CABLE-CATENARY LARGE ANTENNA CONCEPT

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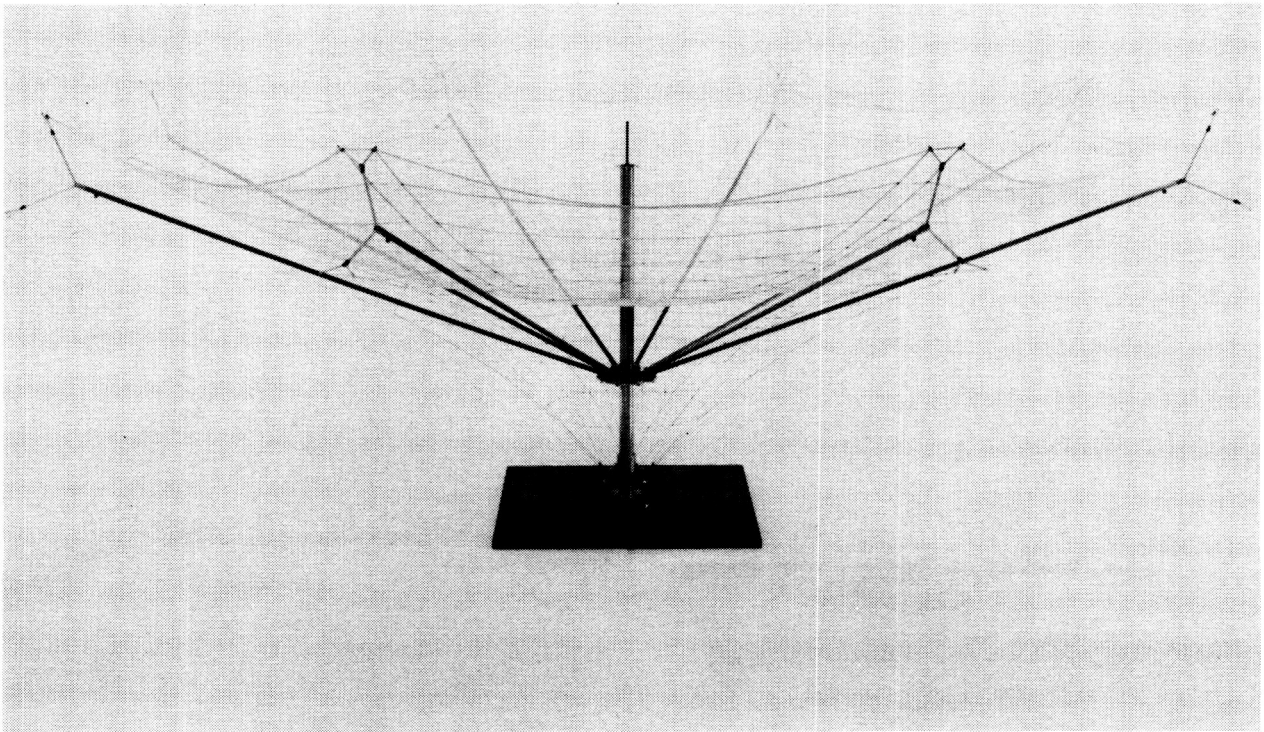
LARGE SPACE ANTENNA SYSTEMS TECHNOLOGY
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THE CABLE-CATENARY ANTENNA

The cable-catenary antenna (CCA) has been under study by TRW since the late 60's. It is deployable to very large diameters (over 1000 ft), while still remaining compatible with a complete satellite system launch by the STS.

The figure shows a 10 ft. working model of the CCA. Its main elements are:

- 8 radial, deployable boom masts
- A deployable hub and feed support center mast
- Balanced front and back, radial and circumferential catenary cabling for highly accurate (mm) surface control
- No interfering cabling in the antenna field
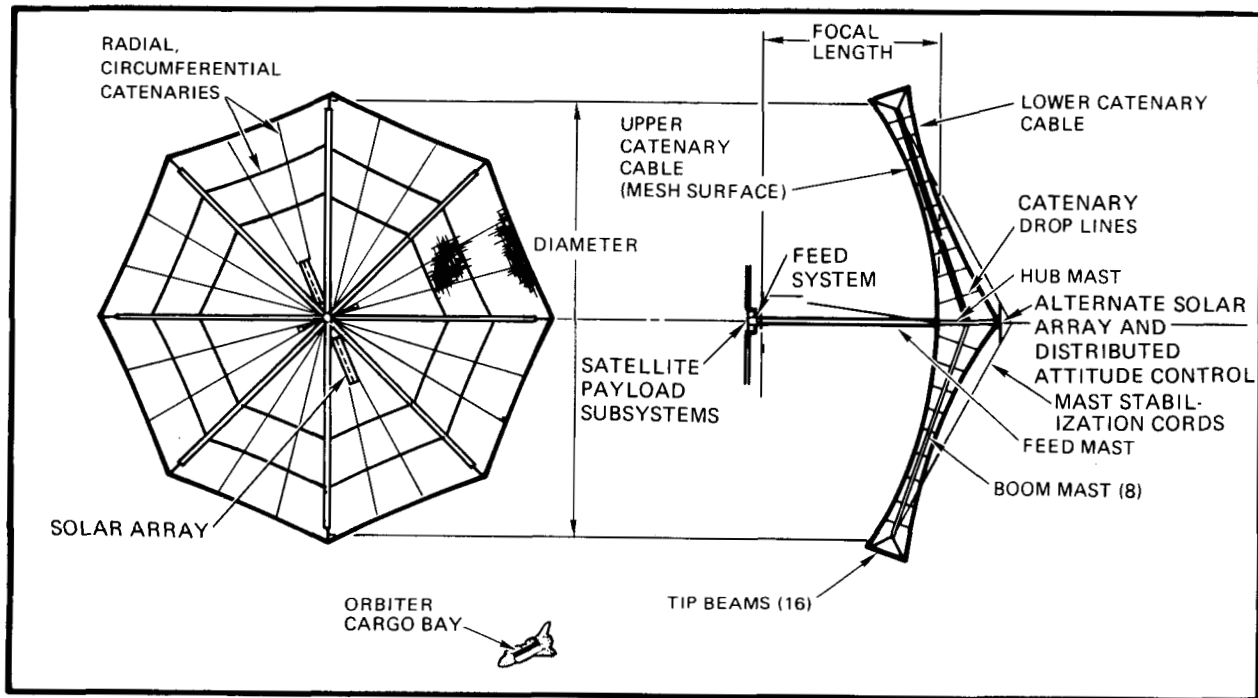- An RF reflecting mesh supported on the front catenaries

CABLE–CATENARY ANTENNA – SATELLITE SYSTEM
DEPLOYED CONFIGURATION

The CCA is shown deployed in a typical large communication satellite configuration.

The satellite main bus is located behind the focal plane (feeds). To preclude antenna aperture shadowing, the solar array wings can be extended further. Attitude control authority can be enhanced by locating control thrusters far appart at the ends of the center mast.

The number of catenaries to form the reflector plane is dependent on the required operating frequency and sidelobe control.
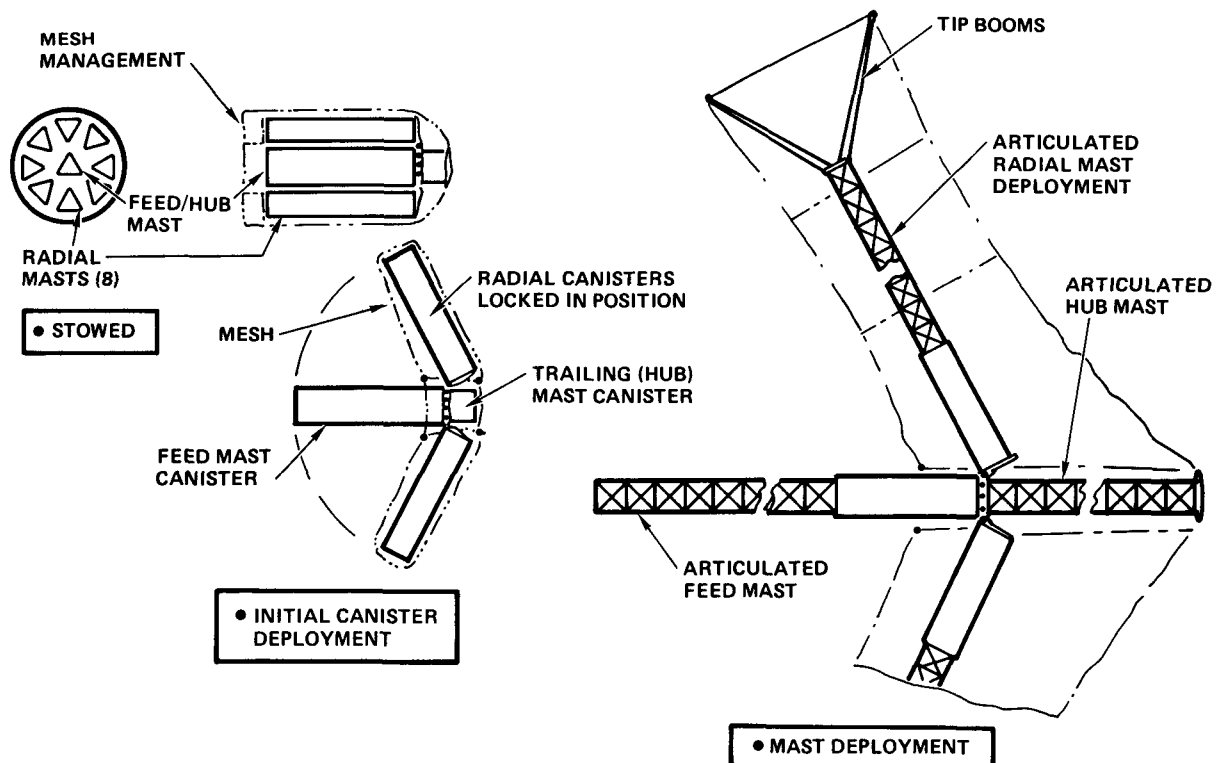
In the stowed condition, the CCA radial mast canisters are rotated against and clustered around the center mast canister. The mesh management system is stowed in between and around the mast canisters.

Deployment starts by rotation of the radial mast canisters into position, with the mesh system following this motion. The tip booms are then extended radially from their stowed position in the canisters.

The feed mast is then deployed. All masts are triangular, articulated truss structures. Following this, the radial masts are deployed, with the mesh playout controlled by the mesh management system.

The mesh management also lends itself to surface accuracy adjustments after the CCA is deployed.

CABLE-CATENARY ANTENNA SATELLITE SYSTEM - STOWED CONFIGURATION

The CCA stows very compactly; less than 10 ft. length for a 300-m aperture. This feature, coupled with a sturdy canister cluster, allows for efficient integration in the Orbiter cargo bay of the complete spacecraft and its Orbital Transfer Vehicle (OTV).

The OTV illustrated is in the Centaur G class; a length allowance of 22 ft is assumed. This leaves approximately 25 ft of effective length for the spacecraft bus and payload. On this basis, the system may be weight limited rather than length/volume limited in the Orbiter cargo bay.

CABLE-CATENARY ANTENNA - DESIGN ANALYSIS LOGIC

The CCA design and sizing analysis is based on dimensional constraints, payload RF requirements, spacecraft mass distribution, and control bandwidth. The process is automated using an internally developed optimization program called LADSGN. Its logic is shown in the figure.
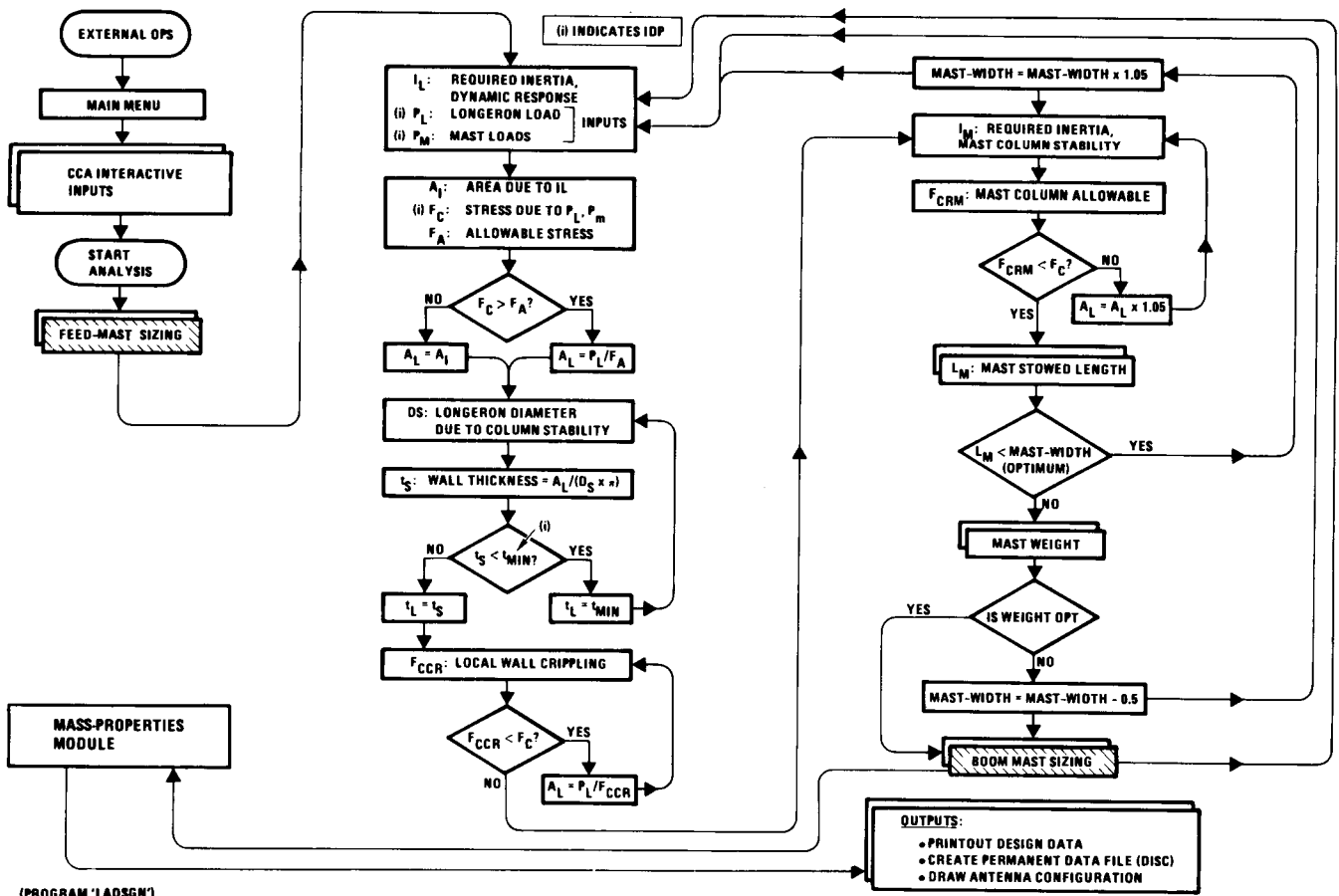
Inputs are of two types: 1) screen interactive (run time), and 2) internal program parameters that are variable for further parametric analysis.

The analysis then considers static loads, dynamic response lower limits, and material properties. Iterative convergence loops are used to satisfy all the system requirements, including stowed dimensional limits imposed by the Orbiter.

EXTERNAL OPS

MAIN MENU

CCA INTERACTIVE INPUTS

START ANALYSIS

FEED-MAST SIZING

MASS-PROPERTIES MODULE

(PROGRAM 'LADSGN')

(i) INDICATES IDP

I_L: REQUIRED INERTIA, DYNAMIC RESPONSE
(i) P_L: LONGERON LOAD ⎤ INPUTS
(i) P_M: MAST LOADS ⎦

A_I: AREA DUE TO IL
(i) F_C: STRESS DUE TO P_L, P_m
F_A: ALLOWABLE STRESS

$F_C > F_A$?
NO   YES

$A_L = A_I$ $A_L = P_L/F_A$

DS: LONGERON DIAMETER DUE TO COLUMN STABILITY

t_S: WALL THICKNESS = $A_L/(D_S \times \pi)$

$t_S < t_{MIN}$? (i)
NO   YES

$t_L = t_S$ $t_L = t_{MIN}$

F_{CCR}: LOCAL WALL CRIPPLING

$F_{CCR} < F_C$?
NO   YES

$A_L = P_L/F_{CCR}$

MAST-WIDTH = MAST-WIDTH x 1.05

I_M: REQUIRED INERTIA, MAST COLUMN STABILITY

F_{CRM}: MAST COLUMN ALLOWABLE

$F_{CRM} < F_C$?
YES   NO

$A_L = A_L$ x 1.05

L_M: MAST STOWED LENGTH

$L_M <$ MAST-WIDTH (OPTIMUM)
NO   YES

MAST WEIGHT

IS WEIGHT OPT
YES   NO

MAST-WIDTH = MAST-WIDTH - 0.5

BOOM MAST SIZING

OUTPUTS:
• PRINTOUT DESIGN DATA
• CREATE PERMANENT DATA FILE (DISC)
• DRAW ANTENNA CONFIGURATION

CABLE-CATENARY ANTENNA - SIZING ANALYSIS OUTPUT

The analysis results in the figure consist of the input system parameters and the output dimensional and weight data for all the critical CCA elements. Detailed mass properties are generated for use by other program modules, such as attitude control.

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                                        09:31:58  20 Oct 1983
              'LADSGN' PROGRAM  ,Wade AKLE  , VERSION 1.1

                   ******* CABLE-CATENARY ANTENNA SIZING ANALYSIS *******
              ANTENNA DIAMETER                    (Ft)=  100
              FOCAL LENGTH/DIAMETER (F/D)            =  .6
              OPERATING RF FREQUENCY            (GHz)=  2
              SURFACE ACCURACY (WAVELENGTH/MAX ERROR)=  16
              MAIN ELEMENT STRUCTURAL  RESPONSE  (Hz)=  .1
               OPERATING RF WAVELENGTH           (Ft)=  .5
              NUMBER OF GORES                       =  14
              OFF-POINTING ANGLE FROM NADIR     (Deg)=  8
              ====================================================
              MASTS SIZED TO OPTIMIZE WEIGHT, WITHIN MAX ALLOWED WIDTH
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===== FEED_MAST DESIGN DATA OUTPUT:              ===== CATENARY BOOM-MAST DESIGN DATA OUTPUT:
   MAST DESIGNED BY LONGERON BUCKLING DUE TO GENERAL   MAST DESIGNED BY LONGERON BUCKLING DUE TO GENERAL
   COMPRESSIVE MAST LOADS (Lb)=    1700              COMPRESSIVE MAST LOADS (Lb)=    1269
   MATERIAL ALLOWABLE STRESS IS CRITICAL!           MATERIAL ALLOWABLE STRESS IS CRITICAL!

   MAST DEPLOYED LENGTH         (Ft)= 67             MAST DEPLOYED LENGTH          (Ft)= 50
    MAST STOWED LENGTH          (Ft)=  2.6            MAST STOWED LENGTH           (Ft)=  1.9
   MAST BAY WIDTH=BAY HEIGHT    (Ft)= 1              MAST BAY WIDTH=BAY HEIGHT     (Ft)= 1
      NUMBER OF BAYS             =    67                NUMBER OF BAYS              =    50

   LONGERON DIAMETER (Ft)= .0289                     LONGERON DIAMETER (Ft)= .0251
   LONGERON THICKNESS(Ft)= .00140                    LONGERON THICKNESS(Ft)= .00239

   CANISTER WEIGHT   (Lb)=   19.0                    CANISTER WEIGHT   (Lb)=   19.0
   LONGERON WEIGHT   (Lb)=   15.4                    LONGERON WEIGHT   (Lb)=    4.8
   BATTENS  WEIGHT   (Lb)=    7.7                    BATTENS  WEIGHT   (Lb)=    2.4
   DIAGONALS WEIGHT  (Lb)=    4.4                    DIAGONALS WEIGHT  (Lb)=    2.5
   JOINTS   WEIGHT   (Lb)=   22.1                    JOINTS   WEIGHT   (Lb)=   16.5
   MECHANISM WEIGHT  (Lb)=   12.0                    MECHANISM WEIGHT  (Lb)=   12.0
   =========== TOTAL MAST WEIGHT (Lb)=        80     =========== TOTAL MAST WEIGHT (Lb)=        57
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              ***** CABLE-CATENARY ANTENNA MASS PROPERTIES *****

          ANTENNA MESH MESH WEIGHT        (Lb)=     19
                   RADIAL CATENARIES WEIGHT  =      12
                   CIRCUMFERENTIAL CATENARIES=       2
                   TIP MASTS WEIGHT          =      81
                   MECHANISMS WEIGHT         =       7
          -------------------------------------------------
              TOTAL ANTENNA WEIGHT                     (Lb) =  664.
              ANTENNA CG FROM PARABOLA APPEX           (Ft)= +7.0

              ANTENNA INERTIA (PERPENDICULAR TO AXIS) (Lb-Ft^2)=+6.01E+05
              ANTENNA INERTIA (PARALLEL TO AXIS)      (Lb-Ft^2)=+7.27E+05
              ANTENNA CROSS INERTIA                   (Lb-Ft^2)=+0.00E+00
              OFF-POINTING ANGLE FROM NADIR            (Deg)= 8.0
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Program LADSGN is used to generate a variety of CCA parametric design data. Weight and stowed dimensions, sensitivity to focal length, aperture, dynamic response lower limit frequency, and other parameters are illustrated in the figure for low RF frequency (MHz) systems.

The CCA is a highly adaptable design. It is applicable to many of the proposed spacecraft requiring large aperture. The preliminary tools required to support system trades and studies are available including cost analysis.

TRW believes that this concept is competitive and should be considered in system studies considering large antennas.