CABLE-CATENARY LARGE ANTENNA CONCEPT

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LARGE SPACE ANTENNA SYSTEMS TECHNOLOGY
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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
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 apart 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 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.
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.
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.
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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'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)= 0

MASTS SIZED TO OPTIMIZE WEIGHT, WITHIN MAX ALLOWED WIDTH

***** FEED MAST DESIGN DATA OUTPUT:*****

MATERIAL ALLOWABLE STRESS IS CRITICAL!

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MAST DEPLOYED LENGTH (Ft)= 67
MAST STOWED LENGTH (Ft)= 2.6
NUMBER OF DAYS= 67

LONGERON DIAMETER (Ft)= .0289
LONGERON THICKNESS (Ft)= .00140
CANISTER WEIGHT (Lb)= 19.0
LONGERON WEIGHT (Lb)= 15.4
BATTENS WEIGHT (Lb)= 7.7
DIAGONALS WEIGHT (Lb)= 4.4
JOINTS WEIGHT (Lb)= 22.1
MECHANISM WEIGHT (Lb)= 12.0
TOTAL MAST WEIGHT (Lb)= 88

***** CABLE-CATENARY BOOM MAST DESIGN DATA OUTPUT:*****

MATERIAL ALLOWABLE STRESS IS CRITICAL!

MATERIAL ALLOWABLE STRESS IS CRITICAL!

MAST DEPLOYED LENGTH (Ft)= 50
MAST STOWED LENGTH (Ft)= 1.9
NUMBER OF DAYS= 50

LONGERON DIAMETER (Ft)= .0251
LONGERON THICKNESS (Ft)= .00239
CANISTER WEIGHT (Lb)= 19.0
LONGERON WEIGHT (Lb)= 4.0
BATTENS WEIGHT (Lb)= 2.4
DIAGONALS WEIGHT (Lb)= 2.5
JOINTS WEIGHT (Lb)= 16.5
MECHANISM WEIGHT (Lb)= 12.0
TOTAL MAST WEIGHT (Lb)= 57

******* CABLE-CATENARY ANTENNA MASS PROPERTIES *******

ANTENNA MESH MESH WEIGHT (Lb)= 19
RADIAL CATENARIES WEIGHT = 12
CIRCUMFERENTIAL CATENARIES= 2
TIP MASTS WEIGHT = 31
MECHANISMS WEIGHT = 7

TOTAL ANTENNA WEIGHT (Lb)= 66.4
ANTENNA CG FROM PARABOLA APPEX (Ft)= 7.0
ANTENNA INERTIA (PERPENDICULAR TO AXIS) (Lb-Ft*2)= 8.6E+05
ANTENNA INERTIA (PARALLEL TO AXIS) (Lb-Ft*2)= 7.2E+05
OFF-POINTING ANGLE FROM NADIR (Deg)= 8.0

ANTENNA CROSS INERTIA (Lb-Ft*2)= 8.00E+00

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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.