INTEGRATED ANALYSIS OF LARGE SPACE SYSTEMS

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Based on the belief that actual flight hardware development of large space systems will necessitate a formalized method of integrating the various engineering discipline analyses, an overall objective was established to produce an efficient highly user oriented software system capable of performing interdisciplinary design analyses with tolerable solution turnaround times. To support expected increase in large space systems design activities in the last half of the 1980's, a goal has been set to have a Version 1 IAC functioning by the end of FY 1983.

- OVERALL OBJECTIVE

  PRODUCE AN ANALYSIS SOFTWARE SYSTEM CAPABLE OF PERFORMING INTERDISCIPLINARY DESIGN ANALYSES OF LARGE SPACE SYSTEMS. MULTI-DISCIPLINES, WITH INITIAL EMPHASIS ON THERMAL, STRUCTURES, AND CONTROLS, ARE TO BE INTEGRATED INTO A HIGHLY USER ORIENTED ANALYSIS CAPABILITY. THE KEY FEATURE OF THE INTEGRATED ANALYSIS CAPABILITY IS TO BE AN EFFICIENT SYSTEM THAT WILL MINIMIZE SOLUTION TURNAROUND TIME.

- SPECIFIC NEAR TERM GOAL

  HAVE VERSION 1 OPERATIONAL INTEGRATED ANALYSIS CAPABILITY (IAC) FUNCTIONING BY END OF FY 1983.

To be more definitive, specific analysis capability goals were set forth with initial emphasis given to sequential and quasi-static thermal/structural analysis and fully coupled structural/control system analysis. Subsequently, the IAC would be expanded to include a fully coupled thermal/structural/control system, electromagnetic radiation, and optical performance analyses.

ANALYSIS CAPABILITY

INITIAL EMPHASIS

- THERMAL/STRUCTURAL COUPLED ANALYSIS IN SEQUENTIAL MODE
- STRUCTURAL/CONTROL SYSTEM COUPLED ANALYSIS
- STRUCTURAL/CONTROL SYSTEM COUPLED ANALYSIS INCLUDING A PRIORI DEFINED TEMPERATURES (QUASI-STATIC THERMAL)

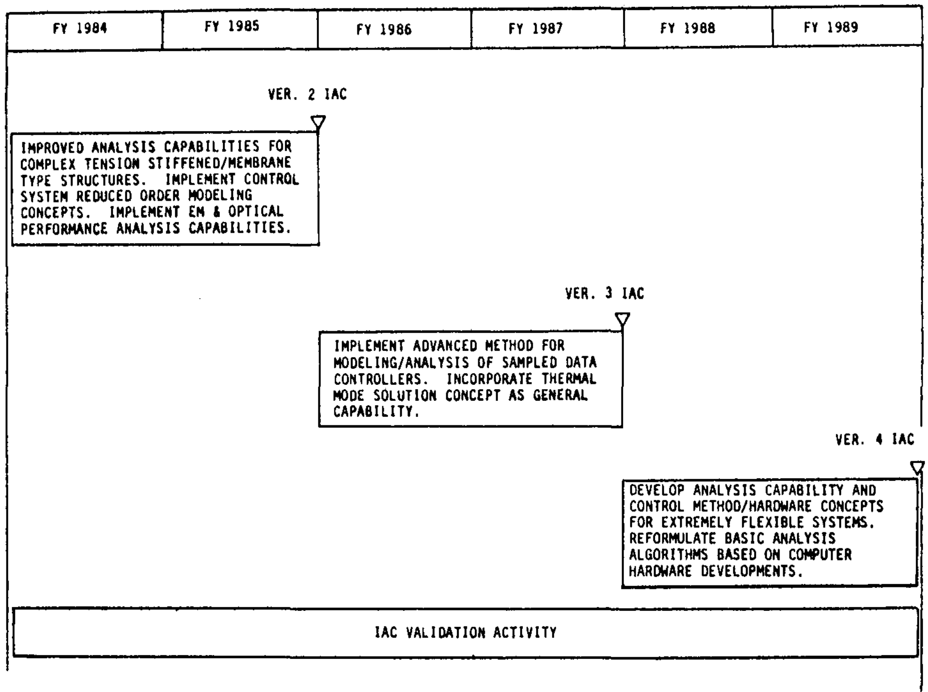
EXPANDABLE TO INCLUDE

- CLOSED LOOP THERMAL/STRUCTURAL/CONTROL SYSTEM ANALYSIS VIA USE OF THERMAL MODE CONCEPT
- ELECTROMAGNETIC RADIATION ANALYSIS
- OPTICAL PERFORMANCE ANALYSIS

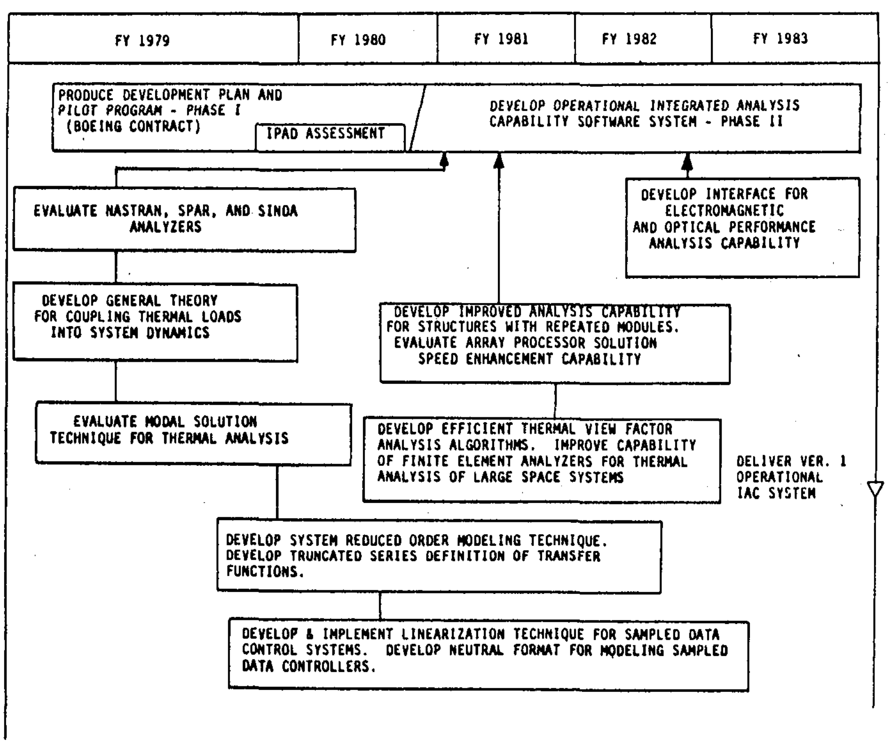
These two charts present a 10-year schedule that depicts a somewhat detailed picture of activities supporting the end of FY 1983 goal of a Version 1 IAC system and a general definition of tasks that support a delivery of enhanced versions of the IAC on 2-year intervals. The top bar in the first chart represents a key contract effort to produce the Version 1 IAC. Boeing Aerospace Company was awarded the Phase I portion July 1979. Completion is scheduled for July 1980. The contract contains a negotiated option to proceed with the Phase II operational software development/delivery portion. Underlying the major contract effort are a number of independent in-house activities at NASA centers that collectively provide support to the overall IAC development plan.

During the 6-year period following release of the Version 1 IAC, there is envisioned a progression of improved versions that will be upgraded to have capabilities for analyzing highly complex tension stiffened/membrane type structures, advanced method for modeling/analyzing sampled data control systems, and analyzing extremely flexible systems.

INTEGRATED ANALYSIS DEVELOPMENT PLAN



INTEGRATED ANALYSIS DEVELOPMENT PLAN



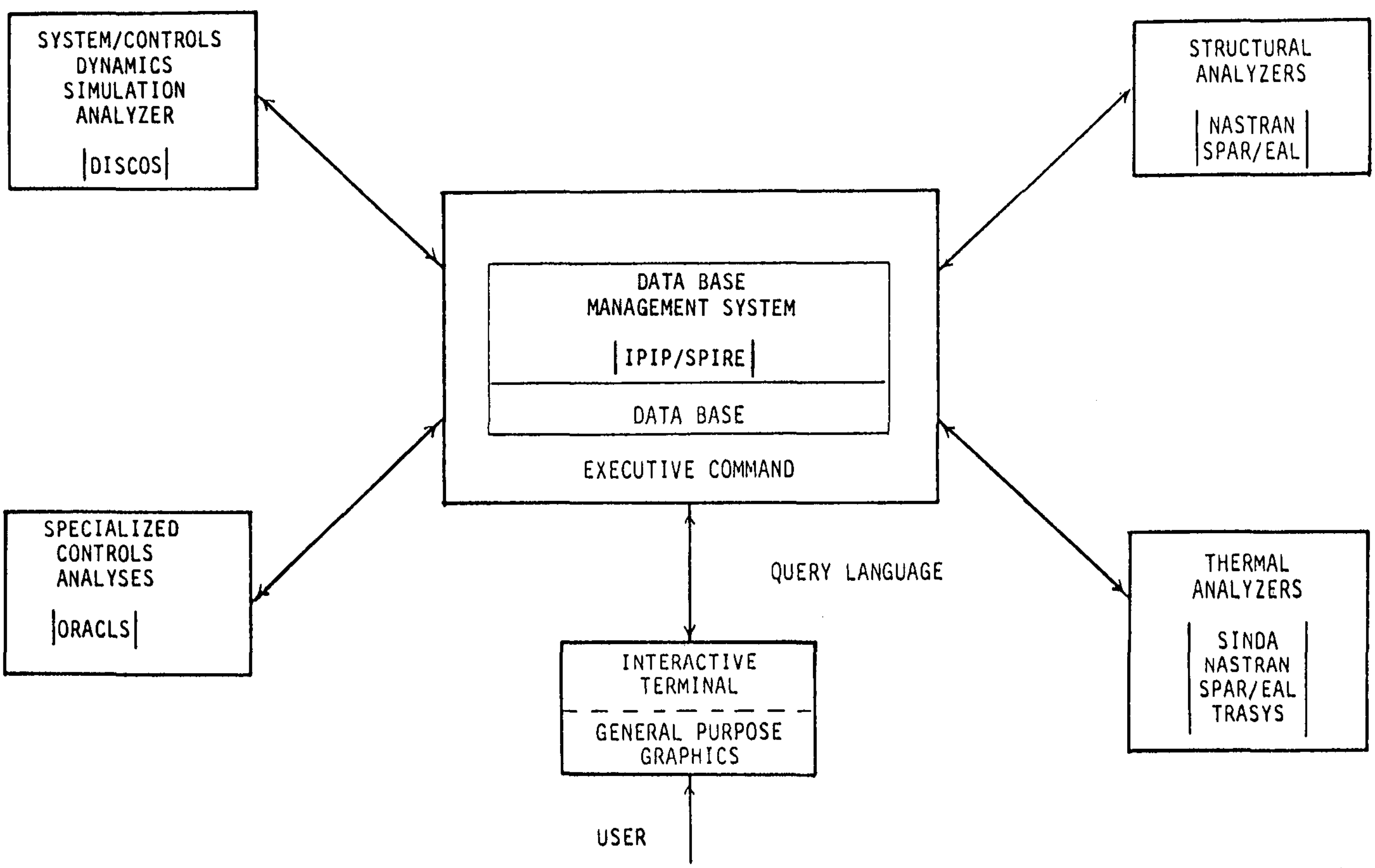
To give general guidance to this program, in the near term, there has evolved some Development Guidelines. The key motivation behind these guidelines is the objective to produce an efficient operational system within a minimum time frame and budget and that will have widest potential usage.

DEVELOPMENT GUIDELINES

- MAXIMIZE USE OF STATE-OF-ART TECHNOLOGY FOR ELEMENTS IN THE SYSTEM
- CONCENTRATE EFFORT ON THE TECHNOLOGY TO INTEGRATED SYSTEM ANALYSIS PROCESS INTO AN EFFICIENT TOOL
- TO PRODUCE SYSTEM WITH WIDEST POTENTIAL USEAGE, WITHIN MINIMUM BUDGET, INITIAL EMPHASIS GIVEN TO NEW BREED OF SUPER-MINICOMPUTERS AS HOST MACHINE
- UTILIZATION OF EXISTING DBMS IS PLANNED
  - BAC IS EVALUATING IPAD/IPIP. THIS IS PREFERRED APPROACH.
  - GSFC IS MODIFYING AN EXISTING DBMS FOR SPECIFIC PROJECT USEAGE. THIS SYSTEM (SPIRE) IS UNDER CONSIDERATION AS AN ALTERNATIVE APPROACH.

This diagram shows conceptually what the end product IAC is to be from a simplified architectural standpoint. The core of the IAC is a DBMS/Executive Command/Data Query capability. The individual technical discipline analyzers, illustrated by the surrounding blocks, are linked together through this central data manager/query system via data flow links (double arrows) thereby producing an Integrated Analysis Capability. These analyzers may exist external to the DBMS as implied by this diagram (i.e., interfaced with the DBMS), or one or more may, from a software standpoint, be integrated into the DBMS. Also shown are the current candidate codes that are seriously being considered for inclusion into the Version 1 IAC.

CONCEPT OF IAC ARCHITECTURE



NASTRAN and SPAR/EAL are considered the current premier general purpose structural analyzers. Over the past several years there have been conflicting opinions on the relative speed/efficiency of one vs. the other. It was believed to be worthwhile for a controlled comparison evaluation to be made, that is, where there is one person that understands the strong features of both codes, that uses the same computer, the same demonstration problems, and uses comparable versions of the codes.

CANDIDATE STRUCTURAL ANALYSIS CODES

CODES:

1. MSC 52 NASTRAN
2. COSMIC 17.5 NASTRAN
3. COSMIC SPAR
4. EAL

COMPARISON FACTORS:

- o SUITABILITY FOR USE IN INTERDISCIPLINARY ANALYSIS SYSTEM
- o LARGE PROBLEM ANALYSIS
- o EASE OF USEAGE
- o USER COMMUNITY
- o MAINTENANCE
- o DOCUMENTATION

This table gives a qualitative picture of the comparison showing, for example, that the MSC NASTRAN and SPAR are quite comparable on execution speed. Overall, the table currently shows MSC NASTRAN to be the most preferable although SPAR/EAL does show considerable potential. In terms of the IAC development, one result of this study has been to lead us to the decision to include both capabilities in the IAC.

STRUCTURAL CODES COMPARISON
<u>PRELIMINARY OBSERVATIONS</u>

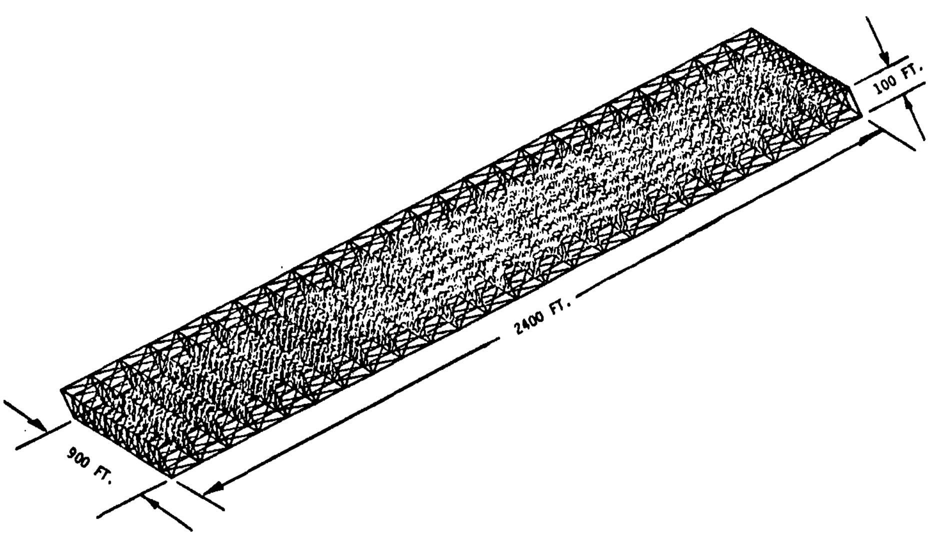
CODE	EXECUTION SPEED	EASE OF USAGE	DUCUMENTATION	USER COMMUNITY	MAINTENANCE
MCS 52 NASTRAN	+	-	+	+	+
COSMIC 17.5 NASTRAN	-	-	+	+	?
COSMIC SPAR	+	+	-	-	-
EAL	TDB	+	-	-	+

Another significant reason for conducting this study was to evaluate the performance applicability of the new breed superminicomputers to large space systems analyses. These two figures illustrate this study. The first figure gives representative minicomputer (DEC VAX 11/780) CPU run times for progressively larger size demonstration problems. The second figure depicts the type of demonstration problem utilized. A plate like structure serves as a good test model since it exhibits a relatively large bandwidth stiffness matrix thereby taxing the computing power of the host computer system. It must be emphasized that these times are only representative of the approximate times one might expect on a superminicomputer be it using either NASTRAN or SPAR. It is expected that about 6000 DOF will be the maximum possible dynamics solution problem due to exceeding typical external memory capacity limitations (25 Mb).

STRUCTURAL TEST PROBLEMS

REPRESENTATIVE MINICOMPUTER CPU RUN TIMES

MODEL	DOF	STATICS	DYNAMICS
A	48	–	0.5 MIN.
B	108	–	1 MIN.
C	1200	5 MIN.	25 MIN.
D	3000	15 MIN.	1 1/4 HR.



LSST PLATFORM-MODEL D

In the thermal analysis area, three aspects have been of concern.

- One, there has been a long standing question of finite element thermal analyzers vs. the finite difference modeling methodology and, in particular, as it pertains to radiation dominated thermal problems.
- Two, how best to compute heat flux input and needed thermal view factors.
- Three, understanding the possible utilization of thermal modes, as would reuslt from a classical eigenvalue analysis, in the world of large space systems thermal analysis.

THERMAL ANALYSIS EFFORT

- NASTRAN((NTA)-SINDA COMPARISON
- SELECTION OF RADIATION, FLUX/VIEWFACTOR, MODULE
- THERMAL MODAL ANALYSIS
  - COMPLETELY COUPLED ANALYSIS
  - REDUCTION OF THERMAL PROBLEM SIZE

The following five charts gives a picture of the IAC as viewed through the eyes of a controls system analyst/designer. Put very briefly, the objective is viewed as providing both a time and frequency domain analysis capability.

IAC-SIMULATION OF SYSTEM DYNAMICS

OBJECTIVE

PROVIDE AN INTERDISCIPLINARY ANALYSIS CAPABILITY
SUPPORTIVE OF BOTH TIME AND FREQUENCY DOMAIN
DESIGN AND PERFORMANCE EVALUATION METHODS

A focus problem that will exercise the IAC system to a very large degree is envisioned to be a Sampled Data Controlled Thermally Deformable Spacecraft. In addition, several functional types of control systems may be required. A focus problem of this type will lead to a number of analysis needs.

IAC-FOCUS PROBLEM

SAMPLED DATA CONTROL OF A THERMALLY DEFORMABLE SPACECRAFT

CONTROL SYSTEM TYPES:

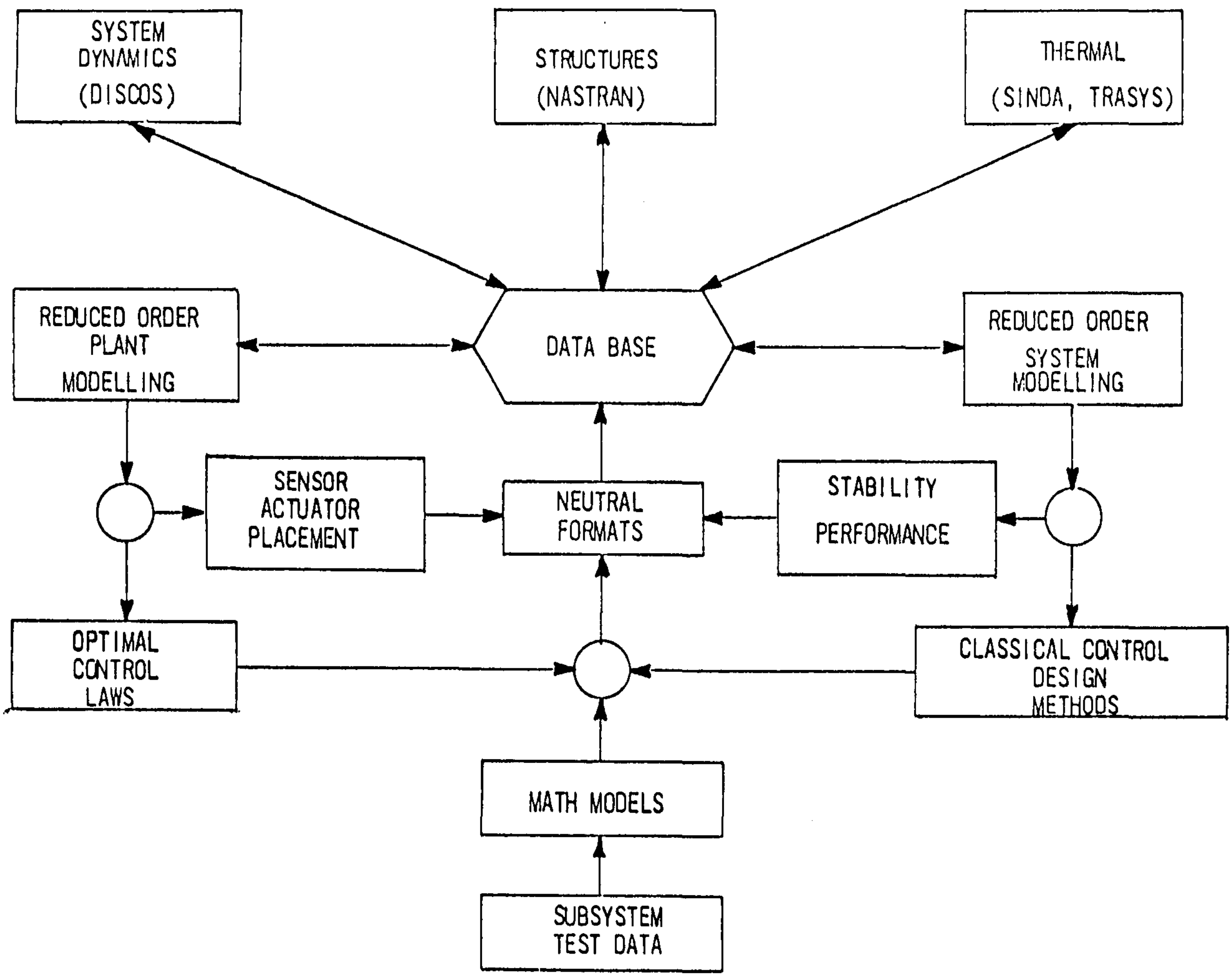
- SPACECRAFT ATTITUDE – POSITION – SHAPE CONTROL
- APPENDAGE POINTING CONTROL
- CONSTRUCTION AND DOCKING CONTROL

ANALYSIS TOOLS FOR THE DETERMINATION OF:

- LOADS AND DEFORMATION
- THERMAL RESPONSE
- SENSOR – ACTUATOR PLACEMENT
- OPTIMAL CONTROL LAWS
- FREQUENCY DOMAIN RESPONSE
- NON-LINEAR PERFORMANCE

This is another view of the IAC architecture with the control system analysis aspect expanded in greater detail showing the modern control theory contribution on the left and the classical control theory coming in on the right.

DATA FLOW PATHS FOR INTERDISCIPLINARY ANALYSIS



This chart contains a list of the most obvious environmental effects that must be considered indicating that capability to account for gravity gradient and thermal loads currently exists. No generalized capability exists for the remaining three loading sources. In addition, there exist some problems related to coupling the thermal and structures disciplines.

ENVIRONMENTAL EFFECTS

GRAVITY GRADIENT	-	CAPABILITY IN DISCOS
THERMAL	-	THERMAL INPUT INTO THERMAL ANALYZER VIA TRASYS
SOLAR PRESSURE AERODYNAMIC DRAG MAGNETIC	}	NO GENERALIZED CAPABILITY

PROBLEMS:

- o INTERPOLATION FOR THERMAL DEFORMATION
  THERMAL NODES TO STRUCTURAL GRID POINTS
- o INTERPOLATION FOR THERMAL INPUT FOR CLOSED LOOP DYNAMICS
  GRID POINT STRUCTURAL DISPLACEMENT TO THERMAL SURFACE ORIENTATION(TRASYS)
- o SOLAR PRESSURE AND AERODYNAMIC DRAG
  ADAPT TRASYS, ASSUME ONLY FREE MOLECULAR FLOW
- o MAGNETICALLY INDUCED DEFORMATION DUE TO LARGE DIAMETER CURRENT CARRYING LOOPS

Modern and classical control theories will interface naturally in several areas of consideration and as a consequence produce a number of problems as shown in this figure.

MODERN-CLASSICAL CONTROL

SENSOR/ACTUATOR PLACEMENT
OPTIMAL CONTROL LAWS
FREQUENCY RESPONSE METHODS
NON-LINEAR PERFORMANCE

PROBLEMS:

- o EFFECT OF SENSOR/ACTUATOR MASS ON PLANT DYNAMICS
- o EFFECT OF SENSOR/ACTUATOR DYNAMICS IN CONTROL LAW IMPLEMENTATION
- o OBTAIN ESTIMATOR MODEL FOR OPTIMAL CONTROL WORK
- o OBTAIN LINEAR EQUATIONS-SAMPLED DATA CONTROL OF CONTINUOUS PLANT
- o OBTAIN REDUCED ORDER SYSTEM EQUATIONS AND REDUCED ORDER TRANSFER FUNCTIONS
- o DEVELOP EFFICIENT NUMERICAL INTEGRATION METHOD FOR MIXED STIFF (THERMAL)-OSCILLATORY (STRUCTURAL)-SAMPLED DATA (CONTROLLER) SYSTEM EQUATIONS

INTEGRATED ANALYSIS CAPABILITY
SUMMARY

- o MAXIMIZE USE OF APPROPRIATE AVAILABLE ANALYZERS AND DBMS
- o DEVELOP NECESSARY DATA FLOW LINK SOFTWARE TO BUILD IAC
- o DEFINE FUNCTIONAL REQUIREMENTS TO BE SATISFIED BY ALL ELEMENTS OF THE IAC
- o MODIFY "AS SUPPLIED" SOFTWARE ELEMENTS TO SATISFY FUNCTIONAL REQUIREMENTS
- o DEVELOP IMPROVEMENTS TO BASIC ANALYZERS, TECHNIQUES FOR IMPROVING CONTROL SYSTEM MATH MODELING/ANALYSIS PROCESS, IMPROVED NUMERICAL SOLUTION ALGORITHMS, AND ANALYSIS SCHEMES FOR REDUCING DEMANDS ON COMPUTER HARDWARE DATA STORAGE CAPACITY
- o DO SOFTWARE INTEGRATION TECHNOLOGY DEVELOPMENT NECESSARY TO MOLD ALL THE ELEMENTS INTO A USER FRIENDLY IAC WITH OBJECTIVE TO PROVIDE AN EFFECTIVE MEANS OF COMMUNICATING INTERDISCIPLINE DATA IN A TIMELY AND EFFICIENT MANNER