The Problem

To develop analysis methods, modeling strategies, and simulation tools to predict with assurance the on-orbit performance and integrity of large complex space structures that cannot be verified on the ground.

Problem Incorporates:

- Large Reliable Structural Models (including non-linear)
- Multi-Body Flexible Dynamics
- Multi-Tier Controller Interaction
- Environmental Models Including 1g and Atmosphere
- Various On-Board Disturbances
- Linkage to Mission-Level Performance Codes

All areas are in serious need of work, but weakest link is multi-body flexible dynamics.
Some Definitions

Structural Dynamics: Motions of an elastic continuous structure under time-varying forces.

Dynamics: Motions of a rigid particle or continuum.

Multi-Body Dynamics: Motions of an assembly of rigid and/or flexible elements mutually interacting via non-elastic connections (trees or rings)

Multi-Body Dynamics are Encounted in Spacecraft with:

1. Very Flexible Fixed Appendages
2. Rotating Appendages
3. Dual-Spinners
4. Isolators or Gimbals between Significant Parts of S/C
5. During Deployments
MULTI-BODY TOOLS WILL PROBABLY BE NEEDED FOR:

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Multi-Body Dynamics Code Needs can be Gathered into Following Classes:

1. Large Area Antenna
2. Space Station
3. Generalized Deployment
4. Optical Systems
5. Miscellaneous General-Purpose Codes
GENERAL-PURPOSE CODE

. FIRST-ORDER ASSESSMENT OF NEW CONCEPTS
  . SAILS, TETHERS, MULTI-RINGS, DEPLOYMENTS
. SMALL TO MEDIUM-SIZE PROBLEMS
. CONTROL-STRUCTURE INTERACTION
. LARGE MINI-COMPUTER ENVIRONMENT, MACHINE INDEPENDENT
. USER-FRIENDLY, FLEXIBLE
. EVOLUTIONARY VERSION OF CURRENT DISCOS

DEPLOYMENT CODE

. DRIVEN MAINLY BY LARGE LIGHTWEIGHT ANTENNAS
. TREES OR RINGS WITH MANY BODIES
. MASS FLOW DURING DEPLOYMENT
. GEOMETRIC STRUCTURAL NON-LINEARITIES
. TIME-VARYING LARGE STRUCTURAL MODEL
. OPEN OR CLOSED-LOOP CONTROL OF DEPLOYMENT

ASSESSMENT ISSUES

. DEPLOYMENT INTO UNACCEPTABLE CONFIGURATION
. DEPLOYMENT INTO NON-RECOVERABLE SPIN MODES
. ENTANGLEMENTS, BREAKAGE, STRUCTURAL INSTABILITY
LARGE ANTENNA DEPLOYMENT

VERY LARGE ANTENNA CODE

- OPERATIONAL CONFIGURATION - LIMITED MULTI-BODY
- VERY LOW-FREQUENCY STRUCTURE
- VERY LARGE STRUCTURAL MODEL (10-50,000 DOF)
- MEMBRANE OR OTHER GEOMETRIC NONLINEARITIES
- CONTROLLED SURFACE, FEED ALIGNMENT, SYSTEM POINTING
- MODAL VS. TRAVELLING-WAVE REPRESENTATION

ASSESSMENT ISSUES

- MAIN LOBE LOSS OF GAIN
- SIDE-LOBE STRUCTURE
- DYNAMIC INTERACTION WITH ENVIRONMENTAL DISTURBANCES
- MAJOR STRUCTURE-CONTROL INTERACTION
TYPICAL LARGE ANTENNA

FEED ASSEMBLY (4 REQUIRED)

FEED MAST

UPPER MAST

HUB

100M DIA (3937 IN.)

LOWER MAST

SURFACE CONTROL CABLES

HOOP SUPPORT CABLE

SURFACE
SPACE STATION CODE

- MULTI-BODY TREES (APPENDAGES & PAYLOAD SENSORS)
- LARGE STRUCTURAL MODEL
- SYSTEM AND EXPERIMENT POINTING CONTROL
- SIGNIFICANT INERTIA CHANGES (CONSTRUCTION, DOCKING)
- EXPERIMENT DISTURBANCES

ASSESSMENT ISSUES

- EXPERIMENT ISOLATION FROM ACCELERATION
- EXPERIMENT POINTING & TRACKING
- OCCUPANT COMFORT
- CONSUMABLES

SPACE STATION
OPTICAL STRUCTURES CODE

- OVERLAPPING CONTROL SYSTEMS
  - SURFACE (WAVEFRONT)
  - VIBRATION
  - RAPID SLEW
  - PRECISION POINTING
- MULTIBODY (TREES)
- ISOLATORS
- MANY SOURCES OF DISTURBANCE
- SLOSH AND POGO
- RAPIDLY VARYING INERTIAS
- RAPID CONFIGURATIONAL CHANGES
- VERY LARGE ELASTIC MODEL

ASSESSMENT ISSUES

- SYSTEMS-LEVEL PERFORMANCE (LINKAGE TO OPTICS CODE)
- ROBUSTNESS OF MULTI-TIER CONTROL
STATUS OF SPACE-SYSTEMS ORIENTED MULTI-BODY TECHNOLOGY

. DIVERSITY OF FORMULATIONS
  . TWO GENERAL FAMILIES
    . ANALYTICAL MECHANICS - "DISPLACEMENT METHOD"
    . EULER/NEWTON - "FORCE METHOD"
    . SEVERAL SCHOOLS OF THOUGHT WITHIN FAMILIES

. DIVERSITY OF SOFTWARE CODES
  . SOME EXCELLENT, MANY MARGINAL
  . SIGNIFICANT LEARNING CURVES, USER HOSTILE
  . GENERALLY LONG RUNNING TIMES
  . UNCERTAIN ACCURACY/VALIDITY
  . MANY USERS UNSOPHISTICATED, TREAT AS BLACK BOX

. GENERALLY AN IMMATURE AREA (UNLIKE STRUCTURAL DYNAMICS)
CONCERN:

. We are proposing more complicated satellites than our current analytical tools can reliably predict.

. In the multi-body area there is a vast diversity of opinion on the proper approach to the formulations.

. The time to develop a unified formulation, and convert it into code, will exceed the time available for immediate needs.

Two Approaches to Resolution

. Integration of available and other near-term codes (2-4 years).

. Basic research and development activity leading to NASTRAN-like multi-body code (5-8 years).
OBJECTIVES OF NEW MULTI-USER CODE

. ENDURING BUT EFFICIENT COMMON FORMULATION
  . TREES, RINGS, MASSFLOW
  . LARGE STRUCTURAL MODELS
  . MULTI-LEVEL CONTROL

. SOFTWARE FEATURES
  . USER-FRIENDLY PROBLEM-LANGUAGE I-O
  . OBJECT-ORIENTED PROBLEM ASSEMBLY
  . INCORPORATED SYMBOLIC MANIPULATION
  . STRIPPED, EFFICIENT CODE FOR EXECUTION

. MACHINE-INDEPENDENCE AND ACCESSIBILITY
  . SUPER-MINIS
  . MAINFRAMES
  . SUPERS
  . FEDERATED PARALLEL PROCESSORS
Basic Approach to Development

. Consolidate Multi-Agency Government Support
  . Theory Phase $T = T_0$
    . Technical Participation by Government, Industry, Academia
    . Study and Consolidation of Alternate Formulations
    . Preliminary Software Architecture Studies
  . Prototype Phase $T = T_0 + 2$
    . Reduce to 2 or 3 Major Formulation and Software Approaches
    . Continue Support to Universities to Train Users
  . Coding Phase $T = T_0 + 3$
    . Choose Best Overall Approach to Code
  . Preliminary Testing Phase $T = T_0 + 5$
    . First Release to Selected Users
  . Public Release $T = T_0 + 6$

Summary

. The problems are there, funding should be pursued
. On-going capabilities fall short
. Near-term needs require the integration of existing codes
. Far-term needs must follow a return to basics