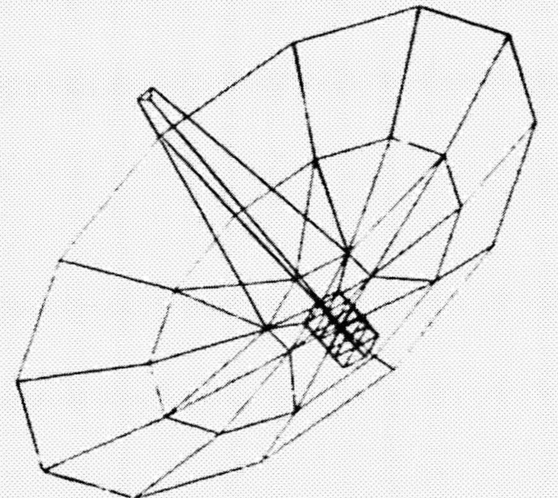
The reflector is assumed to be consisted of aluminum honeycomb panels with 1" core and .020" face sheets. The antenna feed is a triangular plate of the same material, supported by three 16" dia. X .125" w.t. aluminum tubes. A simplified hexagonal spacecraft bus of approximately 100" cube in size is assumed to be attached to the reflector with six aluminum tubes of the same size as the feed supports. The bus and supports have been sized to yield a total weight of 3167 lb.

STRUCTURAL MODEL

30 METER PRECISION DEPLOYABLE ANTENNA

FREQUENCY Hz	MODE
0.00	RIGID-BODY TRANSLATIONS
0.00	RIGID-BODY ROTATIONS
0.43	REFLECTOR BENDING
0.62	FEED SUPPORT TORSION
0.66	REFLECTOR BENDING
0.69	" "
0.95	" "
0.95	" "
1.04	" "
1.23	" "
1.48	FEED STRUCTURE BENDING
6.89	FIRST OVERALL BENDING
6.89	" " "

- o F/D = 0.5
- o FLEXIBLE SPACECRAFT
- o AXISYMMETRIC FEED



Structural Model 100 Meter Mesh Deployable Antenna

A NASTRAN structural model of a 100 meter mesh deployable antenna using a wrap-rib reflector was constructed. The model consists of 30 tapered ribs of lenticular cross-section made of graphite-epoxy layup. The roots of the ribs are attached to an aluminum central hub which also supports the feed with a tripod of aluminum tubes extended to a distance of 100 meters long.

The mesh membrane reflector surface presented special modeling problems. The normal stiffness of the reflector is contributed purely by the stretching of the mesh membrane which occurs only when the reflector is deployed. This differential or geometric stiffness is not accounted for in the stiffness matrix of conventional finite membrane elements in NASTRAN. To simulate this property, artificial thermal loads were introduced to the model. This generates element differential stiffness terms which were then added to the stiffness matrices for the ribs and mesh to produce the total reflector stiffness properties of the reflector.

STRUCTURAL MODEL
100 METER MESH DEPLOYABLE ANTENNA

FREQUENCY Hz	MODE
0.00	RIGID-BODY TRANSLATIONS
0.00	RIGID-BODY ROTATIONS
.053	REFLECTOR "UMBRELLA" MODE
.065	FEED SUPPORT BENDING
.073	REFLECTOR BENDING
.094	REFLECTOR TORSION
.096	REFLECTOR BENDING
.118	REFLECTOR BENDING
.140	REFLECTOR BENDING
.150	REFLECTOR TORSION

- F/D = 1.0
- AXISYMMETRIC FEED
- "WRAP-RIB" REFLECTOR