PRECISION SPACE STRUCTURES

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Large Space Antenna Systems Technology - 1984
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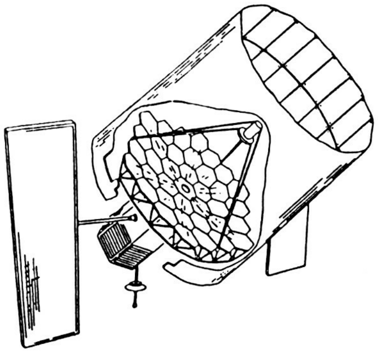
ISSUES

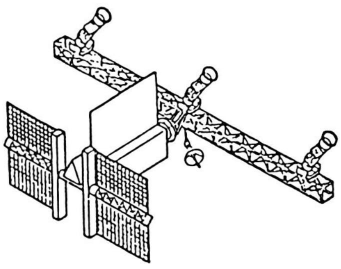
- NASA LARGE SPACE STRUCTURES EFFORTS TO DATE AIMED TOWARDS
  - LARGE, FLEXIBLE ANTENNA-LIKE STRUCTURES (30-100M)
  - RELATIVELY LONG WAVELENGTHS (1-30cm)
  - MODERATE DISTURBANCES LEADING TO SOME STRUCTURE-CONTROL INTERACTION
- NASA ALSO HAS POTENTIAL MISSIONS IN "OPTICS" REGIME
  - SMALLER REFLECTORS/MIRRORS
  - SHORT WAVELENGTHS (VISIBLE TO 100μ)
  - VERY TIGHT TOLERANCES IN SURFACE, ALIGNMENT, POINTING STABILITY
  - POTENTIAL OF CONSIDERABLE ON-BOARD DISTURBANCES
- NEED TO EXAMINE TRANSFERABILITY OF TECHNOLOGY, NEW PROBLEMS

REVIEW OF REQUIREMENTS

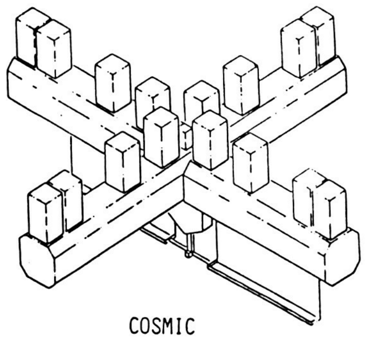
- BASED ON NASA SPACE SYSTEMS TECHNOLOGY MODEL (JAN. 84)
- REVIEW INCLUDED BOTH
  - "MISSION SYSTEMS AND PROGRAMS"
    - APPROVED, PLANNED AND CANDIDATE CONCEPTS
  - "OPPORTUNITY SYSTEMS AND PROGRAMS"
    - GENERALLY POST-1995 SYSTEMS
- "PRECISION SYSTEMS" < 100μ OPERATIONAL WAVELENGTH
- REVIEW TO IDENTIFY STRUCTURE-CONTROL INTERACTION POTENTIAL
  - FIGURE (SURFACE) CONTROL
  - VIBRATION (ALIGNMENT) CONTROL
  - ATTITUDE CONTROL



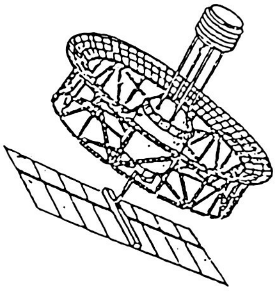
LARGE DEPLOYABLE REFLECTOR



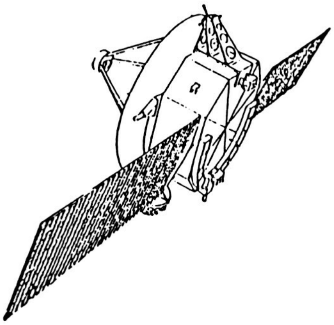
INFRARED INTERFEROMETER



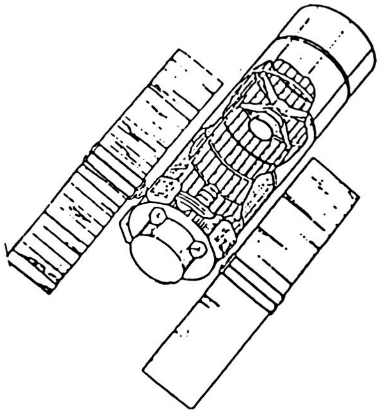
COSMIC



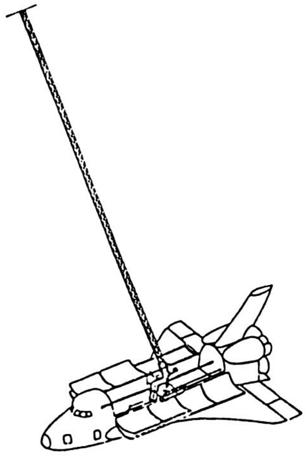
100M THINNED APERTURE



MOLECULAR LINE SURVEY



VERY LARGE SPACE TELESCOPE



PINHOLE OCCULTER FACILITY

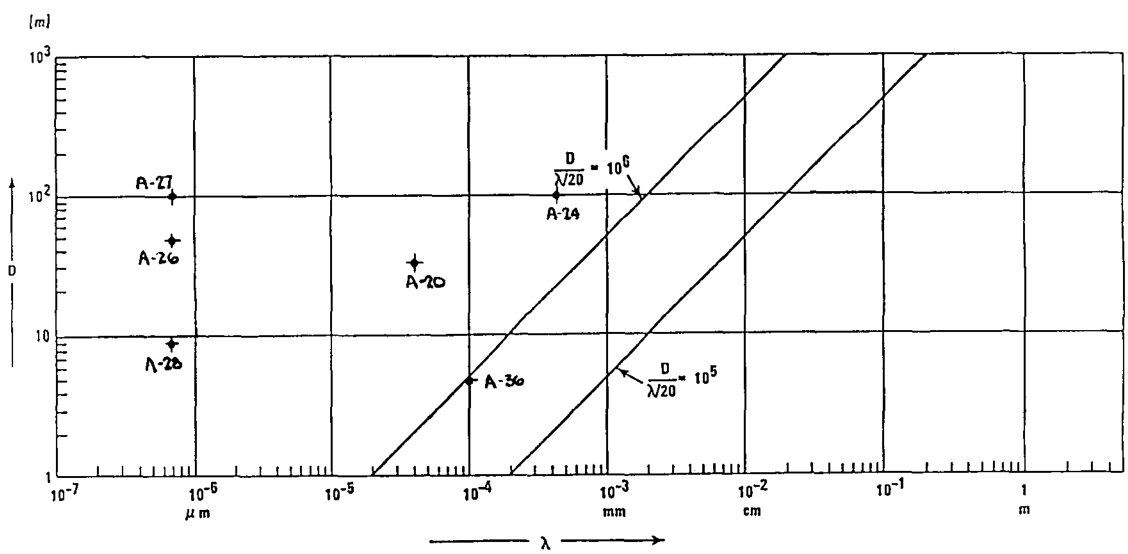
NASA-PLANNED PRECISION SPACE STRUCTURES

NASA NO.	NAME	SIZE	WAVELENGTH	POINTING STABILITY
A-20	LARGE DEPLOYABLE REFLECTOR	20M	30μ+	.15μr
A-24	INFRARED INTERFEROMETER	3M X 100M	300μ+	(5μr)
A-26	COSMIC	1.8M X 34M	VIS	2nr
A-27	100M THINNED APERTURE	100M	VIS	.5nr
A-28	VERY LARGE SPACE TELESCOPE	8M	VIS	10nr
A-36	MOLECULAR LINE SURVEY	3.5M	100μ	(8μr)
A-18	PINHOLE OCCULTER FACILITY	50M	XRAY, UV, VIS	1μr

NASA-PLANNED PRECISION SPACE STRUCTURES

NASA NO.	D/RMS	fn(EST.)	D/fnλ	POSSIBLE DISTURBANCES	CONTROL NEEDS		
					FIGURE	STRUCTURE	ATTITUDE
A-20	10^7	5	10^5	CHOP, SLEW, CMG, CRYO	X	X	X
A-24	6×10^6	2	10^5	CMG, APPEND	X	X	X
A-26	10^8	10	10^6	CMG, APPEND	X	X	X
A-27	1.6×10^9	1	10^8	CHOP, CMG, APPEND	X	X	X
A-28	2.5×10^8	5	2×10^5	CMG, APPEND	X	X	X
A-36	7×10^5	10	3.5×10^3	CHOP, CMG	X	NO	X
A-18	NA	NA	NA	SHUTTLE		(X)	X
THRESHOLD	10^5	THRESHOLD	10^4				

DIAMETER AND WAVELENGTH ESTIMATION



VIBRATION CONTROL

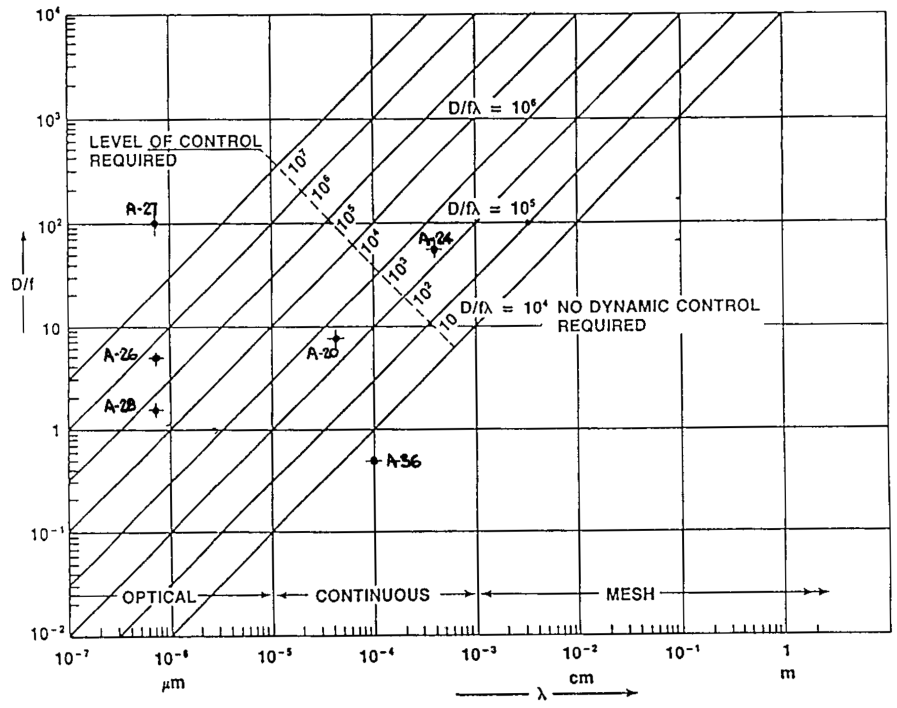
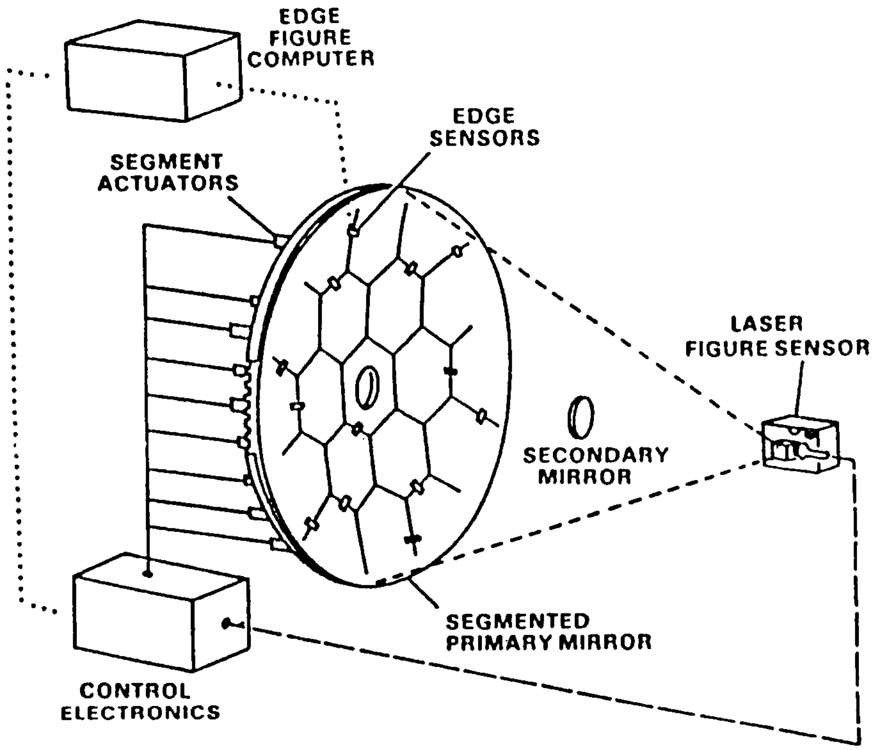


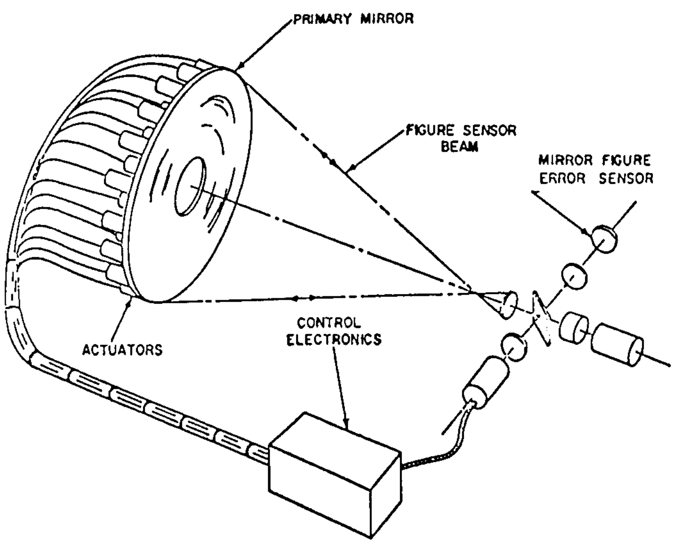
FIGURE CONTROL

- EARLIEST RECOGNIZED INSTANCE OF STRUCTURE-CONTROL INTERACTION
- GENERALLY A QUASI-STATIC CONTROLS APPROACH - THERMAL DRIVERS
  - RIGID SEGMENT ALIGNMENT TO DESIRED FIGURE
    - BACK-UP STRUCTURE MAY NEED TO BE CONTROLLED AS WELL
    - DISPLACEMENT ACTUATORS
  - CONTINUOUS MIRROR - ACTUATORS ELASTICALLY COUPLED
    - FORCE ACTUATORS - HIGH DEGREE OF COUPLING
    - DISPLACEMENT ACTUATORS - EFFECT MORE LOCALIZED
    - REAL ACTUATORS - INTERMEDIATE EFFECT - MUST MODEL
  - HYBRID VERSIONS OF SEGMENTED/CONTINUOUS BEING CONSIDERED
- NOT DIFFICULT TO DO STRUCTURE ANALYSIS OR CONTROLS DESIGN
  - UNLESS MIRRORS EXHIBIT STRUCTURAL DYNAMICS RESPONSE
    - MAY BE POSSIBLE TO STIFFEN MIRRORS SOMEWHAT > 30 HZ
    - OTHERWISE - CONTROLS APPROACHES FROM ANTENNAS - HIGH BW
- SENSORS/ACTUATORS - RESOLUTION TO .01λ OPERATING WAVELENGTH
  - TRANSFER FROM ANTENNAS LESS LIKELY



- THE LASER FIGURE SENSOR MONITORS EACH SEGMENT SURFACE
- THE EDGE SENSOR TESTS ALIGNMENT BETWEEN PAIRS OF SEGMENTS

<u>FIGURE/SURFACE CONTROL</u>

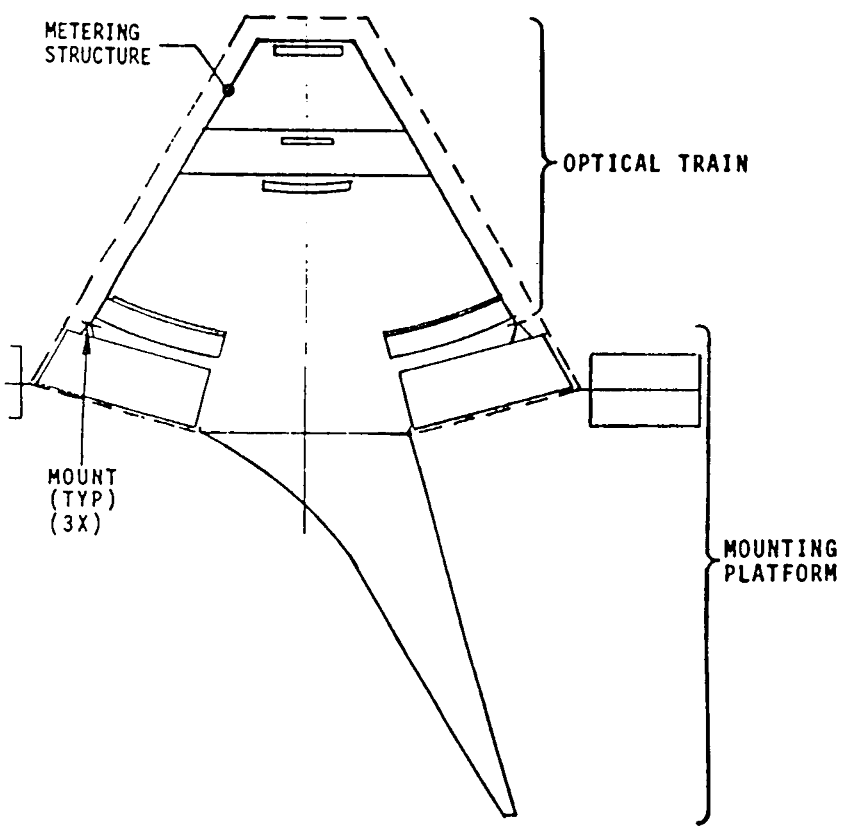


- DISTRIBUTED PARAMETER CONTROL FLEXIBLY COUPLED
- TECHNOLOGY DEVELOPED IN EARLY 1970'S FOR STATIC CORRECTION - NASA/DOD
- HIGH-BANDWIDTH OPTICS DEVELOPED
- CORRECTION FOR MIRROR DYNAMICS LARGELY UNEXPLORED

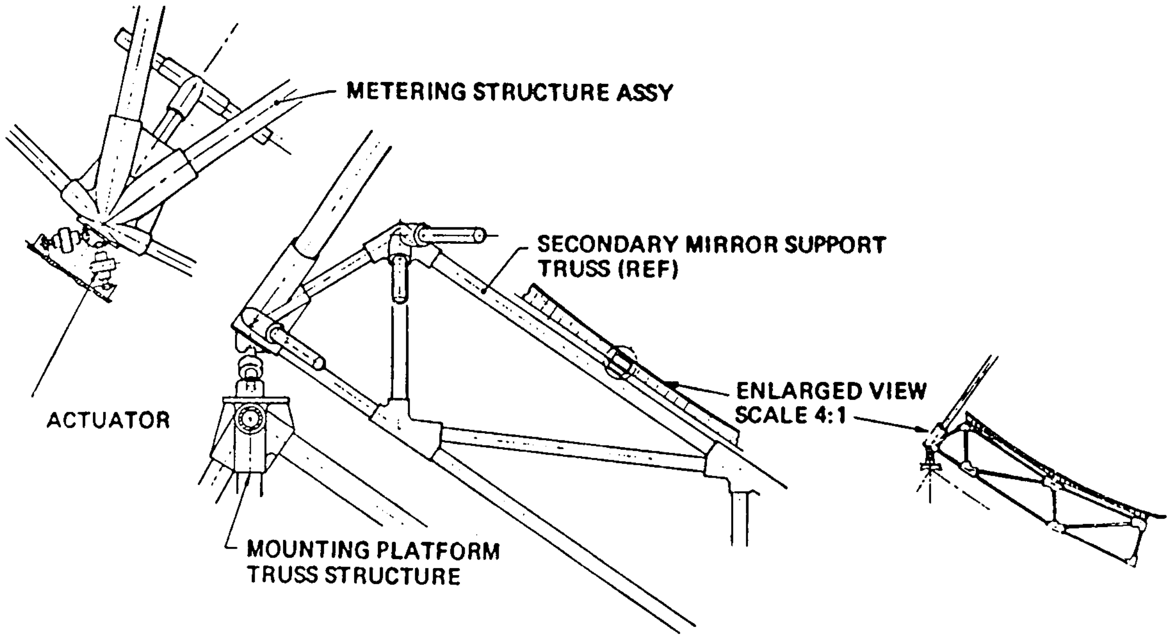
VIBRATION (ALIGNMENT) CONTROL (1)

- SOME BUT NOT MUCH SIMILARITY TO ANTENNA CONTROL PROBLEM
- CONTROL BW ~ 50 HZ; 100 MODES IN BW; 30 MODES CONTROLLED
- RESPONSE REDUCTION GOALS NEAR 10^4
- SPACECRAFT DESIGN OPTIONS PERMIT SOME ATTENUATION
  - ISOLATION (ACTIVE OR PASSIVE) OF OPTICAL TRAIN
  - DISTURBANCE LEAKAGE STILL CAN OCCUR
  - INERTIALLY DISTRIBUTED FORCES NOT AFFECTED BY ISOLATION (SLEW, CHOP)
  - SENSOR-ACTUATOR DYNAMICS AND NOISE CAN BE TROUBLESOME
  - HENCE REDUCTION OF VIBRATIONS IS NEEDED

OVERALL SPACECRAFT DESIGN APPROACH



- TWO MAJOR COMPONENTS
  1) OPTICAL TRAIN
  2) MOUNTING PLATFORM
- OPTICAL TRAIN: "ISOLATED" FROM MAJOR DISTURBANCES
- MOUNTING PLATFORM: A NON-PRECISION STRUCTURE CONTAINING MOST OF THE SOURCES OF DISTURBANCES AND APPENDAGES SUCH AS SOLAR PANEL AND SUN-SHADE
- OPTICAL TRAIN AND PLATFORM ARE ATTACHED THROUGH KINEMATIC MOUNTS. MOUNT DESIGN IS SUCH THAT IT FILTERS UNDESIRABLE LOW FREQUENCIES



VIBRATION (ALIGNMENT) CONTROL (2)

- OPTIONS:
  - NATURAL DAMPING - CLOSER TO .1% OF CRITICAL
  - DAMPING MATERIALS - MAY BE LIMITED BY
    - BROAD BANDWIDTH OF RESPONSE
    - CRYO TEMPERATURES OF SYSTEMS
    - BROAD TEMPERATURE SWINGS OF SYSTEM
    - OUTGASSING AND CONDENSATION ON COLD OPTICS
  - MULTI-INPUT MULTI-OUTPUT CONTROL
    - THEORETICAL BASIS SAME AS IN ANTENNA PROBLEMS
    - MORE DETAILED STRUCTURAL MODELS NEEDED - MORE MODES IN BW
    - STRUCTURAL LINEARITY AT MICRO-STRAINS QUESTIONABLE
    - DEPLOYMENT HINGES AND LATCHES MUST FULLY FREEZE
    - SENSOR-ACTUATOR DYNAMICS CLOSER IN BW TO EXCITED MODES
    - ACTUATOR NOISE CAN BE LARGE DISTURBANCE SOURCE
    - ACTUATOR AND SENSOR RESOLUTION
      - $.01\lambda/D$ ANGULAR
      - $.01\lambda$ LINEAR
      - TRANSFER FROM ANTENNAS UNLIKELY
    - SYSTEM ID MAY BE CONFUSED BY ISOLATORS
    - AVIONICS - MAY NEED TO PROCESS MUCH LARGER SYSTEM

ATTITUDE CONTROL

- ISOLATORS MAY MAKE LOW BW SYSTEM POSSIBLE
  - COARSE POINTING AND SLEW BY MOUNTING PLATFORM
  - FINE POINTING BY OPTICAL TRAIN USING ISOLATORS
- COARSE SENSORS AND ACTUATORS - TRANSFERABLE FROM ANTENNAS
- FINE SENSORS AND ACTUATORS - UNIQUE TO PRECISION MISSIONS

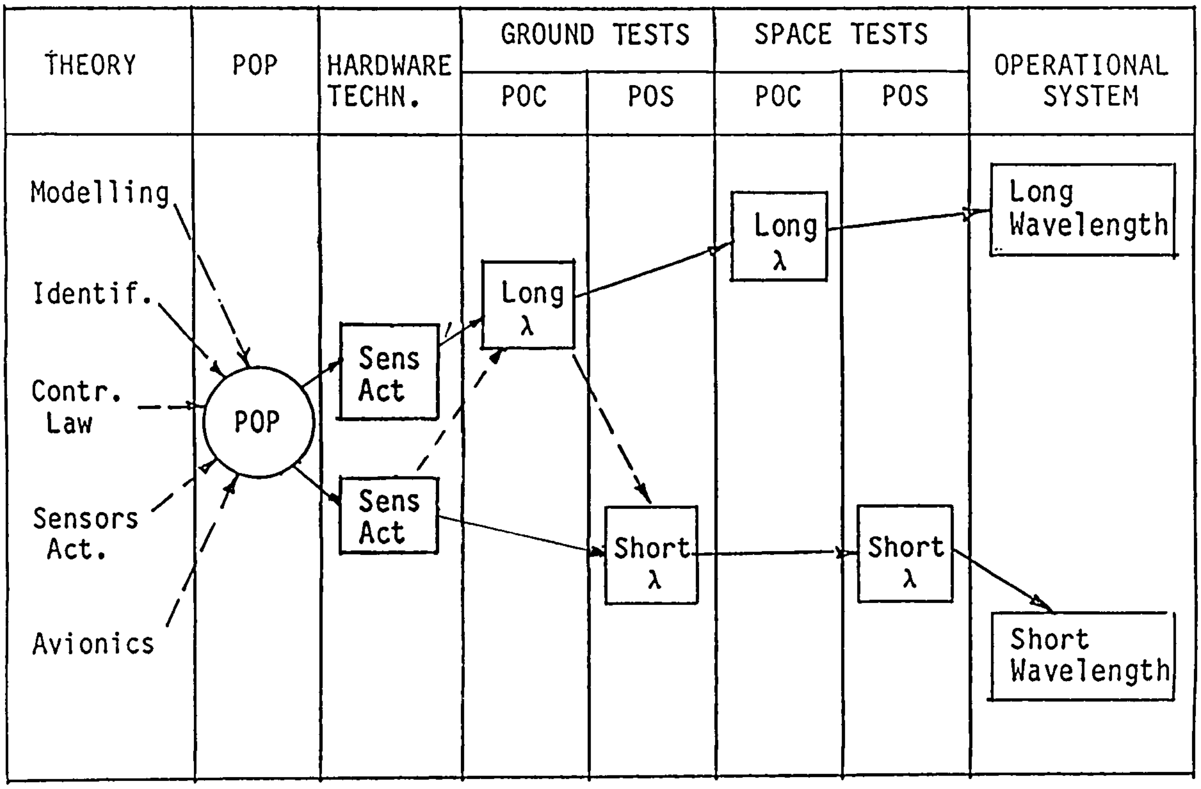
NET NASA MISSIONS - ACTIVE STRUCTURES GOALS

	SHORT λ - OPTICAL	LONG λ - RADAR
D	15	100
λ	1μ	3 cm
TOLERANCES		
SURFACE	0.03μ	0.4 mm
DEFOCUS	0.2 λ	0.2 λ
POINTING	10 nrad	10 mrad
DISTURBANCES	PERIODIC, RANDOM, SLEW	SCAN, SLEW, PERIODIC
CONTROLS GOALS		
LOS	$10^2 - 10^4$	$10 - 10^2$
WAVEFRONT	0 - 10	$10 - 10^2$
MODES IN BW	100	50
CONTROLLED MODES	30	30
CONTROL BW	50	5

TEST AND VERIFICATION - PRECISION SYSTEMS

- SMALLER, STIFFER THAN ANTENNAS
  - LESS OF 1G EFFECTS ON GROUND - LINEARITY MAINTAINED
  - ATMOSPHERIC MASS DURING TEST INSIGNIFICANT
  - ATMOSPHERIC DAMPING MAY BE IMPORTANT SINCE NATURAL DAMPING LOW
  - TESTING IN VACUUM FOR OPTICAL PATH INTEGRITY
- UNLIKE ANTENNAS SIGNIFICANT LEVELS OF SYSTEM INTEGRATION CAN BE TESTED IN A VACUUM TANK

"CRITICAL PATH" CHART



TIME, INCREASING COST, FEASIBILITY →

SUMMARY

- A NUMBER OF NASA PRECISION SPACE STRUCTURES ARE IDENTIFIABLE
- NEARLY ALL EXHIBIT SOME POTENTIAL FOR STRUCTURE-CONTROL INTERACTION
- DIFFERENCES FROM ANTENNA SYSTEMS CAN BE NOTED
    - FIGURE/SURFACE CONTROL CAN BE QUASI-STATIC
    - ACTIVE/PASSIVE ISOLATION SCHEMES ARE POSSIBLE
    - VIBRATION CONTROL IS NECESSARY
        - THEORETICAL FOUNDATION TRANSFERABLE
        - STRUCTURAL LINEARITY AT SMALL STRAINS OF CONCERN
        - ON-BOARD DISTURBANCES CAN BE SIGNIFICANT
        - HIGHER BW, LARGER NUMBER OF MODES
        - ACTUATOR/SENSOR RESOLUTION MUCH HIGHER
    - ATTITUDE CONTROL SYSTEM CAN BE LOW BW
    - GROUND TESTING MORE FEASIBLE THAN WITH ANTENNAS