NASA TM-8...

NASA Technical Memorandum 85661

NASA-TM-85661 19830023824

STRUCTURES AND DYNAMICS DIVISION

RESEARCH AND TECHNOLOGY PLANS FOR FY 1983 AND ACCOMPLISHMENTS FOR FY 1982

Kay S. Bales

June 1983

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

STRUCTURES AND DYNAMICS DIVISION

RESEARCH AND TECHNOLOGY PLANS FOR FY 1983

AND ACCOMPLISHMENTS FOR FY 1982

By

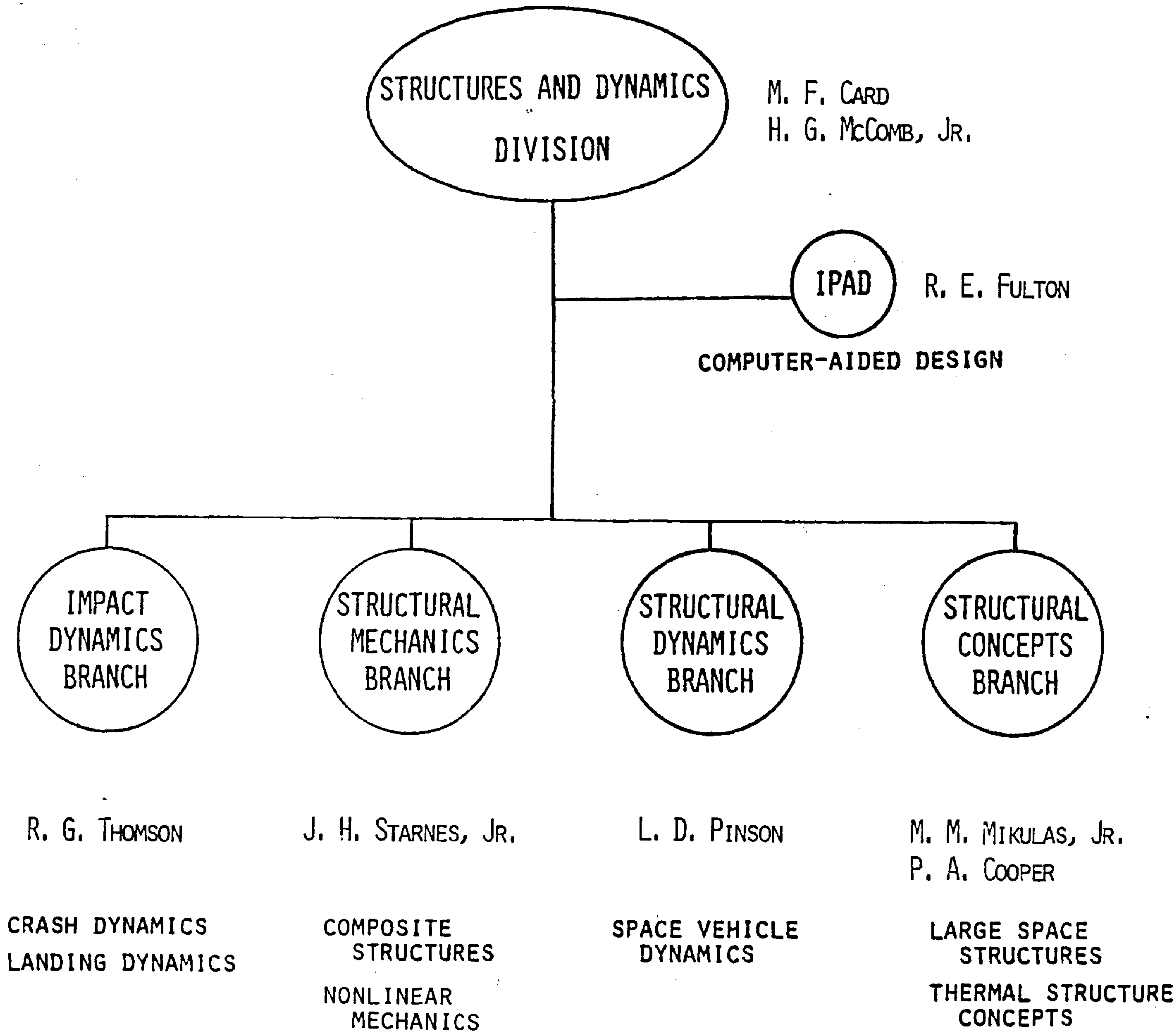
KAY S. BALES

SUMMARY

The purpose of this paper is to present the Structures and Dynamics Division's research plans for FY 1983 and accomplishments for FY 1982. The work under each branch/office is shown by RTR Objectives, Expected Results, Approach, Milestones, and FY 1982 Accomplishments. Logic charts show elements of research and rough relationship to each other. This information is useful in program coordination with other government organizations in areas of mutual interest.

TABLE OF CONTENTS

I STRUCTURES AND DYNAMICS DIVISION ORGANIZATION CHART


STRUCTURES AND DYNAMICS DIVISION
M. F. CARD
H. G. MCCOMB, JR.
IPAD
R. E. FULTON
COMPUTER-AIDED DESIGN
IMPACT DYNAMICS BRANCH
STRUCTURAL MECHANICS BRANCH
STRUCTURAL DYNAMICS BRANCH
STRUCTURAL CONCEPTS BRANCH
R. G. THOMSON
J. H. STARNES, JR.
L. D. PINSON
M. M. MIKULAS, JR.
P. A. COOPER
CRASH DYNAMICS
LANDING DYNAMICS
COMPOSITE STRUCTURES
NONLINEAR MECHANICS
SPACE VEHICLE DYNAMICS
LARGE SPACE STRUCTURES
THERMAL STRUCTURE CONCEPTS

II FACILITIES

II FACILITIES

The Structures and Dynamics Division has four major facilities to support its research (shown in figure 1.)

The Structures and Materials Laboratory equipment includes a 1,200,000 lbf capacity testing machine for tensile and compressive specimens up to 6 feet wide and 18 feet long; lower capacity testing machines of 300,000, 120,000, 100,000 and 10,000 lbf capacity; torsion machine of approximately 60,000 in.-lbf capacity; combined load testing machine; hydraulic and pneumatic pressurization equipment; and vertical abutment-type backstop for supporting and/or anchoring large structural test specimens.

The Impact Dynamics Research Facilities consist of the Aircraft Landing Dynamics Facility (ALDF) currently being upgraded under a $15M CoF project, and the Impact Dynamics Research Facility. The ALDF will consist of a rail system 2,500 ft. long x 30 ft. wide, a 1.73 Mlbs. thrust propulsion system, a test carriage capable of approximately 220 knots, and an arrestment system. A wide variety of runway surface conditions, ranging from dry and flooded concrete or asphalt to solid ice, can be duplicated in the track test section. In addition, unprepared surfaces such as clay or sod can be installed for tests to provide data on aircraft off-runway operations.

The Impact Dynamics Research Facility simulates crashes of full-scale aircraft under controlled conditions. Simulation is accomplished by swinging the aircraft by cables, pendulum-style, into the ground from an A-frame structure approximately 400 ft. long x 240 ft. high.

The Structural Dynamics Research Laboratory is designed for carrying out research on spacecraft and aircraft structures, equipment, and materials under various environmental conditions, including vibration, shock, acceleration, thermal and vacuum. Equipment in the laboratory includes a 55-ft. (inside diameter) thermal vacuum chamber with a removable 5-ton crane, a flat floor 70 feet from the dome peak, and whirl tables.

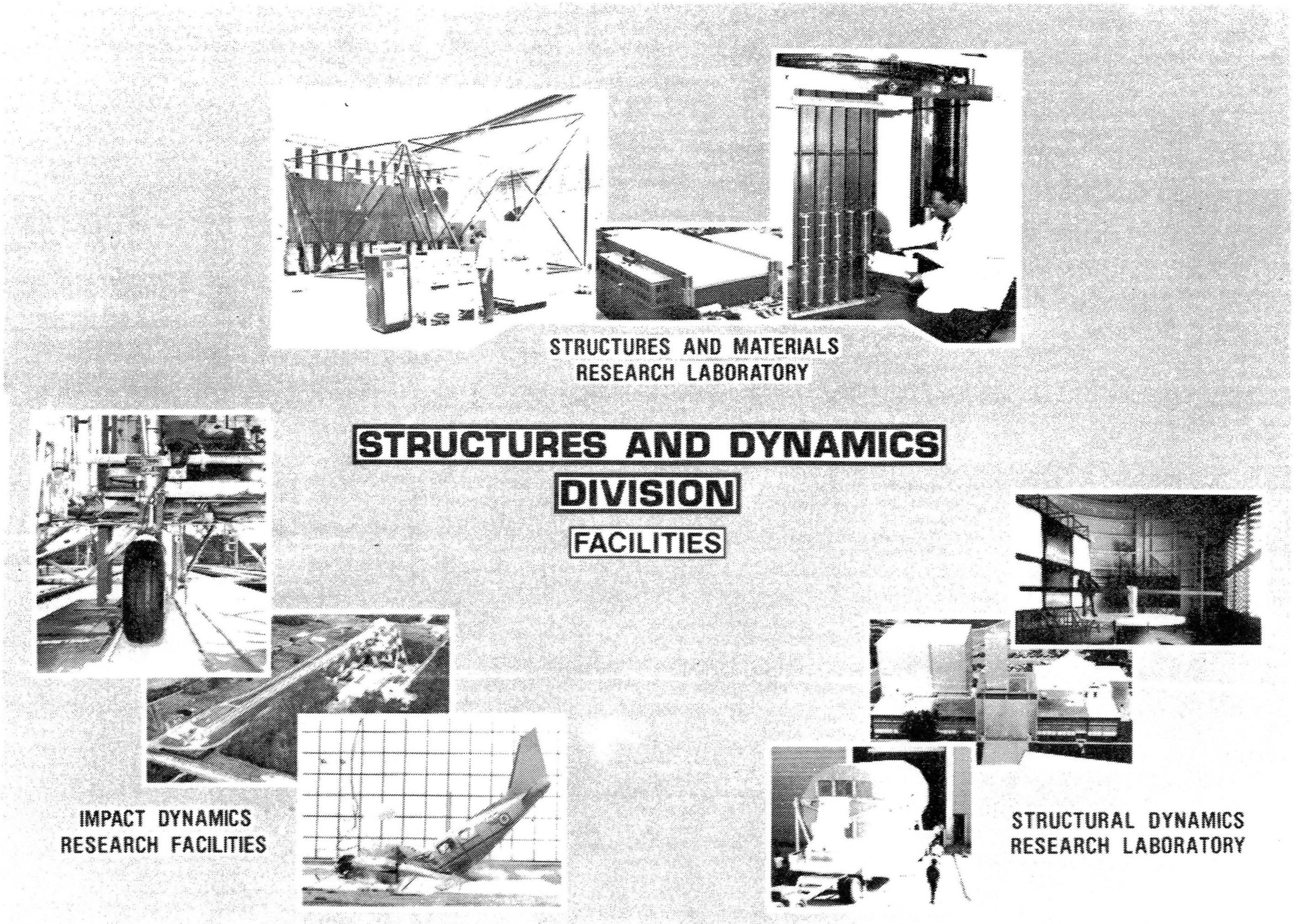
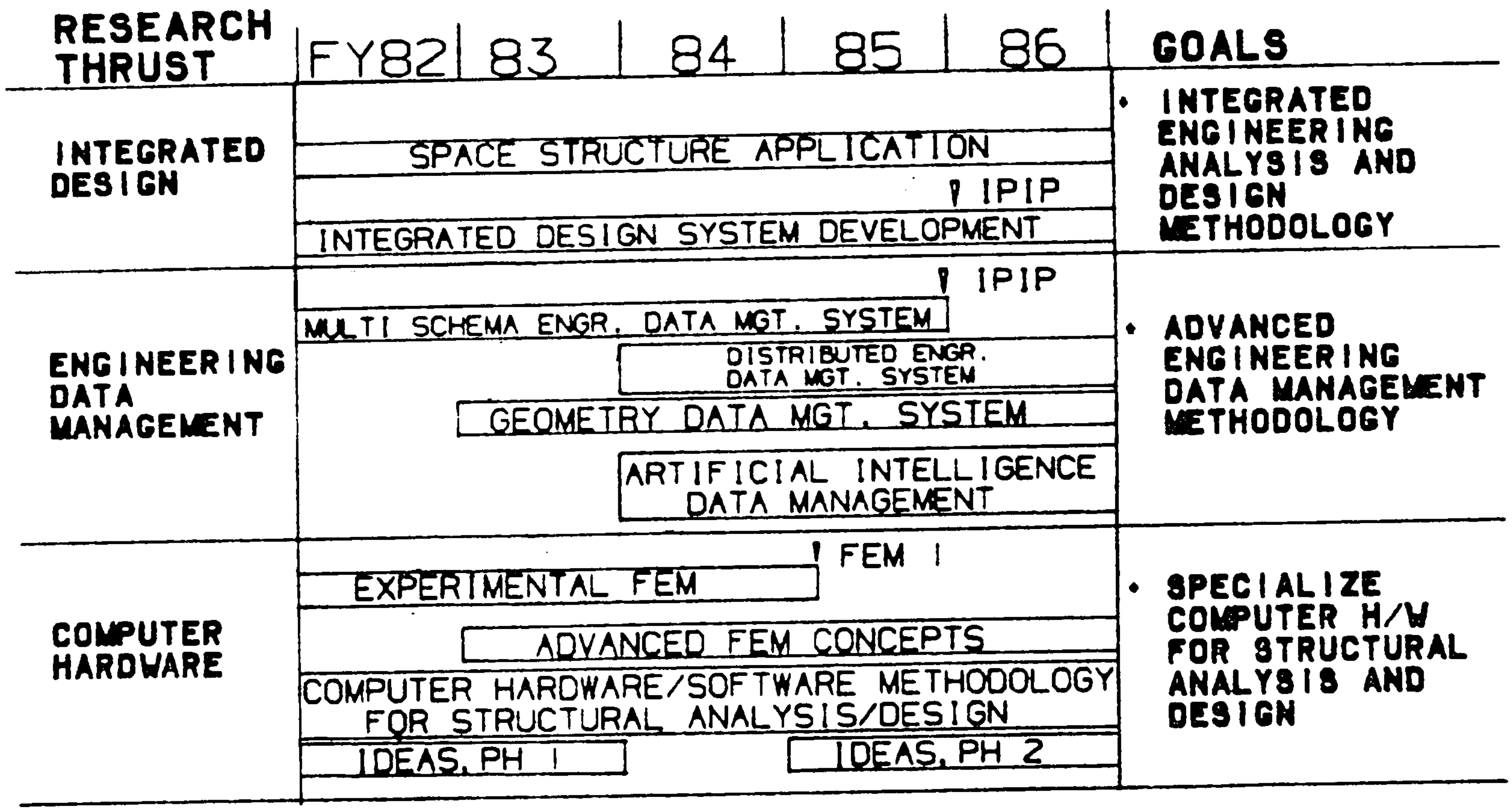

STRUCTURES AND MATERIALS
RESEARCH LABORATORY
STRUCTURES AND DYNAMICS
DIVISION
FACILITIES
IMPACT DYNAMICS
RESEARCH FACILITIES
STRUCTURAL DYNAMICS
RESEARCH LABORATORY

Figure 1.

III IPAD PROJECT OFFICE

COMPUTER AIDED DESIGN



III IPAD PROJECT OFFICE

RTOP 505-37-13 Computer Aided Design

RTR 505-37-13-01 Finite Element Machine

OBJECTIVE:

Complete 36-node (processor) prototype Finite Element Machine, develop algorithms, run applications, and assess future capability of parallel processing for structures problems.

EXPECTED RESULTS:

Develop a prototype Finite Element Machine (FEM) using microprocessors to demonstrate efficient computational methods for large-scale structural analysis applications by the end of FY 1985

Develop a second-level Finite Element Machine (FEM 2) based on advanced MIMD (multiple instruction, multiple data) distributed architecture concepts to demonstrate several orders of magnitude reductions in time and cost for finite element/finite difference calculations typical of solid/fluid mechanics applications by the end of FY 1987

APPROACH:

To understand possible advantages of parallel processing, the feasibility of obtaining structural analysis solutions using microprocessors will be investigated. Under the FEM program, a series of microprocessors will be assembled and used to solve a variety of structural analysis problems. Various methods of solution including relaxation techniques and direct inversion will be studied to determine which solution techniques are most suitable for rapid solutions.

MILESTONES:

- o Purchase/deliver FEM controller, October 1982
- o 16-node FEM hardware operational, January 1983
- o Application of FEM to structural studies, October 1983

FY 1982 ACCOMPLISHMENTS:

- o 4-node test bed FEM operational
- o Test problems solved on 4-node system show FEM potential

- o 36-node hardware completed preparatory to system implementation and testing

- o Effectiveness of minicomputer and array processors for CAD demonstrated

- o INTEL approves proposal to donate to ICASE 432 microprocessors and data base processor for hardware research

RTR 505-37-13-02 Integrated Programs for Aerospace Vehicle-Design (IPAD)

OBJECTIVE:

To develop the preliminary design of a full IPAD software system and implement a prototype system (denoted IPIP) for the total management of aerospace-vehicle design processes in the 1980's which will permit reductions in the design cycle time and cost.

EXPECTED RESULTS:

Establish IPAD data base management software on CDC host computer, including geometry capability and limited computer networking by the end of FY 1985

Develop and validate a distributed IPAD engineering/scientific data management software capability for a network of mainframe/mini/microcomputers which supports design/analysis and geometry data for representative aerospace and space platform configurations by end of FY 1989

APPROACH:

Under existing IPAD program, The Boeing Company will develop prototype software appropriate for engineering data base management of an integrated computer-aided design system of the future. The development will include system architecture for multischemata (multiviews) of the data and consideration of data networking. The functionality and efficiency of the prototype software will be evaluated by Boeing, NASA, and members of an Industrial Technical Advisory Board (ITAB).

MILESTONES:

- o Release of IPIP Version 4.0 (with wire frame geometry) for CDC computer, January 1983

- o Interim geometry standards release, May 1983

- o Release of RIM/IPIP coupled system, June 1983

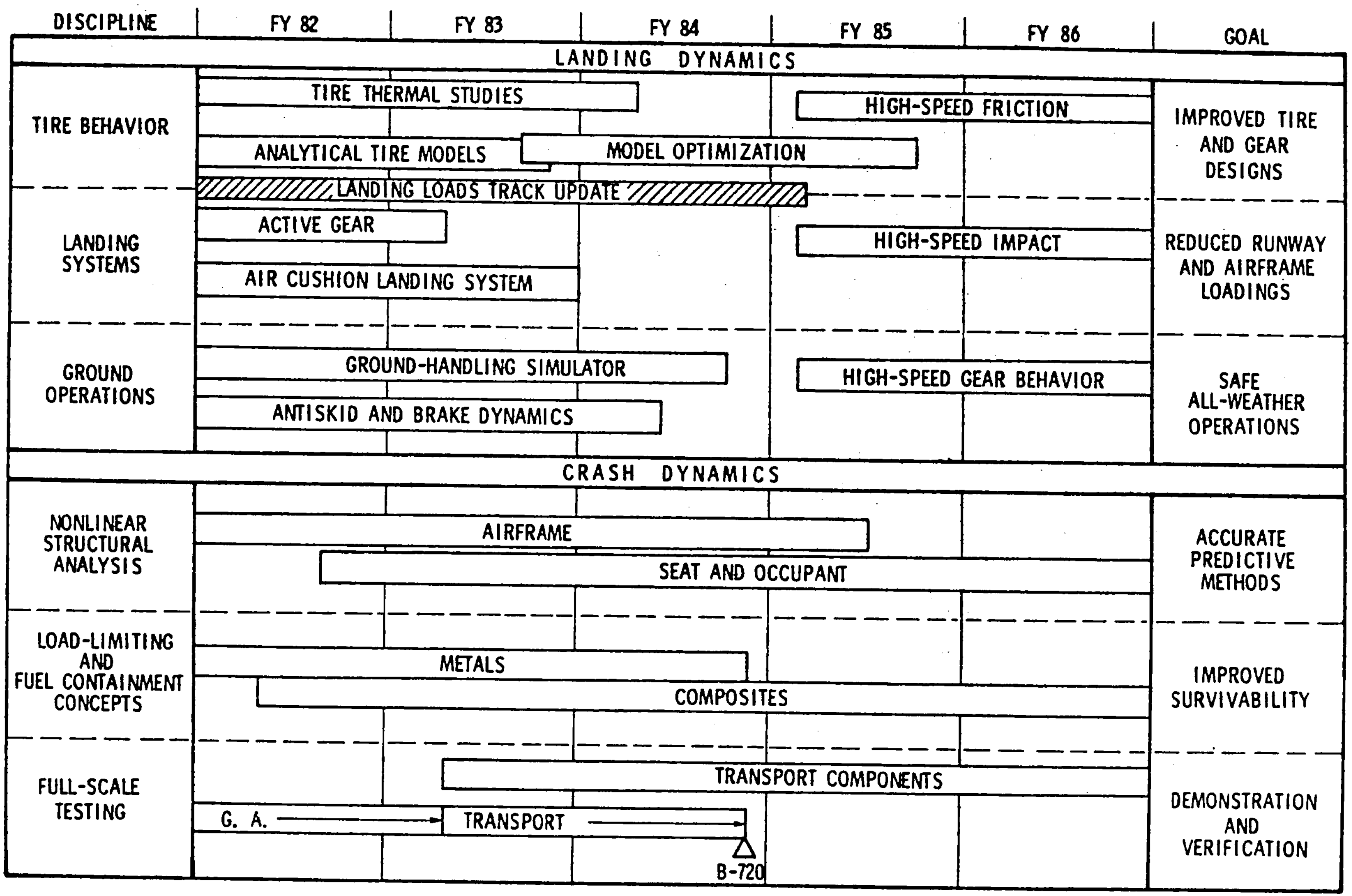
- o Requirements for microcomputer DBM system, August 1983
- o Complete IPIP Version 4.0 operational at LaRC, September 1983

FY 1982 ACCOMPLISHMENTS:

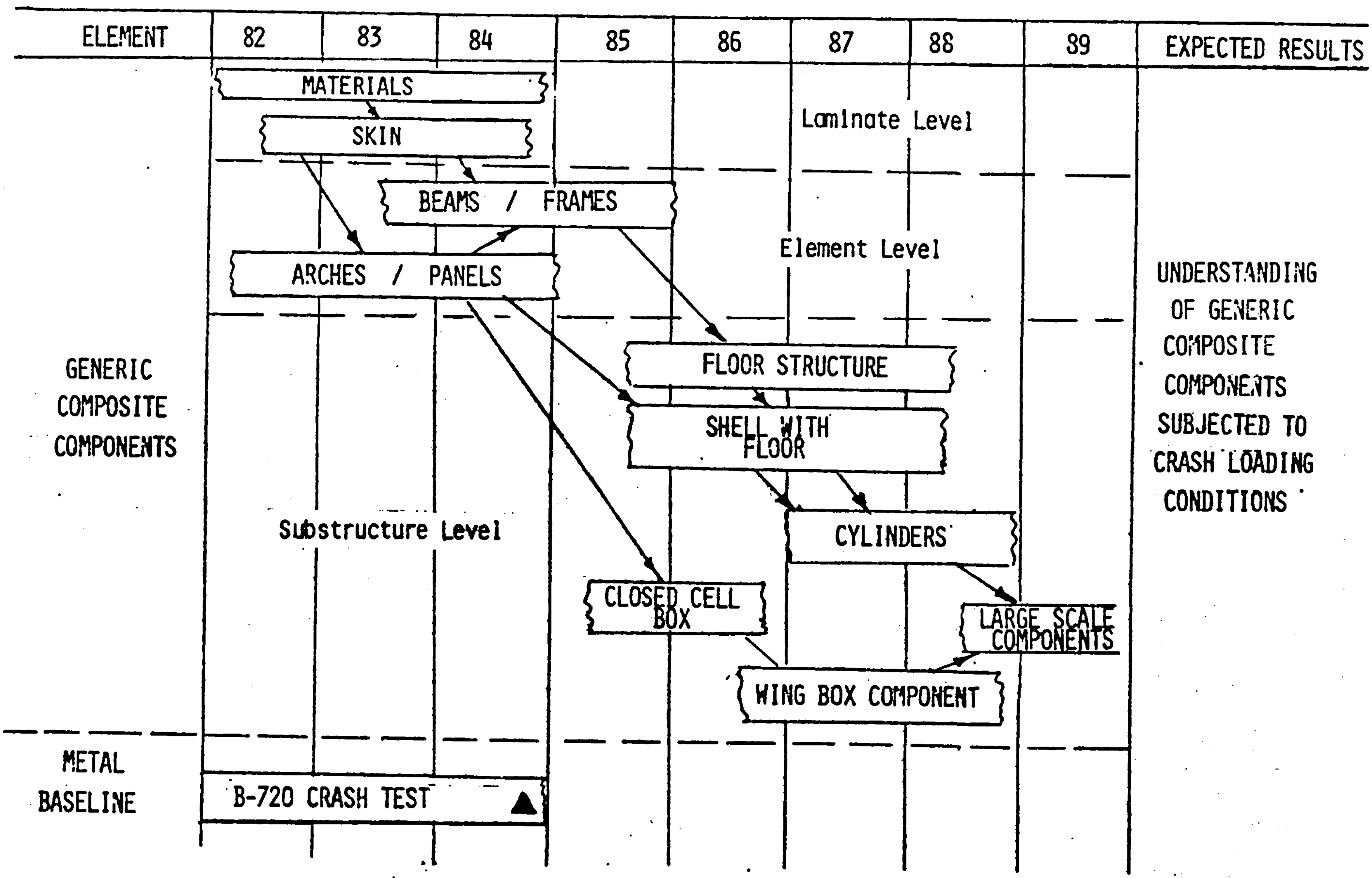
- o IDEF IPIP documentation (4 volumes)
- o IPIP 3.0 multischema data management system
- o RIM 5.0 relational data management system
- o Partial integration of geometry schema with IPIP
- o Draft documentation of IPIP system, geometry schema, and RIM/IPIP interface

IV IMPACT DYNAMICS BRANCH

IMPACT DYNAMICS PROGRAM



RESPONSE CHARACTERISTICS OF GENERIC COMPOSITE COMPONENTS
TO SIMULATED CRASH LOADINGS



IV IMPACT DYNAMICS BRANCH

RTOP 505-33-53 Advanced Structural Analysis Methods

RTR 505-33-53-05 B-720 Crash Test

OBJECTIVE:

To enhance passenger safety through improvement of analysis methods, airframe structural concepts, and seat/restraint system concepts for future aircraft under crash conditions.

EXPECTED RESULTS:

Demonstrate improved static and new dynamic seat test methods in FY 1983

Analytically and experimentally demonstrate load-limiting concepts for GA seat and subfloor structure in FY 1983

Develop and validate multiple occupant/seat/restraint system simulation by FY 1985

Develop definitive transport crash loads by full-scale testing and compare with analytical predictions by FY 1985

APPROACH:

Nonlinear analytical techniques potentially suited to integration into design methods will be used to predict crash dynamic response of fuselage sections, seat/restraints/occupant systems, and complete airplanes. From load-limiting structures the most promising seat and fuselage concepts will be selected and dynamically tested. A data acquisition system will be designed, fabricated, and installed in the B-720 test article. A full-scale B-720 crash test will be performed to provide archival crash response data as a metal baseline for future composite structures research.

MILESTONES:

- o Assemble prototype data system for onboard measurements, October 1982
- o Analytical modeling by Boeing using DYCAST, December 1982
- o Specifications and procurement of dummies and cameras, January 1983
- o Design and fabricate energy absorbing passenger seat concepts, January 1983

- Conduct vertical drop test of fuselage section, May 1983

FY 1982 ACCOMPLISHMENTS:

- Released DYCAST to industry through a workshop in April 1982
- Completed data system design and procured hardware for a 147-channel prototype system
- Initiated transport seat development program with a leading seat manufacturer
- Completed crash scenario definition
- Modified seat/occupant model (DYSOM) computer program being executed at LaRC

RTR 505-33-53-09 Impact Behavior of Composite Structures

OBJECTIVE:

To establish a data base, develop a better understanding of the behavior, and generate/or verify analytical and empirical tools to predict global response characteristics of composite structures under crash loading conditions.

EXPECTED RESULTS:

Develop a data base on composite structural behavior under crash loading conditions by FY 1986

APPROACH:

Conduct static and dynamic tests on representative composite structural components. Test articles will be aimed at building fundamental understanding of crash dynamics behavior. Develop methods, procedures and apparatus in-house to conduct these tests. Develop a data base to evaluate effect of combined loadings on global response, stiffness and failure. Analytical predictions using existing nonlinear computer programs will be compared to experimental results. Supportive contractual efforts will be used mainly to fabricate composite components requiring special tooling.

MILESTONES:

- Predict behavior of composite arches during snap-through, conduct static tests, and compare with analysis, December 1982

- o Conduct abrasion tests on composite and metal coupons, February 1983

- o Fabricate arches for dynamic tests, March 1983

- o Conduct abrasion tests on beams and stiffened skin components, December 1983

FY 1982 ACCOMPLISHMENTS:

- o Planned comprehensive program on generic composite components subjected to crash loadings

- o Abrasion test machine purchased; abrasion coupons received from contractor

- o Initial study of tearing of composite skin completed (Lockheed-California)

- o Obtained composite beam elements for abrasion tests from contractor (Lockheed-California)

RTOP 505-42-23 Rotorcraft Airframe Systems

RTR 505-42-23-04 Composite Crash Dynamics

OBJECTIVE:

To better understand the response characteristics of generic composite components subjected to crash loading conditions.

EXPECTED RESULTS:

Develop in-house test methods, procedures and apparatus to conduct static and dynamic combined loading tests on representative composite beam elements

APPROACH:

To collect and assess the data, evaluate the effect of combined loading on global response, stiffness and failure, and define residual strength after failure. Analytical predictions using DYCAST will be compared to the experimental results. Supportive contractual efforts will be used mainly to fabricate composite components requiring special tooling.

MILESTONES:

- o Have straight and curved composite beam elements designed and fabricated for combined loading tests by Contractor (Lockheed-California), January 1983

- Design and fabricate test fixture for static and dynamic combined loading tests of composite beam elements, March 1983

- Conduct combined loading static tests on beams, July 1983

- Compare combined loading static tests results with analysis, September 1983

FY 1982 ACCOMPLISHMENTS:

- Planned and initiated a comprehensive program on generic composite components subjected to crash loadings

RTOP 505-45-23 Aircraft Landing Dynamics

RTR 505-45-23-01 Aircraft Landing Dynamics

OBJECTIVE:

Advance the technology for safe, economical all-weather aircraft ground operations, including the development of new landing systems.

EXPECTED RESULTS:

Develop and validate software simulation of ACLS and active control gear concepts in FY 1983

Conclude study of thermal effects on tire integrity by FY 1984

Complete modified flight simulator for research on aircraft ground handling in FY 1984

Conduct comprehensive interagency study to validate predicted aircraft stopping performance under all-weather conditions by FY 1984

Develop and optimize analytical tire models to facilitate tire and gear designs by FY 1985

APPROACH:

In tire modeling efforts, in-house research and grants will be continued to develop a family of analytical tire models capable of predicting both static and dynamic response as well as tire heat transfer. The reduced basis vector method will be exploited to simplify nonlinear analysis. The accuracy of the models will be established by comparison with experiment.

For antiskid systems, research results on braking pressure-type response and simplified tire stiffness models will be incorporated into software for antiskid simulation. A hydraulic breadboard will be fabricated to provide an accurate analog of the braking system. Upon completion, antiskid simulations wil be compared with DC-9 flight test data as well as data obtained on the landing loads track. An AGARD summary paper on aircraft simulation fidelity for ground performance operations will be co-authored by NASA and BAC (British Aerospace Corp.).

In research on advanced landing systems, studies of air cushion landing systems will continue. An analysis model of air bay response will be improved. Studies of braking and steering concepts using a modified swamp buggy vehicle and models will be conducted on runways as well as water surfaces.

MILESTONES:

- Improved tire static load/ground reaction apparatus operational, November 1982
- Publish results from tire thermal studies, February 1983
- Develop contact algorithm for tire finite element model, December 1982
- Complete hardware modifications to aircraft ground handling simulator, January 1983
- Complete software simulation of a hydromechanical anti-skid system, March 1983
- Publish results from air cushion landing system (ACLS) braking and steering tests and tests to validate ACLS analysis, May 1983
- Prototype acceleration-monitoring system evaluated for on-board aircraft use, July 1983
- Conduct full-scale and model studies as needed to support landing loads track update

FY 1982 ACCOMPLISHMENTS:

- Tire modeling workshop in September 1982
- Studies of brake dynamics and tire tread temperatures generated during antiskid operations completed and results published
- Track data from F-14 FOD tests and F-4 bomb-damaged runway tests transmitted to Navy and Air Force, respectively

- Technique developed for accurately monitoring speed, heading, and ground track of freebody vehicle

- Concepts evaluated for steering and braking air cushion landing systems operating on concrete and grass

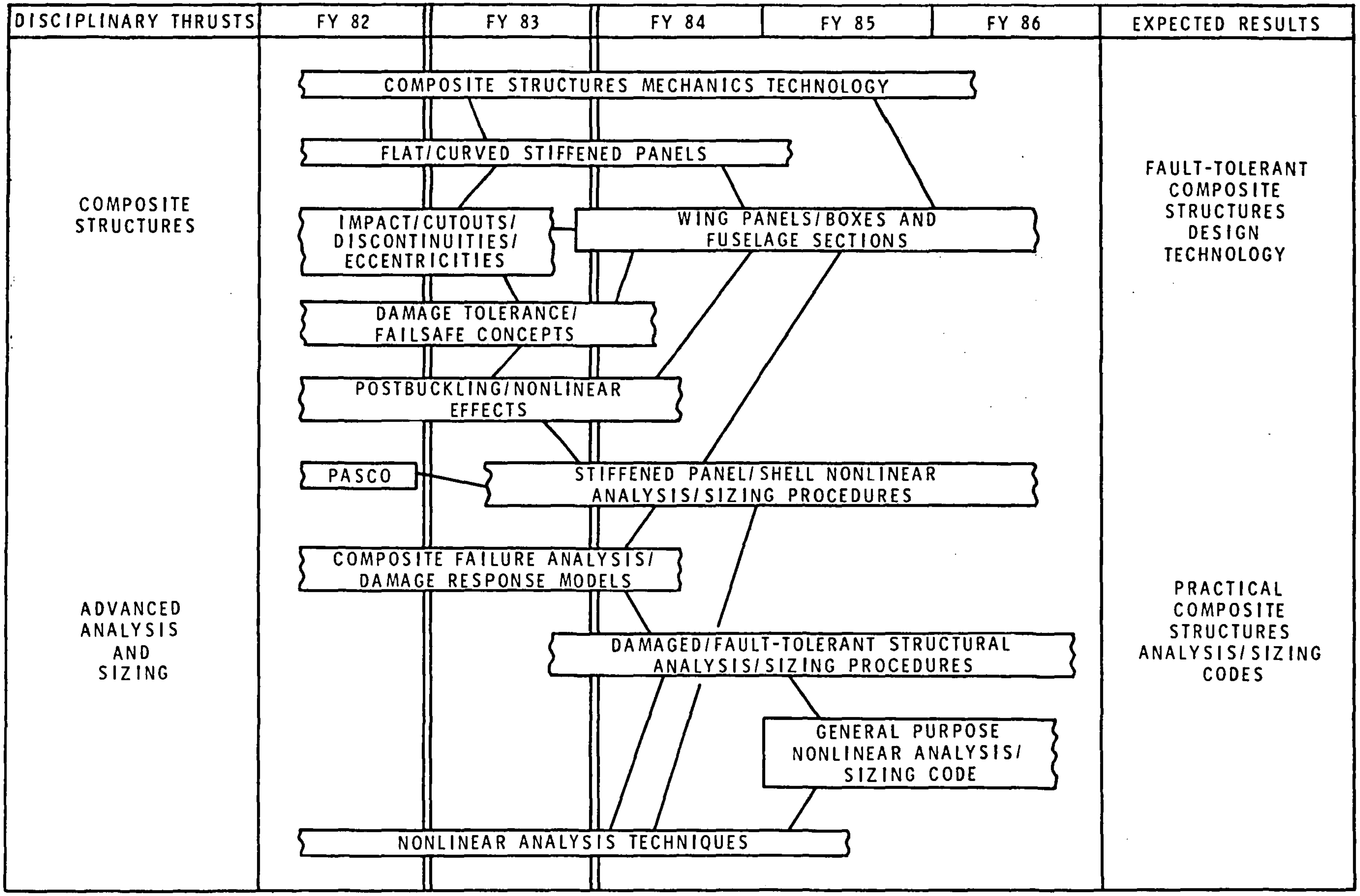
- Agreement obtained between air cushion analytical model and experimental behavior of ACLS test vehicle

- F-4 main gear and electronic controller modified for active gear experiments

- On-site support provided for Space Shuttle STS-3 landing at White Sands

V STRUCTURAL MECHANICS BRANCH

STRUCTURAL MECHANICS



V STRUCTURAL MECHANICS BRANCH

RTOP 505-33-33 Composites

RTR 505-33-33-06 Composite Structures Design Technology

and

RTOP 534-03-23 Composite Materials and Structures

RTR 534-03-23-07 Composite Structures Design Technology

OBJECTIVE:

Develop mechanics technology required for the design of efficient, fault-tolerant advanced-composite aircraft structural components subject to combined loads, impact, postbuckling effects and local discontinuities.

EXPECTED RESULTS:

Understand mechanics of buckling and effects of flaws and damage on strength predictions for composite structures in FY 1985

Demonstrate the ability to predict the postbuckling response of complex composite structures in FY 1986

APPROACH:

The advanced structural concepts and configurations that exploit the advantages of composites as well as advanced design methods for advanced composite flat and curved panels and stiffened shell structures will be developed. Compression, tension, shear and combined loads representative of aircraft primary wing and fuselage components will be considered. Methods will be developed for predicting strength, buckling and stiffness of composite components including the effects of foreign-object damage, cutouts and postbuckling. An experimental data base will be established for composite airframe structural components including damage, cutouts and postbuckling and correlated with analytical predictions.

MILESTONES:

- o Initiate cutout reinforcement study for composite panels, October 1982
- o Complete study of damage-tolerance concepts for pressurized composite fuselage structures, December 1982
- o Extend stiffener pull-off failure analysis and verify with tests, December 1982

- o Develop test plan to study the damage tolerance of composite fuselage panels, January 1983
- o Initiate study of the effects of impact damage and holes on the behavior of composite shear panels, March 1983
- o Document preliminary study of the effects of internal pressure on curved composite panels, March 1983
- o Initiate analytical study of stiffened fuselage shells with buckled skins, June 1983
- o Develop mathematical models for predicting compressive strength of multidirectional composite laminates, June 1983
- o Complete preliminary postbuckling study of stiffened and unstiffened composite shear webs, September 1983
- o Complete preliminary study of the effects of stiffener eccentricity and skin discontinuities on the response of stiffened compression panels, September 1983

FY 1982 ACCOMPLISHMENTS:

- o Preliminary study of flat stiffened composite compression panels completed and documented
- o Picture-frame shear-panel test fixtures with improved corner kinematics designed, fabricated and placed in service for stiffened and unstiffened shear panels. Four stiffened and two unstiffened panels have been tested; analysis and additional testing under way
- o Crashworthy composite fuselage component test plan developed
- o Preliminary study of effect of stacking sequence on compression strength of finite-width composite plates with holes documented and extended study under way. Results include the effects of drilled and punched holes and cracks
- o Three stiffened curved compression panels have been tested; analysis and comparison with flat panel results under way
- o Composite Failure Mechanisms and Failure Analysis Workshop held at Langley, March 23-25, 1982
- o Two-dimensional buckled delamination propagation analysis documented

- o Microbuckling failure mechanism identified as a critical failure mechanism for compression loaded laminates with impact damage and holes

- o Preliminary study of the effects of cut stiffeners on the postbuckling behavior of stiffened compression panels under way

RTR 534-03-23-08 Failsafe Composite Structures

OBJECTIVE:

Develop structures technology and damage containment concepts required for the design of efficient, damage-tolerant advanced-composite aircraft structural components subject to combined loads, impact, local discontinuities and nonlinear effects.

EXPECTED RESULTS:

Develop and verify fault-tolerant structural concepts for composite wing and fuselage structure in FY 1986

APPROACH:

Damage-tolerant structural concepts and configurations will be developed for low-strain fuselage components with buckled skins and high-strain buckling-resistant wing components. Compression, tension, shear and combined loads representative of aircraft primrary structures will be considered. Methods will be developed for predicting strength and response characteristics of damage-tolerant structural concepts including the effects of damage, cutouts, postbuckling and internal pressure. Failure mechanisms will be identified and analytical procedures will be verified by testing structural components of the appropriate size.

MILESTONES:

- o Initiate analytical and experimental study of effect of resin shear modulus on microbuckling and compression failure of composites, October 1982

- o Initiate study of internal load redistribution due to local stiffener failure of stiffened compression panels, October 1982

- o Initiate in-house testing of L1011 composite fin PRVT spars and covers with and without damage, October 1982

- o Evaluate damage-tolerant characteristics of Kevlar-epoxy-skins and graphite-epoxy-stiffener hybrid compression panel concept, November 1982

- o Complete concept development and design report for damage-tolerant high-strain wing compression panels, February 1983

- o Release RFP for damage-tolerant wing panel contract, March 1983

- o Initiate study of wing-panel longitudinal-splice joint concept for improved damage tolerance, April 1983

- o Fabricate four damage-tolerant wing compression panels, June 1983

- o Complete design and fabrication of stiffened composite fuselage panels for combined-load testing, September 1983

FY 1982 ACCOMPLISHMENTS:

- o Contract to initiate analytical study of stiffened composite fuselages with buckled skins in final RFP release stage

- o Contract task awarded to design and fabricate test specimens representative of large composite stiffened fuselage panels subjected to combined loads

- o Contract task awarded to design and fabricate damage-tolerant wing compression panels

- o Defined standardized compression-loaded impact test that has been adopted by industry to evaluate damage-tolerant material systems

- o Soft-skin and discontinuous-laminate structural concepts demonstrated for improved damage tolerance of compression-loaded stiffened panels

RTR 534-03-23-09 Nonlinear Analysis

OBJECTIVE:

Develop structural analysis methods for predicting the nonlinear behavior of aerospace structures.

EXPECTED RESULTS:

Develop nonlinear procedures for reduced degree-of-freedom and time-integration analyses of aerospace structures with large deflections in FY 1984

APPROACH:

Advanced structural analysis procedures for aerospace structures with nonlinear responses will be developed.

MILESTONES:

- o Document study of reduction methods for nonlinear transient dynamic problems with step loadings, November 1982
- o Document matrix partitioning approach for nonlinear structural problems with closely spaced modes and modal interaction, January 1983
- o Complete preliminary study of corotational elements with large rotations for STAGSC-1/RRSYS, August 1983
- o Evaluate approaches for incorporating nonlinear postbuckling analyses in sizing procedures, September 1983
- o Introduce an accurate advanced analysis procedure on generalized Newton's method into a prototype nonlinear analysis code, September 1983
- o Extend study of reduction methods for nonlinear transient dynamics problems to include additional loading conditions, September 1983

FY 1982 ACCOMPLISHMENTS:

- o Matrix partitioning approach developed for nonlinear structural problems with closely-spaced small eigenvalues and modal interaction
- o Installed nonlinear analysis code for general shells (STAGC-1) on Langley CYBER-203 and improved its computational efficiency
- o Identified and documented column impact dynamic response characteristics
- o Reduced methods for 1-D nonlinear transient dynamics problems extended to 2-D problems with step loadings

RTOP 505-33-53 Advanced Structural Analysis Methods

RTR 505-33-53-10 Structural Mechanics Analysis

OBJECTIVE:

Develop structural analysis and sizing methods for predicting and designing for nonlinear behavior of aerospace structures including postbuckling phenomena and ultimate strength.

EXPECTED RESULTS:

Develop pilot nonlinear analysis and sizing procedures for composite structural components in FY 1985

APPROACH:

Using combinations of in-house research, contracts, and grants, develop and assess analytical techniques for studying the buckling nonlinear response of composite aerospace structures. Compare that response with failure criteria, also to be developed and assessed, to predict the ultimate strength of aerospace structures. Develop and assess structural sizing algorithms that can be combined with these analysis techniques and failure criteria to produce procedures for sizing composite aerospace structures that undergo large, complex, nonlinear deformations.

MILESTONES:

- o Initiate study of effects of geometric imperfections on postbuckling behavior of curved composite panels, January 1983
- o Introduce crack finite element into pilot structural sizing code to study damage-tolerant designs for stiffened panels, March 1983
- o Identify governing parameters for postbuckling of orthotropic composite plates under combined compression and shear, September 1983
- o Extend application of generalized Newton's method to postbuckling of stiffened orthotropic plates, September 1983

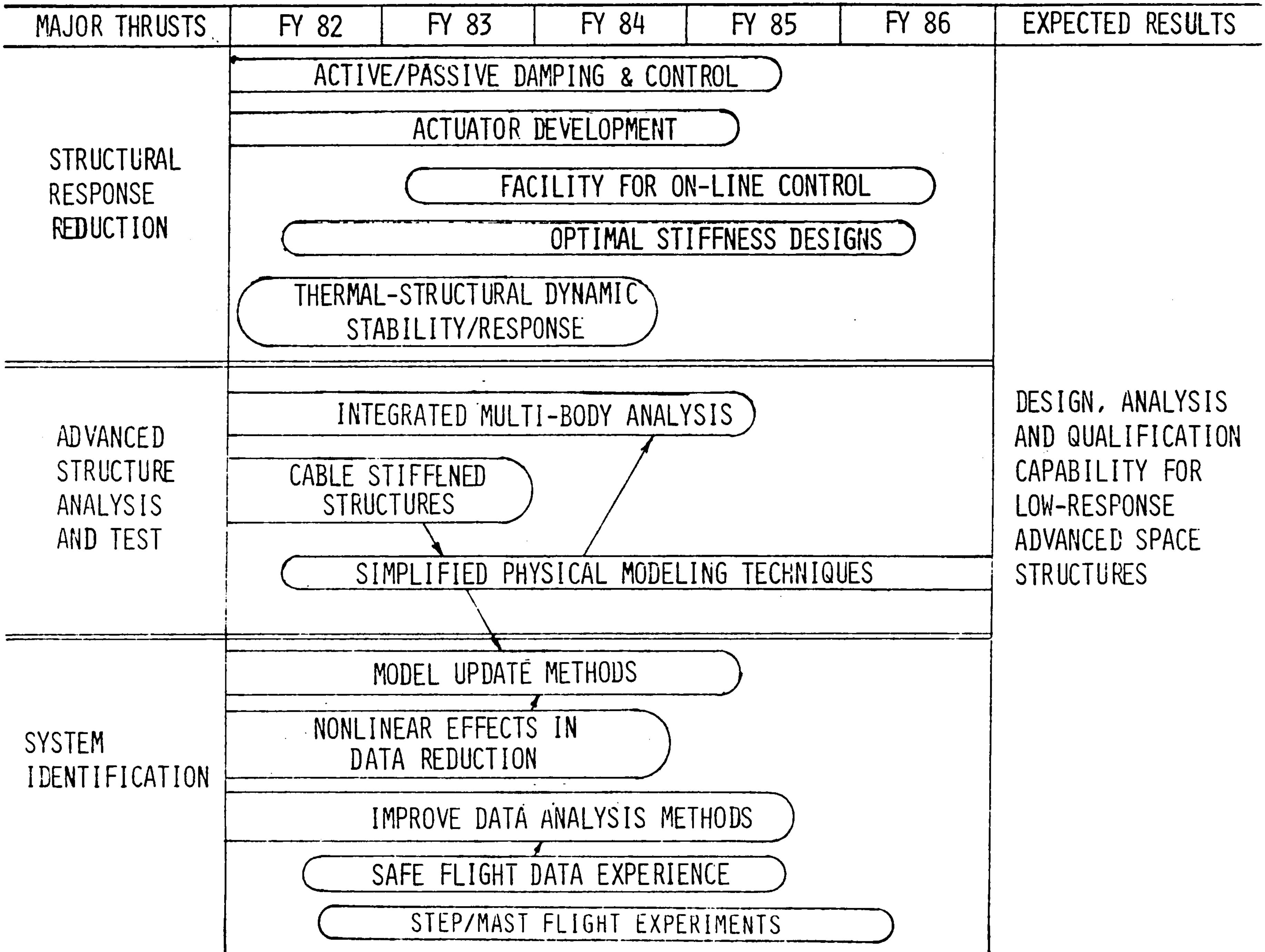
FY 1982 ACCOMPLISHMENTS:

- o Identified modeling detail required for analyzing flat stiffened composite compression panels with postbuckling response. Excellent analytical correlation with test results

- Identified governing parameters for postbuckling response of orthotropic composite plates loaded in shear
- Developed improved shear buckling analysis procedure for stiffened composite panels
- Developed and documented structural sizing capability with collapse constraints
- Multiparameter reduced bases technique developed for buckling and postbuckling analyses of composite plates

VI STRUCTURAL DYNAMICS BRANCH

DYNAMICS OF ADVANCED SPACE STRUCTURES



VI STRUCTURAL DYNAMICS BRANCH

RTOP 506-53-53 Analysis and Synthesis

RTR 506-53-53-08 Analysis and Design - Structural Dynamics

OBJECTIVE:

Accomplish validated capability to control excessive responses of large flexible space structures by active and passive methods.

EXPECTED RESULTS:

Evaluate, by end of FY 1983, new or improved nonlinear algorithms for dynamic analysis

Develop and validate methods for predicting and reducing the response of large flexible space structures by FY 1984

APPROACH:

Coordinated test and analysis programs will be performed on simple structures for development of analysis, system identification, test, and control concepts. Evaluation of methods on more complex structures will then be conducted. Active damping concepts will be demonstrated on an eight-foot-square grillage model with emphasis on actuator types and characteristics in a joint program with CTFMD. Advanced actuator concepts will be studied under grant and in-house and developed to give desired control characteristics. Advanced off-line system identification algorithms for structural vibration data applications are being evaluated and improved for use in realistic condition of noise, non-linearities, available test times and excitation forces. Current emphasis is on large amplitude effects and closely spaced modes. An accurate automated math model improvement method for matching measured modal characteristics is being extended to include damping and selected constrained term provisions. An automated design method for improving the dynamic response of structures is under development and will be improved to include active/passive control combinations and sensitivity analyses. Flight dynamics control and deployment of dynamics of large flimsy booms for antenna mast and space station applications will be studied. Also ground test methods will be sought which allow characterizing these flimsy booms to the extent possible in a one-g environment. Method for identifying equivalent partial differential equations for complex structures will be investigated as a method for simplifying mathematical models of booms, dishes, and trusses.

MILESTONES:

- o Begin closed-loop tests on grillage, October 1982
- o Begin tests of beam in 16.7-meter thermal-vacuum chamber, October 1982
- o Begin closed-loop active damping tests on grillage, October 1982
- o Complete nonlinear FFT modal test study, November 1982
- o Establish requirements for low frequency ground tests, December 1982
- o Begin tests of first space station component, May 1983

FY 1982 ACCOMPLISHMENTS:

- o Defined structural dynamics flight experiment requirements for large space structure experiment
- o Completed experimental study of active damping of beam
- o Completed analytical/experimental study of membrane dynamics
- o Developed passive stiffness design approach for structures
- o Designed thermal flutter experiment
- o Completed sensitivity study of ITD modal test method
- o Demonstrated accurate automated model improvement computer program on LDEF
- o Completed analytical/experimental study of ITD modal data analysis of two hardening nonlinear systems
- o Completed investigation of slender element impact dynamics
- o Completed preliminary design of active dampers for grillage
- o Initiated eigenvalue sensitivity study for optimal stiffness design
- o Initiated experimental and analytical study of pretensioned hexagonal rings

RTR 506-53-53-09 Space Station Dynamics

OBJECTIVE:

Develop new analytical methods for predicting the coupled structural dynamics and control of multibody space station configurations. Specific objective for FY 1983 is establishment of needs for space station analysis.

EXPECTED RESULTS:

Develop, by FY 1985, an integrated analysis/synthesis capability which addresses the dynamic behavior of large aerospace structures under mechanical and thermal excitations, including structure/controls interactions

APPROACH:

Assess state-of-the-art analysis technology for multibody structure/control. Evaluate analysis technology through application to fundamental low-frequency structure/control problems and multibody configurations. Fabricate and perform tests of simple configurations for comparison with analyses. Develop new method where needed such as improvements or adaptation of modal synthesis techniques, nonlinear steady-state solutions, and improved transient algorithms for low frequency dominated system. Identify and pursue needs in passive damping models and connection interfaces.

MILESTONES:

- o Initiate assessment of existing methods for coupled dynamics/control of multibody configuration, October 1982
- o Design multibody space station generic structure, February 1983
- o Identify technology needs for adaptation of modal synthesis techniques to multibody vibrations and interfacing modeling, March 1983

FY 1982 ACCOMPLISHMENTS:

- o Initiated state-of-the-art methods assessment study for space stations

RTR 542-03-04-01 Solar Array Dynamics

OBJECTIVE:

To obtain video taped optical observations of the solar array during its orbital flight test. To develop a TV/image processing based photogrammetry system capable of making motion measurements in the laboratory on a large, flexible structure and use this system to analyze the video tapes of the solar array flight test. To use results from analysis of flight test to study the structural and control dynamics of a large, flexible structure. Primary objective for FY 1983 is to demonstrate capability of optical measurement/analysis on a low-frequency solar array type test article.

EXPECTED RESULTS:

Comparison of flight results with analytical prediction of the solar array dynamics

To prove techniques for remote measurement/detection of dynamics of large flexible structures

APPROACH:

This is a joint and cooperative effort with the Marshall Space Flight Center in conjunction with their Solar Array Flight Experiment. The shuttle closed circuit television (CCTV) system will be used to obtain video taped optical observations of a system of passive targets on the Solar Array during the flight test. Parallel with the MSFC development of flight hardware, LaRC will develop a laboratory prototype measurement system. This system will utilize a combination of analog and digital processing techniques to analyze TV images of a model or simulated structure. From the analysis will come a mathematical description of the displacement time history of the model. In conjunction with this prototype development, existing math models will be used in simulation studies to understand the dynamic characteristics of the Solar Array and possible modal responses to expected excitations on orbit. Appropriate existing analysis techniques will then be selected which are capable of using time domain displacement data to determine the modal and frequency responses and damping characteristics. After the flight test, the above developed system and analysis techniques will be used to process CCTV video tapes and study the flight dynamics of the Solar Array.

MILESTONES:

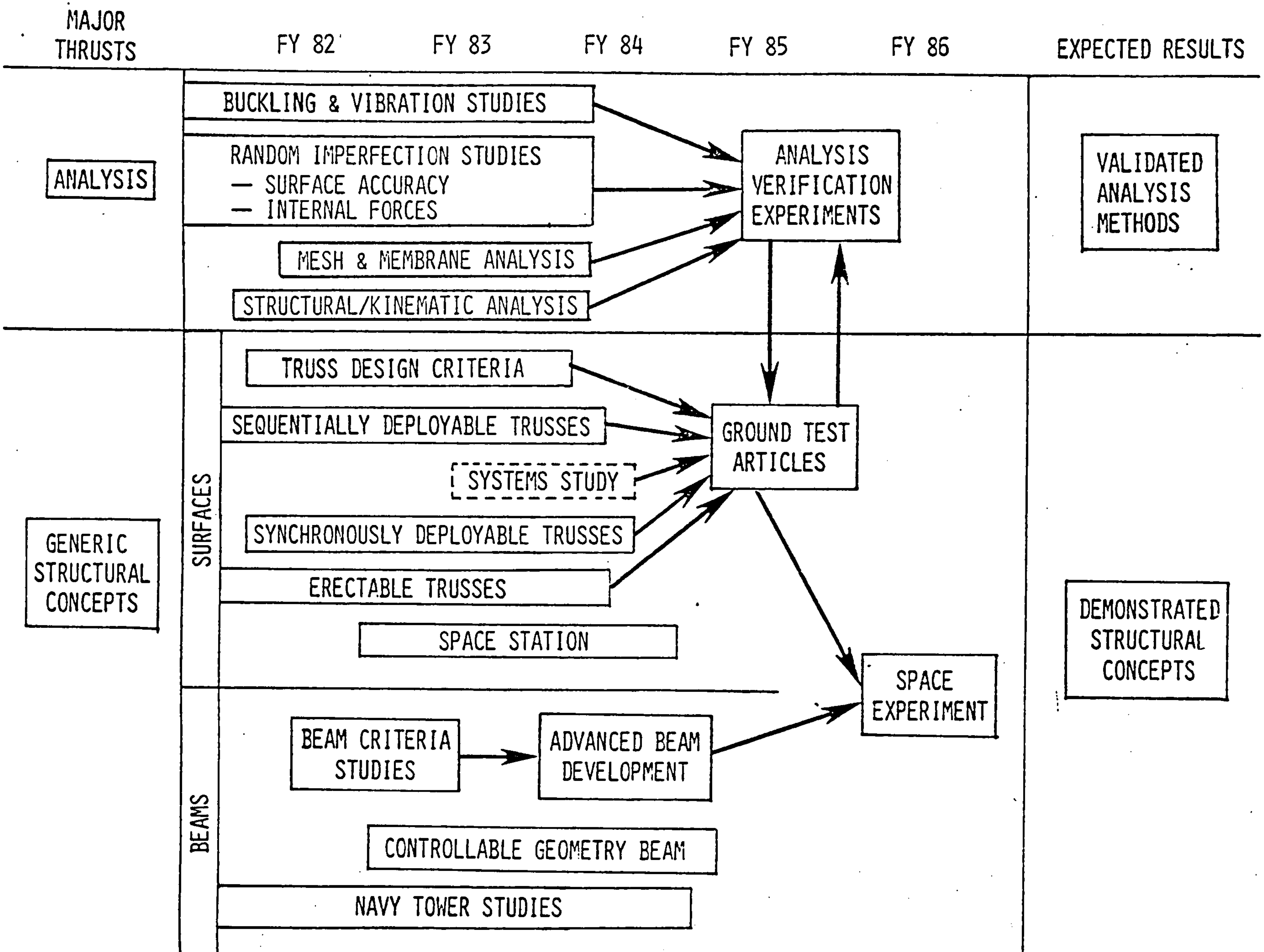
- o Complete video demonstration on 1/10-scale test article, December 1982
- o Complete dynamic analyses of flight array, December 1982
- o Complete development of on-orbit experimental procedures with MSFC, March 1983
- o Test large-scale model, May 1983

FY 1982 ACCOMPLISHMENTS:

- o LaRC experimental requirements have been baselined in the MSFC Flight Program
- o CCTV system has been designed and implementation authorized at JSC
- o Preliminary design of the video analysis system has been done and acquisition and fabrication of prototype is in progress
- o A stereo triangulation displacement analysis system has been identified and is on order

VII STRUCTURAL CONCEPTS BRANCH

STRUCTURAL CONCEPTS (ADVANCED SPACE STRUCTURES)



VII STRUCTURAL CONCEPTS BRANCH

RTOP 506-53-43 Advanced Space Structures

RTR 506-53-43-01 Advanced Space Structures
RTR 506-53-43-53 Navy VLF Tower Model and Test

OBJECTIVE:

Develop deployable and erectable structural concepts and associated design technology for future large space structures.

EXPECTED RESULTS:

Validated analysis and design capability for large spacecraft by the end of FY 1984

Establish feasibility of controllable geometry "serpentine" beams by FY 1984

Establish, by the end of 1985, structural concepts, deployment schemes, and packaging techniques that will permit planar structures on the order of 100 to 200 meters in size to be carried into orbit in one shuttle flight and automatically deployed

Establish erectable concepts and asembly methods for structures of 100 to 1000 meters in size by end of FY 1985

APPROACH:

In the structural concepts area, folding and packaging techniques for very lightweight deployable structures will be investigated. The effects of using very slender members to achieve high packaging efficiency will be evaluated. A truss structure will be constructed for static and dynamic tests to confirm the theoretical predictions. Research will also be carried out on structural concepts which are capable of being rapidly erected on orbit.

Structural parametric studies will be conducted on large, faceted antenna concepts. Studies of achievable accuracy in erectable and deployable concepts will be investigated. Selected problems in construction/operational dynamics will be performed. The effects of orbital transfer thrust loads on structural sizing will be investigated. Parametric studies will also be conducted on structures appropriate for use on low earth orbit space stations.

Conceptual studies including hardware development will be conducted on new deployable and erectable structural members and structural configurations. The major emphasis of this effort will be focused on providing highly controlled and

reliable on-orbit structural construction. Exploratory studies will be made of introducing multiple actuation devices into the structure such that its geometry can be controlled at will. Initial efforts will be on a controlled geometry boom.

MILESTONES:

- o Test 10-bay serpentine beam, December 1982
- o Fabricate 2-D synchronously deployable truss, January 1983
- o Fabricate first generation slender strut, May 1983
- o Fabricate erectable beam concept, July 1983
- o Fabricate 6-bay model of synchronously deployable truss, September 1983
- o Fabricate 4-bay (1 meter) model of sequentially deployable truss

FY 1982 ACCOMPLISHMENTS:

- o Testing and documentation of mobile work station erection test in the MSFC neutral buoyancy tank completed
- o Working models of two serpentine beam concepts completed and demonstrated
- o Contractor study on low coefficient of thermal expansion materials completed
- o Working model of a critically damped synchronizer joint for deployable trusses completed
- o Working model of a sequentially deployable truss completed
- o Studies completed on low drag struts for low orbit space stations

STRUCTURAL CONCEPTS (SPACE TRANSPORTATION)

LOGIC DIAGRAM

DISCIPLINARY THRUSTS	FY 82 – FY 86	EXPECTED RESULTS
SYSTEM STUDIES	FUTURE SPACE TRANSPORTATION SYSTEMS (MODERATE & HEAVY LIFT) ON-DEMAND UTILITY & MILITARY STS ORBITAL TRANSFER VEHICLES RSI	o IDENTIFICATION OF ENABLING AND ENHANCING RESEARCH TECHNOLOGY o STRUCTURAL CONCEPTS o THERMAL MANAGEMENT
STRUCTURAL CONCEPTS	CRYOGENIC TANKAGE (FSTS, OTV, SPACE STATION) CARBON/CARBON HOT STRUCTURE (BODY FLAP, AEROSHELL) LIGHTWEIGHT PANELS (CORR SKIN, SANDWICH, METAL MATRIX) INSULATED STRUCTURE	o VALIDATION OF STRUCTURAL CONCEPTS
THERMAL MANAGEMENT TECHNIQUES	DURABLE TPS (METALLIC & CERAMIC) CRYO-INSULATION HEAT PIPE L.E. PACKAGED INTERNAL INSULATION	o VALIDATION OF THERMAL MANAGEMENT CONCEPTS
THERMAL STRUCTURES LABORATORY	FACILITY PLANNING (HIGH TEMP-CRYO) HIGH TEMP LAB	o NATIONAL THERMAL STRUCTURES RESEARCH LAB

RTR 506-53-43-02 STS Structural Concepts

OBJECTIVE:

Develop and validate through analysis and test efficient structural concepts and thermal management techniques critical to the design of future space transportation systems (STS).

EXPECTED RESULTS:

Develop advanced carbon-carbon (ACC) hot aeroshell structure/daze fastener through design and tests by FY 1985

Develop concepts for hot ACC body flap designs and conduct component tests by FY 1985

Define and provide test data of effective cryo tankage structure for advanced STS by FY 1986

APPROACH:

Fabrication of panel and joint components of lightweight cryogenic tankage structural concepts will continue on contract. Completed panel test specimens will be tested in tension and in compression stability tests to validate concepts. Funding permitting, validated concepts will be scaled-up leading to tests of cylindrical tank structure of representative construction. Fastener concepts for advanced carbon-carbon/superalloy attachments will be tested under contract and in-house. Element and small component testing of advanced carbon-carbon materials to obtain preliminary material design values at elevated temperatures and evaluate the structural ability of the material system will begin both in-house and under contract. Manpower under this RTR will continue to support an in-house study of future space transportation systems including second generation space shuttle and orbital transfer vehicles.

MILESTONES:

- o Receive initial tankage panel test components, February 1983
- o Initiate ACC material characterization contract, April 1983
- o Complete ACC fastener study, June 1983

FY 1982 ACCOMPLISHMENTS:

- o Completed design and initiated fabrication of reusable cryogenic tankage wall concept test articles

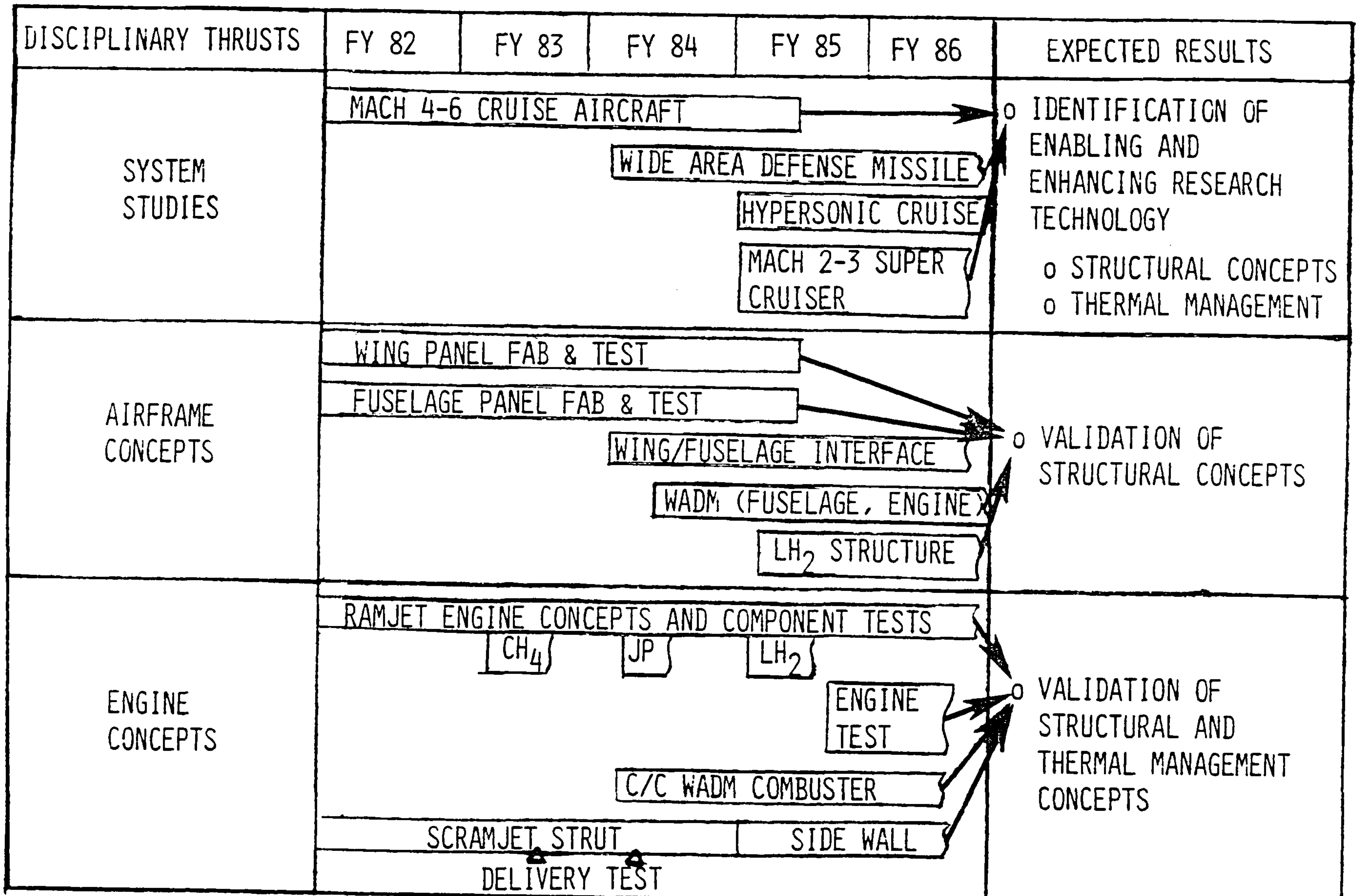
- Completed initial structural definition of a future space transportation system based on ACC hot aeroshell with thrust-supporting non-integral tankage

- Completed preliminary design of ACC shuttle orbiter body flap with top surface removed

- Initiated contract to evaluate low thermal stress fastener concept for use with ACC materials (Director's Discretionary Fund)

STRUCTURAL CONCEPTS (AERO)

LOGIC DIAGRAM



RTOP 505-33-53 Advances Structural Analysis Methods

RTR 505-33-53-11 High-Speed Aircraft Structural Concepts

OBJECTIVE:

Develop and evaluate airframe and engine structural concepts and thermal management techniques appropriate for aircraft which cruise in the flight regime ranging from supersonic to hypersonic.

EXPECTED RESULTS:

Complete fabrication and test of lightweight compression panel concepts for supersonic aircraft by end of FY 1983

Define and provide test data on effective structural concepts and thermal management techniques for Mach 4-5 aircraft airframe by end of FY 1986

APPROACH:

Fabricate curved cap panel fuselage wall concepts leading to compression panel tests to validate SPF titanium fabrication procedures and structural efficiency projections. Initiate the development of high-speed aircraft fuselage panel optimization studies using existing structural optimization analysis codes. Investigate high-temperature thermal management techniques applicable to internal insulation concepts for a Mach 5 ramjet, including the use of zirconia tubes as isolators for the combustion liner and LiH phase-change heat-sink system for thermal control of the internal wall of the diffuser. Titanium panel fabrication procedures using superplastic forming will be studied in-house.

MILESTONES:

- Delivery of fuselage panel test components, February 1983
- Initiate in-house test program investigating high temperature thermal management, March 1983
- Completion of first series of fuselage panel tests at Dryden, August 1983

FY 1982 ACCOMPLISHMENTS:

- Completed optimum sizing of curved cap panel concept for high-speed aircraft fuselage and initiated fabrication of compression panel test specimens

- o Initiated ramjet engine design study contract for engine using methane fuel
- o Completed all contractual testing of welded and diffusion bonded 6-2-4-2 titanium
- o Completed initial design of ramjet engine combustor liner for a JP fueled engine

RTOP 505-43-83 Hypersonic Vehicles

RTR 505-43-83-07 Hypersonic Aircraft Structural Concepts

OBJECTIVES:

Develop and evaluate engine structural and thermal management concepts suitable for air-breathing engines which operate at high altitudes in speed regimes greater than Mach 4.

EXPECTED RESULTS:

Demonstrate fabricability and determine thermal/structural performance of hydrogen cooled scramjet fuel injector strut by end of FY 1983

Define and provide test data on effective structural concepts and thermal management techniques for Mach 4-5 aircraft liquid methane ramjets by end of FY 1986

APPROACH:

Two areas of research are under way in support of the technical objectives. First, titanium sandwich panels suitable for the wing skin of Mach 5 aircraft have been designed, are currenty being fabricated under contract, and will be tested at elevated temperature at the Dryden Flight Research Facility. Second, two studies in air-breathing engines are under way. The fuel-injection strut of the scramjet engine is under construction and funds will be used to validate the multiple brazing processes required during fabrication before proceeding with final fabrication. A study of structural concepts for the combustor and nozzle of a Mach 5 ramjet engine is under way investigating concepts applicable for a methane fueled engine. The contractual and in-house study will be extended to include concepts applicable for a JP fueled engine.

MILESTONES:

- o Initiate contract extension for ramjet engine, December 1982
- o Take delivery of titanium sandwich panels, May 1983

o Take delivery of scramjet fuel-injection strut, July 1983

FY 1982 ACCOMPLISHMENTS:

o Completed wing titanium sandwich skin design and initiated test specimen fabrication using FY 1982 funds made available at Dryden

VIII ACCOMPLISHMENT HIGHLIGHTS

IPAD PROJECT OFFICE

SPECIALIZED COMPUTER HARDWARE PROMISES BENEFITS IN STRUCTURAL COMPUTATIONS

Robert E. Fulton
IPAD Project Office
2887

(RTOP 505-33-63)

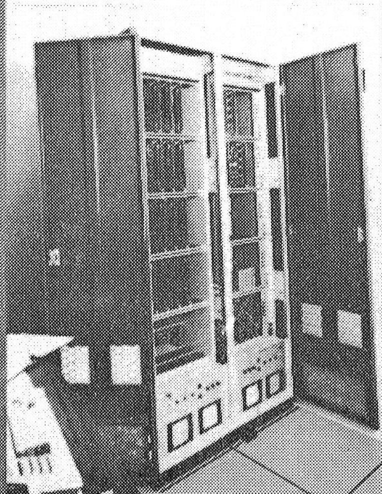
As a part of the computer-aided design research conducted in-house by the IPAD Project Office staff, an effort is underway to develop computational devices specialized for structural calculations. This research is to take advantage of new advances in microprocessors and to reduce the time and/or cost of structural computations. The design concepts for a specialized computer, denoted Finite Element Machine, are under investigation and an experimental version composed of 36 separate microcomputers is under development at Langley. Each of the 36 microcomputers is used to model structural equations at one or more sets of nodes. The 36-node hardware is nearing completion, as indicated on the attached slide, and some early results for plane stress analysis have been obtained with four processors operating in parallel. The slide shows on the right a cantilevered plate in plane stress which has been solved by the finite element method. The finite element equations for the indicated four regions were assigned to four different processors and the equations solved iteratively by the successive over-relaxation method. The problem was also solved with one processor and the relative speedup in computational speedup was 2.84 as compared to the theoretical maximum of 4.0. The difference is due to the overhead in the computation process wherein each processor has some wait time while others are still calculating. The results indicate that dramatic gains in computation time are possible when the number of processors is large ($\gtrsim$1000's).

1/25/82

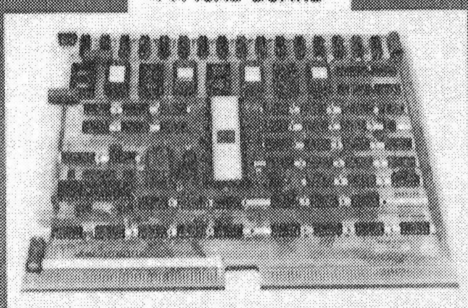
NASA
L–81–11,161

FINITE ELEMENT MACHINE

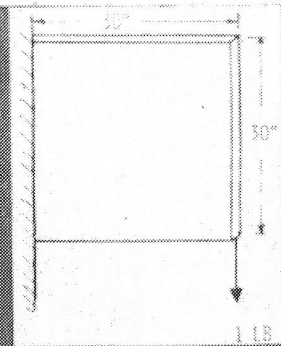
PROTOTYPE FEM HARDWARE



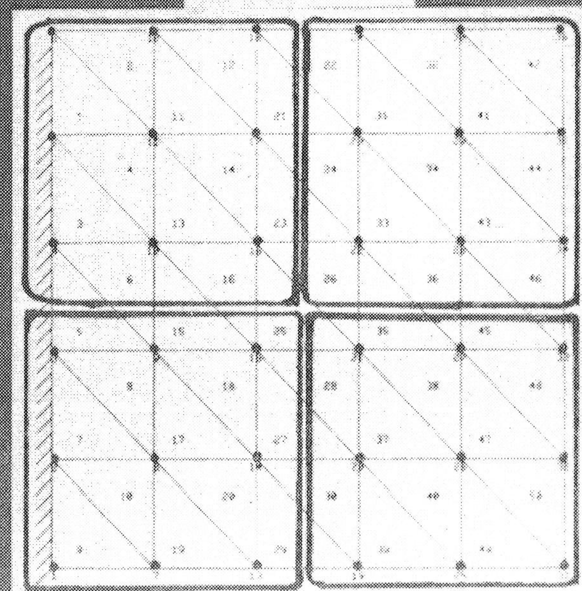
TYPICAL BOARD



PLANE STRESS ANALYSIS OF PLATE



PROCESSOR REGION



COMPUTATIONAL SPEEDUP = 2.84

4 vs 1 PROCESSOR

(THEORETICAL MAXIMUM = 4.0)

IMPACT DYNAMICS BRANCH

JAARS/NASA MODIFIED SEAT EFFECTIVE IN PREVENTING INJURY

Robert G. Thomson and Dwight G. McSmith
Impact Dynamics Research Facility
Extension 3795, 3210
January 25, 1982

(RTOP 505-33-53)

Jungle Aviation and Radio Services (JAARS), along with Mission Aviation Fellowship and Wings of Hope, have sustained in their daily operations serious accidents resulting in injury and, on some occasions, death. In recent years, attention has been focused on serious back injuries from high vertical decelerations. Also noted were other serious injuries apparently connected with restraint problems and/or seat separating from connecting tracks. There are about 30 missionary organizations flying more than 400 aircraft in countries all around the world. This fleet is comprised of a cross section of most single and light twin aircraft such as the Helio Courier; Cessnas 180, 185, 206, 210 and various 400 series twin; Piper single engine aircraft of various types and Piper twins such as the Aztec and Navajo. Also included are Douglas DC-3's, Aero Commanders, a Twin Otter and rotor wing aircraft such as Hughes 500, Hiller and Bell.

A contact with Dwight McSmith of NASA-Langley Research Center was made at Oshkosh, Wisconsin during an annual convention of the Experimental Aircraft Association. This contact, along with the injury-related accidents within the above-mentioned organizations, led JAARS and NASA to a cooperative effort towards a common goal of crash protection. Modification coming to JAARS attention from NASA research included use of a sheet metal seat pan in aircraft seats, a double shoulder harness, and lap belt with metal-to-metal hardware. In addition, early tests indicated that a material called temper foam, developed to provide improved support for astronauts in spacecraft, when used over a sheet metal seat pan, offered greater protection in terms of reduced "G" loads and less slack in the lap belt than conventional seat cushion material. JAARS modified as many seats as possible with a sheet aluminum pan and 3 inches of temper foam on the seat and 2 inches for the back. JAARS also designed an 'S' frame (see figure) to obtain as much attenuation protection as possible within limited space constraints.

Recently, Langley Research Center completed crash test #20, a controlled crash of a light twin (Aztec) impacting at 60 miles per hour, at a minus 15^{o} flight path and 0^{o} pitch. One of JAARS' newly designed 'S' frame seats, complete with temper foam cushions, was installed in the pilot's section of this aircraft for this test. The crash data showed the anthropomorphic dummy on the 'S' frame seat received 20 G's while the anthropomorphic dummy in the standard co-pilot seat received 30 G's at a sink rate of 7 m/s (23 fps).

In February of 1981, a Cessna 206 crashed in Papua, New Guinea, during a training flight. Three basic modifications dealing with crashworthiness had been incorporated: the seats had a sheet metal pan, temper form dushions were used, and double shoulder harnesses and lap belts with metal-to-metal hardware were included. All these modifications had been demonstrated by NASA research to be more effective than conventional equipment in protecting occupants from injury in crashes.

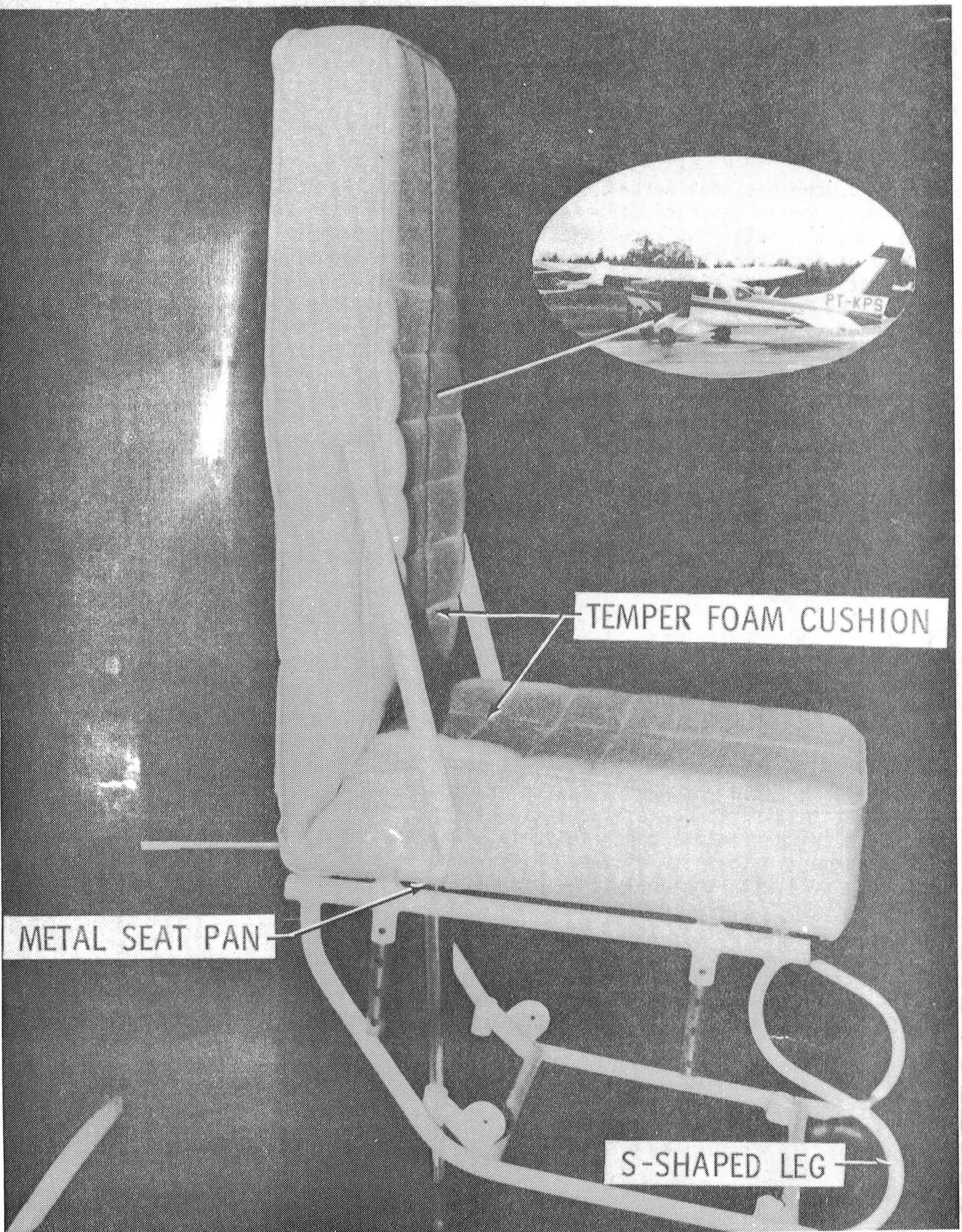
In this accident, the aircraft stalled and impacted the ground with an estimated sink rate of at least 8 m/s. The aircraft continued on approximately 728 feet with a collapsed nose gear, and came to a halt on the side of the runway. The aircraft was at 3,500 pounds gross weight at the time of impact and the cargo pod struck the ground first preventing potential gear separation.

The resultant damage was downward distortion of the wings and flaps with wrinkles in the vertical stabilizer. The rear door and door frame were distorted, thus preventing proper operation of the door. The tail cone was distorted and buckled. Both front seat tracks had a downward deformation of 1/4 to 3/8 inch. Both of the sheetpan seat had a 1/4 to 3/8 inch deformation.

Each pilot was given a thorough physicial immediately following the accident. The pilot was in excellent condition with no cuts, abrasions, sprains, or broken bones. The pilot in the right seat suffered only a stiffness in the neck for several days.

JAARS believes the simple and relatively inexpensive modifications ($300/ aircraft with 8-10 labor hours) of the metal seat pans, temper foam cusions, a double shoulder harness, and metal-to-metal lap belt closure, prevented back injuries in this Cessna 206 accident in Papua, New Guinea, in February 1981. Four accidents, under similar circumstances but with unmodified seats, resulted in broken backs, other types injuries, and one fatality.

JAARS/NASA MODIFIED SEAT EFFECTIVE IN PREVENTING INJURY



CRASH DATA CORRELATED WITH FLIGHT PARAMETERS AT IMPACT

Huey D. Carden
Impact Dynamics Branch, SDD
Extension 3795
May 17, 1982
(RTOP 505-41-33)

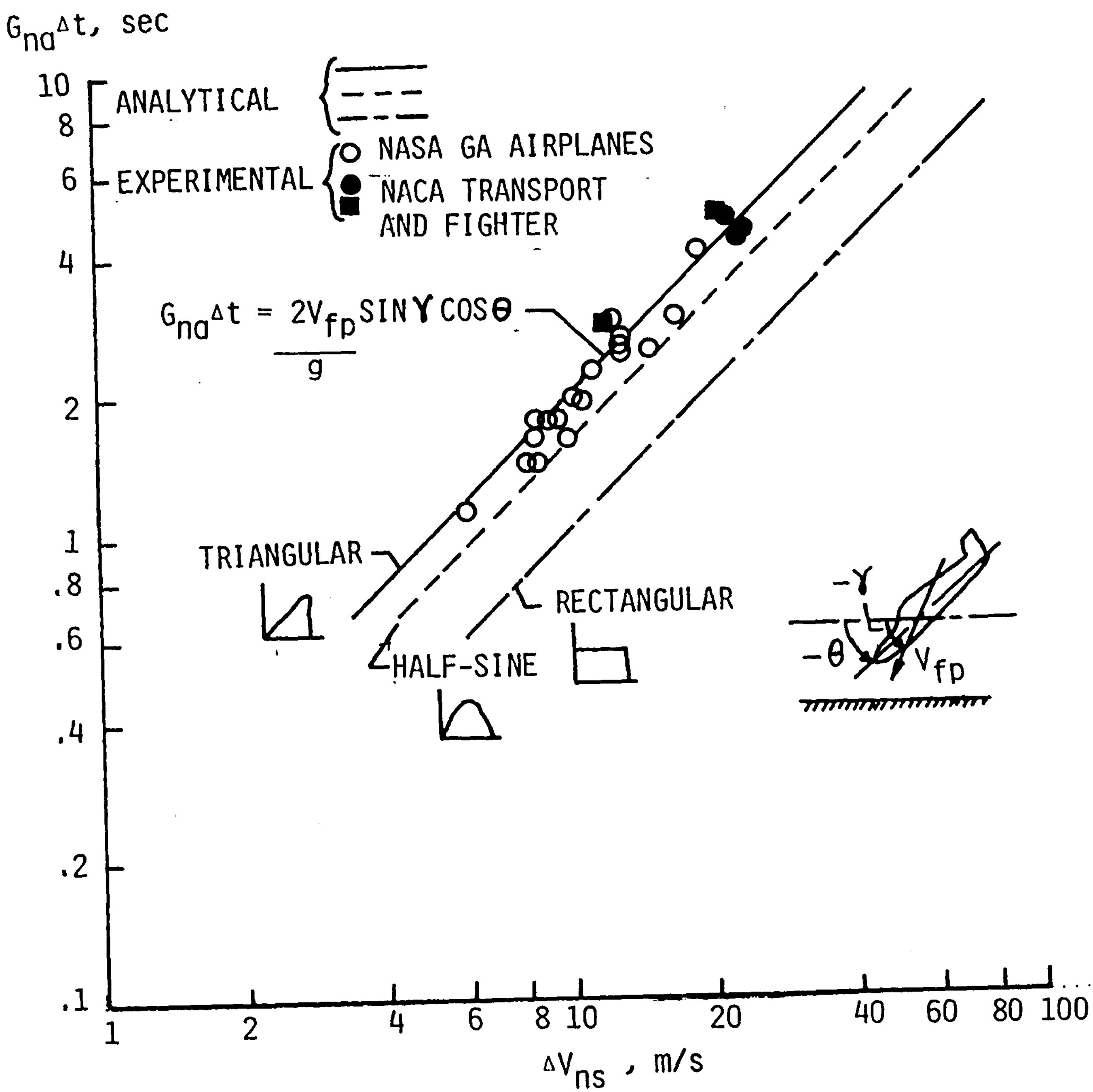
Since 1973, the National Aeronautics and Space Administration (NASA) has conducted a program on crash dynamics of general aviation airplanes under controlled, free flight impact conditions. The objective of this program is to determine the dynamic response of airplane structures, seats, and occupants during a crash, and to determine the effect of flight parameters at impact (i.e. flight velocity, flight path angle, pitch angle, roll angle, and ground condition) on loads and structural damage experienced by the airplane and/or occupants. NASA has conducted twenty-one (21) controlled, full-scale crash tests of single engine and twin engine general aviation airplanes and generated a substantial data base on crash behavior of airplanes heretofore unavailable in the literature.

A simplified analysis of the complex crash scenario has been developed based on impulse-momentum relationships. Assumptions were made which uncouple the analytical expressions for normal and longitudinal airplane impulses. These impulses can then be calculated in terms of flight path velocity, V_{fp}, pitch angle, θ, flight path angle, γ, and acceleration of gravity g. Crash deceleration pulse data from NASA full-scale crash tests and other data in the literature are plotted in the chart for comparison with the simplified analysis.

The chart shows normal impulse, G_{na} Δt, plotted as a function of the vertical change in velocity on a log-log scale. Lines on the chart represent analytical results for three assumed crash impulse shapes, a triangular shape, a half-sine wave shape, and a rectangular wave shape. Symbols represent experimental data. Experimental results cluster near the line for an assumed triangular deceleration shape. The lower cluster (G_{na} $\Delta t \approx 1.5$) is data for general aviation tests at a flight path angle $\gamma = -15^o$. The middle cluster (G_{na} $\Delta t \approx 2.5$) is data for general aviation tests at flight path angle $\gamma = -30^o$. The upper cluster (G_{na} $\Delta t \approx 4.5$) is data for transport and fighter tests. The general aviation tests, with the exception of two tests into dirt, were crashes onto a concrete surface whereas the transport tests were into a dirt embankment. In spite of these differences the crash pulse data correlates reasonably well with the analytical prediction for the triangular pulse assumption.

The crash test parameters included in these data do not encompass all crash scenarios, of course. It is believed, however, that the data represent adequately the serious but potentially survivable general aviation aircraft crash situation. Thus, these results should be useful in the assessment of design crash loads at the seat/floor interface.

CORRELATION OF CRASH DATA WITH FLIGHT PARAMETERS AT IMPACT



ANALYTICAL DATA FOR F-4 AIRCRAFT WITH ACTIVE AND PASSIVE MAIN LANDING GEARS DURING TRAVERSE OF A HASTILY-REPAIRED BOMB CRATER

John R. McGehee
Impact Dynamics Branch, SDD
Extension 2796
July 19, 1982

(RTOP No. 505-44-33)

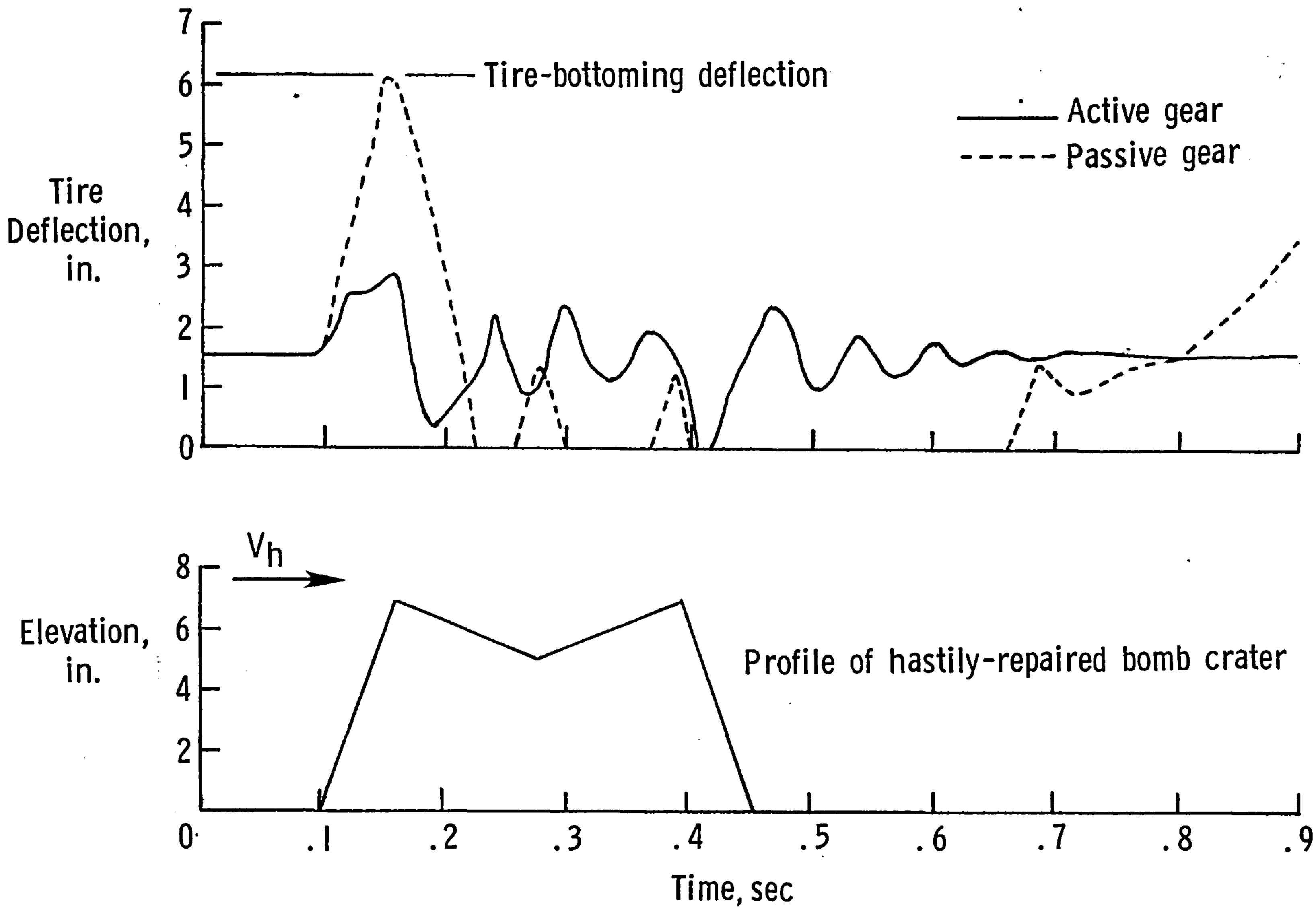
During the conduct of NASA Contract NAS1-16420 entitled "Development of an Electronic Control for an Electro-hydraulic Active Control Landing Gear for the F-4 Aircraft," the contractor conducted analytical simulations of the F-4 aircraft with active and passive gears for traverse of a hastily-repaired bomb crater. On the basis of the results of these simulations, the active gear, as previously reported, is not only very effective in reducing the ground loads applied to the airframe during traverse of the repaired crater, but is also very effective in maintaining tire contact with the surface and thus enhances braking effectiveness during landing rollout.

Typical results of this study are shown in the figure for both active and passive main gears during traverse of the hastily-repaired crater at a ground speed of 101 knots. The profile of the repaired crater is shown in the lower part of the figure as a function of time for the 101 knot ground speed. Tire-deflection time histories for the active and passive gear simulations are shown plotted to the same time scale as the crater profile in the upper part of the figure.

The passive gear data show that during traverse of the initial positive slope of the repaired crater, the tire deflects to the wheel rim (tire-bottoming) as a result of the very large shock strut force developed. The tire deflection for the active gear, during traverse of the initial positive slope of the crater was only 45% of the tire-bottoming stroke because the control system limited the shock strut force and hence the tire deflection. Subsequent to the traverse of the initial positive slope of the repaired crater, the passive gear data show that the tire rebounds from the surface three times. The third rebound occurred as the tire traversed the final negative slope of the repaired crater and the tire was off the ground for approximately 0.27 seconds. In contrast the active gear data show that the tire maintained contact with the surface of the repaired crater with the exception of a very brief period following traverse of the final negative slope. Consequently, the active gear was very effective in keeping the tire in contact with the surface during traverse of the repaired crater. Following traverse of the repaired crater, the active gear quickly returned the tire to the surface and effectively damped oscillations in the tire deflection.

F-4 AIRCRAFT TRAVERSING HASTILY-REPAIRED BOMB CRATER

Ground Speed (V_h) = 101 knots



TIRE MODELING WORKSHOP UNCOVERS NEED TO UNIFY MODELING EFFORTS IN U.S. TIRE INDUSTRY

John A. Tanner, 2796
Impact Dynamics Branch, SDD
September 20, 1982
RTOP 505-44-33

Objective:

Provide forum for the interchange of information among tire analysts and to establish goals and objectives for future NASA tire modeling research.

Approach:

Held Tire Modeling Workshop on September 7-9, 1982, so that tire and finite element experts could assess status of tire modeling and establish future research needs.

Accomplishments:

Approximately 60 industry, university and government representatives attended the workshop. This workshop was the first meeting of automobile and aircraft tire manufacturers to discuss mutual problems and the first meeting of either tire group with the finite element development community. The discussions indicated that there is no unified modeling effort in the U.S. tire industry due to proprietary concerns. Furthermore the physics of tire loading and the thermal environment are not fully understood. It was the consensus of the workshop attendees that the development of a family of finite element models for tire design is a nonlinear structural mechanics problem that should be addressed vigorously. Langley is in a unique position to contribute to the solution of this problem by virtue of its nationally recognized analytical and experimental capabilities.

Plans:

A research plan that is currently in preparation will use the ongoing Langley tire analytical model studies as the framework for an expanded finite element development program. This analytical program will be accompanied by a parallel effort to establish a data base of experimental measurements to be used as a verification tool for the new tire models. This effort will also define a family of benchmark problems for tire modeling. Both the analytical and experimental programs will be supervised by Langley personnel and coordinated with the U.S. tire industry through the ASTM Committee F-9 on Tires.

NASA LANGLEY TIRE MODELING WORKSHOP - OVERVIEW

DATE HELD: SEPTEMBER 7 - 9, 1982

ATTENDANCE: 60 INDUSTRY, UNIVERSITY, AND GOVERNMENT PERSONNEL

* CURRENT STATUS

  - NO UNIFIED MODELING EFFORT IN U. S. TIRE INDUSTRY
  - PRINCIPLES OF TIRE PHYSICS NOT FULLY UNDERSTOOD

* SUGGESTED COURSE OF ACTION

  - INITIATE GOVERNMENT SPONSORED FINITE ELEMENT MODEL DEVELOPMENT PROGRAM
  - DEFINE FAMILY OF BENCHMARK PROBLEMS FOR TIRE MODELING
  - ESTABLISH DATA BASE OF EXPERIMENTAL MEASUREMENTS

STRUCTURAL MECHANICS BRANCH

2-D DELAMINATION PROPAGATION ANALYSIS DEVELOPED FOR COMPRESSION LOADED COMPOSITE LAMINATES

James H. Starnes, Jr.
Structural Mechanics Branch, SDD
Extension 2552
October 16, 1981

(RTOP 505-33-33)

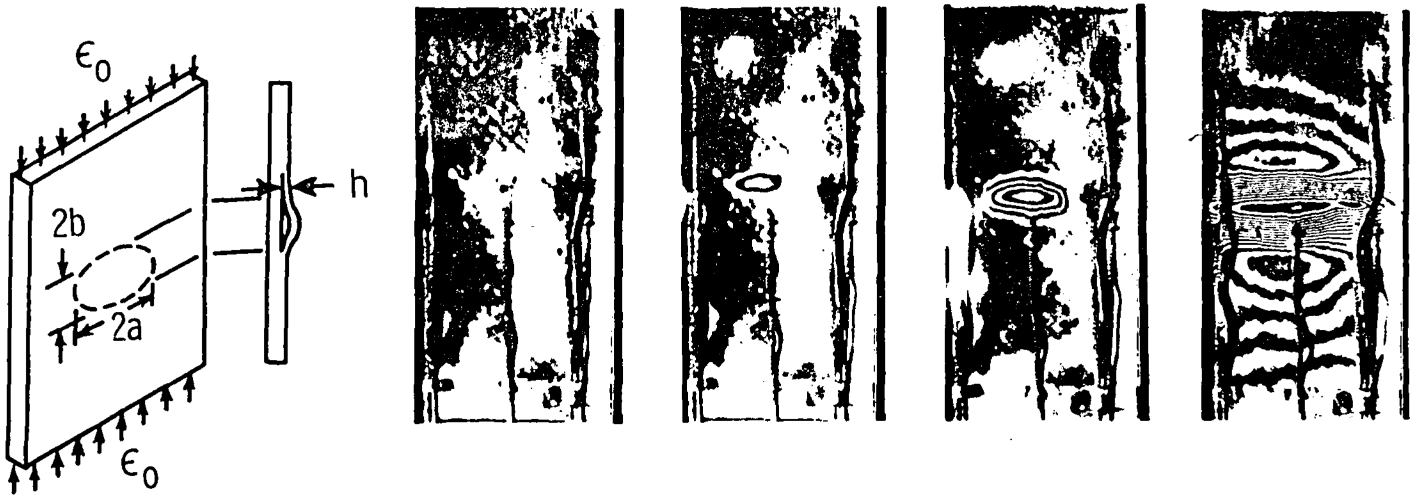
Tests performed at Langley have shown that local delaminations in graphite-epoxy laminates can severely degrade laminate compressive strength. Laminated plate specimens subjected to low-speed impact damage have been observed to fail prematurely as a result of an impact-induced local delamination propagating across the specimens. A two-dimensional analysis that describes what happens when a local delamination is suddenly introduced in a compression loaded laminate has been developed by Professors C. D. Babcock and W. G. Knauss at the California Institute of Technology under NASA Grant NSG-1483. The local delamination is assumed to be elliptical (semimajor axis a; semiminor axis b) and to be located at a distance h from the laminate surface. Depending on the magnitude of the applied strain ε_0 and the dimensions a, b and h of the ellipse, the local delamination will (second photograph) or will not (first photograph) buckle. Depending on the energy per unit area Γ_0 required to produce a new unit of delamination surface (a material property), the buckled delamination can remain stable or it can propagate. If the buckled delamination propagates, it can arrest (third photograph) or it can propagate across the specimen (fourth photograph).

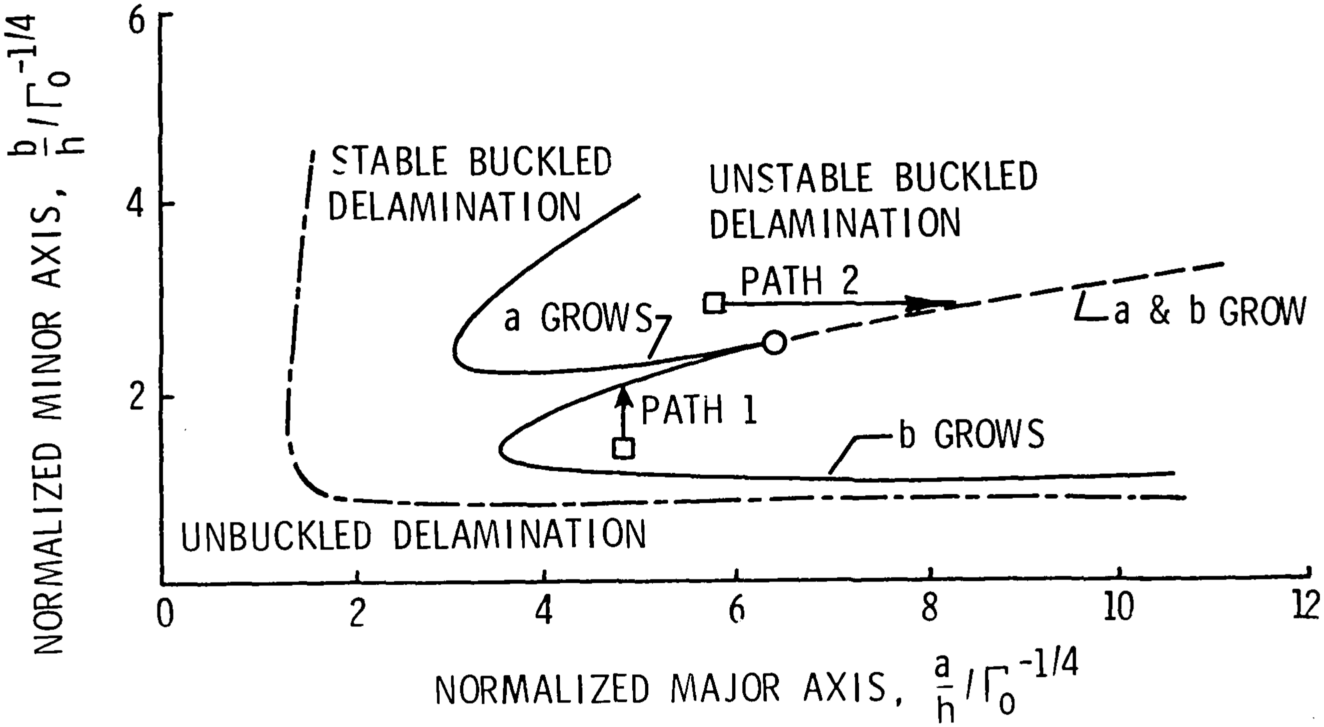
The analysis couples the effects of local buckling (a nonlinear problem) with fracture mechanics to describe the behavior of the delaminated region and some typical results for a given applied strain ε_0 are shown on the figure in terms of the parameters a, b, h and Γ_0. For this example, the delamination does not buckle if the values of the governing parameters a, b, h and Γ_0 fall between the coordinate axes of the figure and the dot-dashed curve. For values of the parameters between the dot-dashed curve and the solid curves, the delamination buckles but does not propagate. For values of the parameters above and to the right of the two solid curves the buckled delamination propagates. The upper solid curve corresponds to a propagating delamination where only a grows and the lower solid curve corresponds to a propagating delamination where only b grows. If the growth in a or b is such that the results reintersect a solid curve (path 1), the propagation arrests. The two solid curves intersect at the circle and the continuation of the curves represented by the dashed curve represents unstable growth. If the growth in a or b is such that the results intersect the dashed curve (path 2), the propagation does not arrest.

These analytical results are qualitatively consistent with laboratory observations. Additional work is underway to make selected quantitative comparisons with test data.

NASA
L-81-10.230

2-D DELAMINATION PROPAGATION ANALYSIS DEVELOPED FOR COMPRESSION LOADED COMPOSITE LAMINATES





REQUIRED MODELING DETAIL IDENTIFIED FOR STIFFENED PANELS WITH BUCKLED SKINS

Norman F. Knight, Jr.
Structural Mechanics Branch, SDD
Extension 4585
January 25, 1982

(RTOP 505-33-33)

The design of stiffened panels with buckled skins is of considerable interest to the aerospace industry because of the significant weight saving potential of buckled skin designs when compared with buckling resistant designs. In buckled skin designs, local skin buckling is allowed which results in additional load being transferred to the stiffeners. Because postbuckling deformation shapes can be highly complex, the analytical modeling detail that is required is not known in advance and must be established for each stiffened panel design. One modeling criterion that appears to have merit is based on the requirement that the model used to predict the postbuckling response of a stiffened panel must first predict accurately the initial buckling response. With this criterion in mind, a study was made to identify the modeling detail required by a nonlinear finite element code called STAGS that can be used to study the postbuckling response of stiffened panels. The buckling load and corresponding mode shape obtained with PASCO, an efficient and accurate code for calculating only initial buckling results, were used as the standards for comparison in this study. The panel selected for the study is a flat graphite-epoxy panel with a 16-ply skin and four I-stiffeners. The buckled cross section of the panel as determined by PASCO is shown in the upper figure. These buckling results indicate that the stiffener webs deform and that local bending occurs near the skin-stiffener interface.

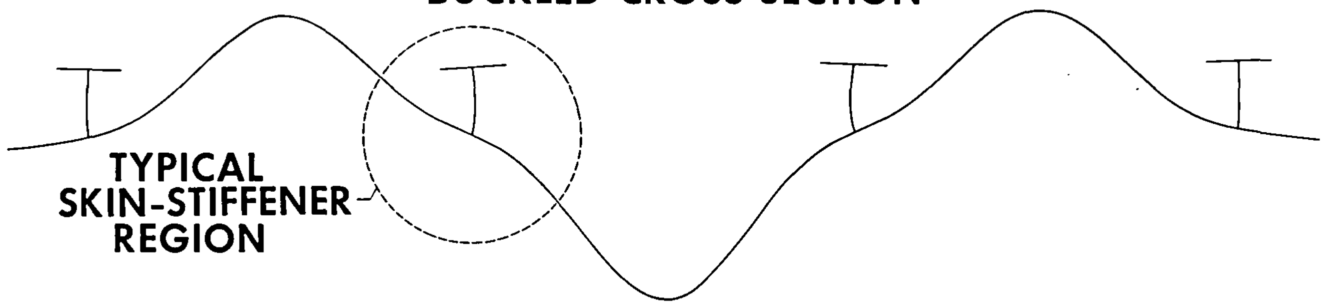
Several STAGS models with varying levels of modeling sophistication in the skin-stiffener region are shown in the table along with the buckled cross sections. In the analysis of stiffened panels, the traditional approach has been to model the stiffeners as discrete beams. A discrete beam model accounts for extensional, bending and torsional stiffnesses and any eccentricities of the stiffener by lumping these properties at the skin-stiffener attachment points. As such, the discrete beam model, STAGS-1, neglects not only the cross sectional deformations of the stiffener but also any local bending near the skin-stiffener interface. The buckling load for the STAGS-1 model is 10.6% smaller than the PASCO results because the STAGS-1 model has a larger effective stiffener spacing. The larger effective stiffener spacing is a result of lumping the properties of the attachment flanges at discrete points. In order to model the local bending near the skin-stiffener interface, a plate model, STAGS-2, of the attachment flanges is used and gives a buckling load which is 17.9% higher than the PASCO buckling load. The buckling load is higher because the discrete beam representation of the stiffener webs used in the STAGS-2 model does not allow for the rolling of the stiffeners. The next refinement, STAGS-3, treated the stiffener webs, in addition to the attachment flanges, as plate elements which then allows both local bending and cross sectional deformations of the web to be predicted accurately.

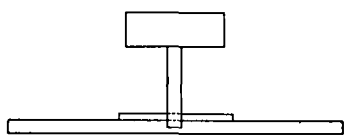
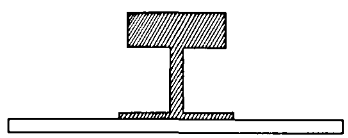
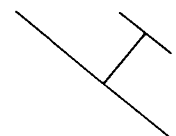
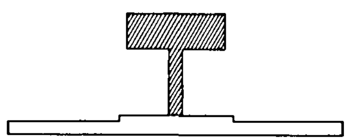
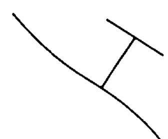
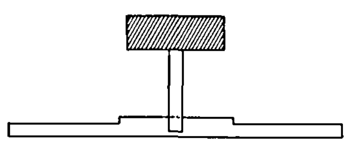
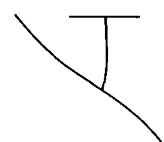
It appears that the level of modeling detail required for accurate analyses of stiffened composite panels which are designed to operate with buckled skins is greater than the level of modeling detail that previously was used throughout the discipline for buckling resistant panels.

NASA
L-81-10,877

REQUIRED MODELING DETAIL IDENTIFIED FOR STIFFENED PANELS WITH BUCKLED SKINS

BUCKLED CROSS SECTION



ANALYTICAL MODEL	MODEL OF TYPICAL SKIN-STIFFENER REGION	BUCKLED CROSS SECTION OF TYPICAL SKIN-STIFFENER REGION	DEVIATION FROM PASCO BUCKLING RESULTS
PASCO			---
STAGS -1			-10.6%
STAGS -2			17.9%
STAGS -3			1.4%

---PLATE ELEMENT   ---BEAM ELEMENT

SOME OBSERVATIONS FROM THE WORKSHOP ON FAILURE ANALYSIS AND MECHANISMS OF FAILURE OF FIBROUS COMPOSITE STRUCTURES

Mark J. Shuart and James H. Starnes, Jr.
Structural Mechanics Branch, SDD
Extensions 2813 and 2552
April 16, 1982

(RTOP 505-33-33)

Objective

To assess the current state-of-the-art of failure analyses and mechanisms of failure of composite structures.

Approach

A workshop was held at NASA-Langley during March 23-25, 1982, with approximately 80 invited participants from government, industry, and universities. Twelve formal presentations covered topics ranging from fundamental failure mechanisms to fail safe structural design practices, and each presentation was followed by indepth discussion from workshop participants.

Accomplishment Description

Some observations from the workshop are:

1. The response and failure mechanisms of composites involve understanding at five structural levels.

2. The performance of composite structures can be limited by the effects of discontinuities and "secondary" loads.

3. Current heuristic failure models may need to be updated when new failure mechanisms are identified.

4. Designers could use verified design charts and simple analyses that show the parametric trends for the response of composite structures.

5. Failure experiences from large structural components (e.g., ACEE and military components) could provide valuable information about composite structural behavior for future composite component designs.

6. Researchers can provide important information to industry by identifying the possible problem areas for composite structures.

Future Plans

The proceedings of the workshop will be documented by a NASA Conference Proceedings to be published in fall 1982.

SOME OBSERVATIONS FROM THE WORKSHOP ON FAILURE ANALYSIS AND MECHANISMS OF FAILURE OF FIBROUS COMPOSITE STRUCTURES

NASA LANGLEY RESEARCH CENTER
MARCH 23-25, 1982

- RESPONSE AND FAILURE OF COMPOSITE STRUCTURES MUST BE UNDERSTOOD AT FIVE LEVELS: MICROMECHANICS; SUBLAMINATE; LAMINATE; SUBCOMPONENT; AND FULL SCALE STRUCTURE.

- STRESS CONCENTRATIONS, DISCONTINUITIES, LOCAL EFFECTS AND "SECONDARY" LOADS MUST BE BETTER UNDERSTOOD FOR COMPOSITE STRUCTURES.

- CURRENT FAILURE ANALYSES FOR COMPOSITE STRUCTURES ARE BASED ON HEURISTIC MODELS AND SIMPLE FAILURE CRITERIA. AS NEW FAILURE MECHANISMS ARE IDENTIFIED, NEW MODELS WILL BE NEEDED.

- TRENDS FROM VERIFIED NACA-LIKE DESIGN CHARTS AND SIMPLE ANALYSES FOR RESPONSE AND FAILURE OF COMPOSITE STRUCTURES WOULD BE USEFUL FOR DESIGNERS.

- RESULTS FROM ANALYSES OF MAJOR STRUCTURAL COMPONENT FAILURES CONTRIBUTE TO THE FUNDAMENTAL UNDERSTANDING OF COMPOSITE STRUCTURES AND SHOULD BE DOCUMENTED.

- INDUSTRY WOULD LIKE THE RESEARCH COMMUNITY TO IDENTIFY PROBLEM AREAS FOR COMPOSITE STRUCTURES SO THEY CAN SOLVE THEM OR DESIGN AROUND THEM.

EXTENDED "REDUCED-BASIS" TECHNIQUE PROVIDES EFFICIENT SOLUTIONS FOR COMPOSITE PLATES UNDER COMBINED LOADING

Ahmed K. Noor and Jeanne M. Peters
George Washington University
Extension 2897
July 19, 1982
(RTOP 505-33-33)

Research Objective

Develop efficient buckling and postbuckling analysis techniques for composite panels subjected to combined loading.

Approach

A multiple-parameter reduced basis technique has been developed for significantly reducing the cost of finite element buckling and postbuckling analyses. In this technique an initial set of basis vectors (or global approximation functions), which captures the major features of the response, is generated using the chosen finite element model of the plate. The cost of generating the vectors is little more than that of solving the linear system of finite element equations of the model. The vectors are then used to construct a reduced eigenvalue problem (of dimension 15), from which *the entire interaction curve shown in the left figure is generated.*

The buckling mode associated with a particular combination of compressive and shear loading is used as a predictor and a nonlinear solution is generated by using a single Newton-Raphson iteration. Also a new set of 15 basis vectors is generated at the same point. The cost of generating the nonlinear solution and basis vectors is little more than that of a single solution of the linear finite element equations.

The *same set* of 15 vectors is used to trace *a number of different postbuckling paths, each with a fixed compressive load* and variable shear load. The accuracy of the reduced system is monitored and new set of basis vectors is generated whenever the error exceeds a prescribed tolerance.

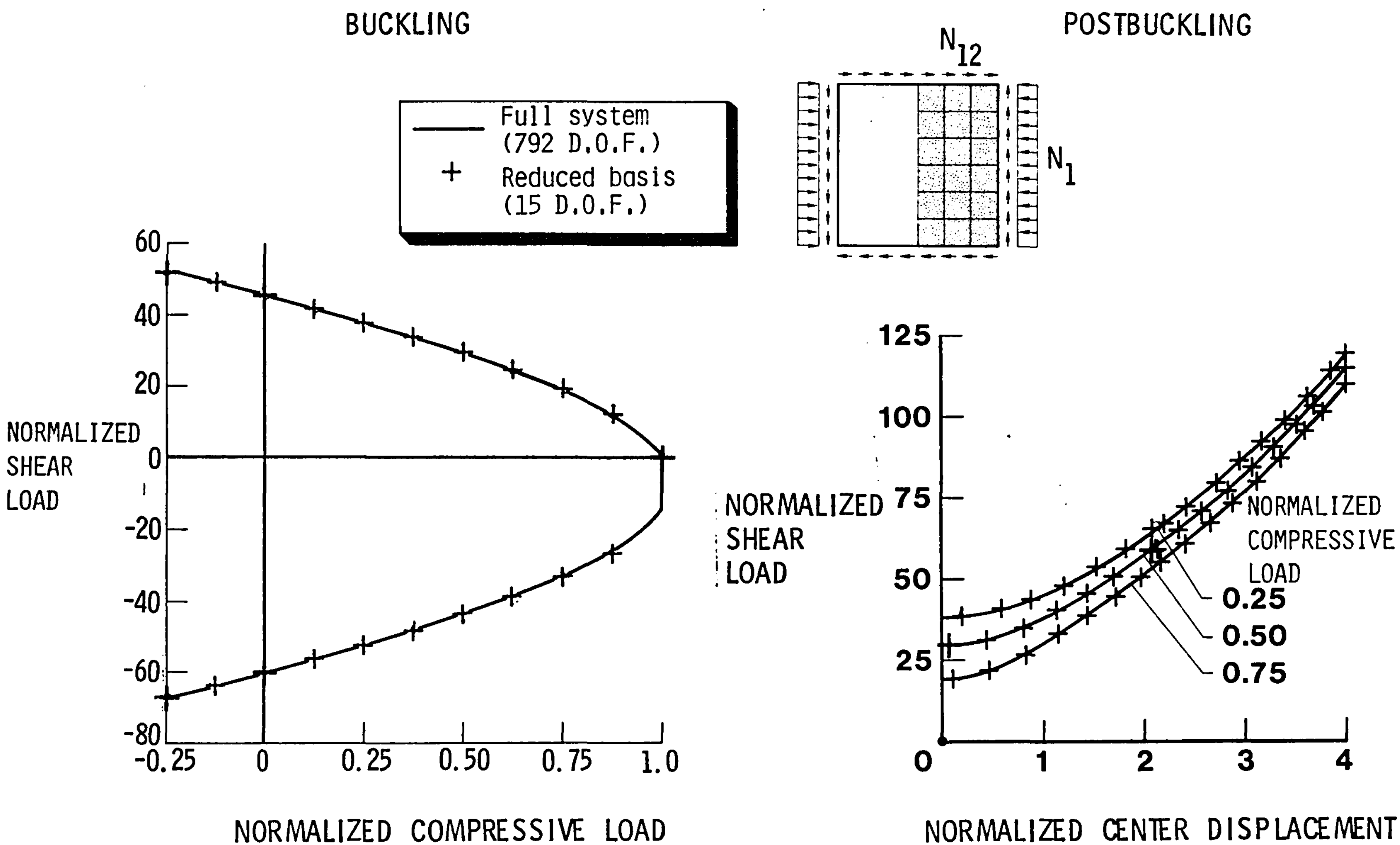
Accomplishment

For the plate considered in the figure the total cost of buckling and postbuckling analyses was little more than three linear solutions of the original finite element equations.

Future Research

Further refinement and improvements in the technique will be made in order to have an efficient, design-oriented, buckling and postbuckling analysis capability. Application of the proposed technique to buckling problems with mode interactions will be attempted.

EXTENDED 'REDUCED-BASIS' TECHNIQUE PROVIDES EFFICIENT SOLUTIONS FOR COMPOSITE PLATES UNDER COMBINED LOADING



DAMAGE-CONTAINMENT CONCEPT
SUCCESSFULLY TESTED FOR GRAPHITE/EPOXY COMPRESSION PANELS

Jerry G. Williams
Structural Mechanics Branch, SDD
Extension 3524
August 18, 1982
(RTOP 505-33-33)

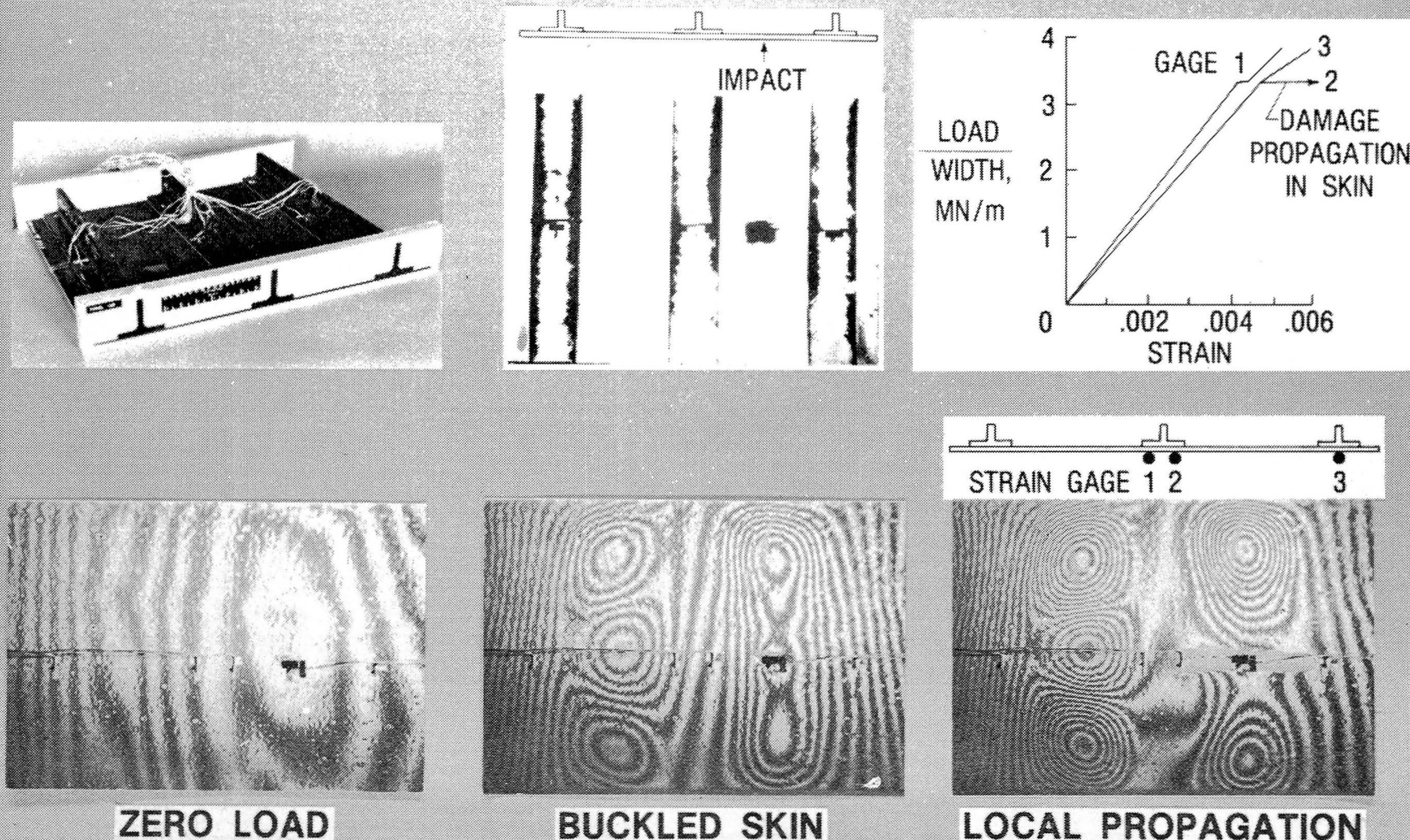
Research Objective: To develop structural arrangements for graphite/epoxy composite stiffened panels which prevent potential damage from propagating and thereby increase compression load-carrying capacity in the presence of local damage.

Approach: Local damage can notably degrade the compression strength of graphite/epoxy structures in aircraft. The design of structural components to allow for the possibility of such damage is currently addressed by limiting allowable ultimate strain to around 0.0030. For lightly-loaded, stiffness-designed components such as control surfaces, this limit does not lead to significant mass penalties. To make graphite/epoxy attractive for primary structure in commercial transports, on the other hand, allowable ultimate strain should be increased at least to 0.0050. Research is underway to determine if and how such an increase can be achieved.

Accomplishment Description: The attached chart shows a recently demonstrated damage-containment arrangement for stiffened graphite/epoxy panels. A photograph of the test panel is shown in the upper left. The skin of the panel is composed totally of $\pm 45^{\circ}$ oriented plies (relative to the 0° load direction). For a wing-cover application this skin orientation provides shear stiffness, and panel axial stiffness is provided by 0° plies placed in the stiffeners. The test panel was 23 inches wide and was initially loaded to 350,000 pounds or 0.0035 strain and impacted under load with a ½ inch diameter aluminum sphere at 300 feet/sec. The panel survived with local damage only as shown in the C-scan photograph top center. A subsequent load cycle was applied, and the sequence of events which occurred is shown in the moire fringe photographs at bottom and the load-strain diagram at upper right. At a strain of 0.0034 the skin buckled into 3 halfwaves between stiffeners (bottom center). At a strain of 0.0040 the damage propagated rapidly across the skin but was contained at two adjacent stiffener interfaces. The panel was then loaded to 500,000 pounds or 0.0050 strain without further damage propagation, and the test was terminated. C-scan inspection confirmed that skin damage did not extend beyond the stiffeners. This test demonstrates for the first time the potential of a structural configuration design for damage containment in a compression loaded graphite/epoxy structure.

Plans: Further research on damage containment configurations encompasses tests on panels long enough so that load redistribution can be studied and in which a stiffener is damaged.

BONDED-STIFFENER DAMAGE — CONTAINMENT CONCEPT



STRUCTURAL DYNAMICS BRANCH

NONLINEAR EFFECTS ON THE ITD MODAL DATA ANALYSIS METHOD

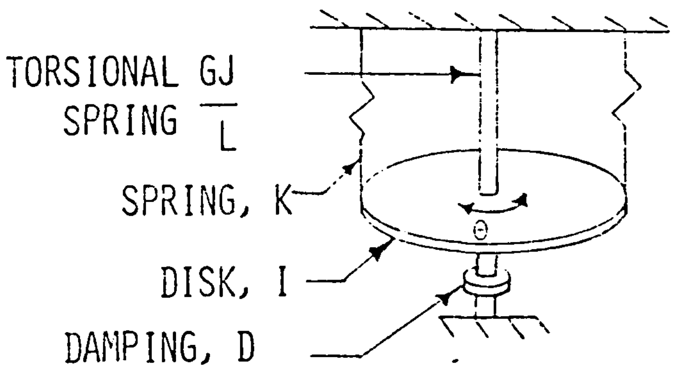
Lucas G. Horta and Brantley R. Hanks
Structural Dynamics Branch
2738 10-16-81
506-53-43

In recent years, significant advances have been made in developing automated data analysis methods for determining the vibration characteristics of linear structures from experimental data. However, the physical nature of structures is such that they frequently have nonlinear characteristics which violate the basic assumptions of these linear methods. Therefore the detection and assessment of nonlinearities when using linear data analysis methods is imperative. A study has been initiated using a single degree of freedom analytical model in which a cubic spring nonlinearity was added to a simple linear torsional system. The simulated physical system, its equation of motion and typical responses are shown at the top of the attached figure. The objectives of the study are to determine how the presence of nonlinearities can be detected and to assess the extent to which linear system algorithms can provide useful information on nonlinear systems. It should be noted that nonlinear systems actually have no true modal responses since their response is a function of amplitude and other factors.

The advanced linear system method used in this study, to date, is the Ibrahim Time Domain (ITD) Algorithm which analyzes free-decay data. Some of the results obtained using this method are shown in the plots at the bottom of the figure. As mentioned before, nonlinear system responses are a function of amplitude. These plots relate two of the modal parameters identified by the method, frequency and damping, with initial amplitude (a high initial amplitude amplifies nonlinear effects). Both plots show that for small initial amplitude the method identified the approximate modal parameters of the linear system (dashed lines) but for higher initial amplitudes the method indicates false degrees of freedom in the system. The frequencies identified are not necessarily harmonics of each other as might have been expected based on nonlinear system theory. Also, negative values of damping sometimes occur indicating a non-existent divergent response (see figure). In all cases the calculated "modal confidence factor" was nearly 100 percent, erroneously confirming the incorrect results. Other indicators of the presence of nonlinearities, not shown on the figure, are variations in frequency and damping with data sampling frequency and with total time length of the data sample. Further studies with more degrees of freedom and other advanced data analysis methods are planned.

NONLINEAR EFFECTS ON ITD MODAL DATA ANALYSIS METHOD

SYSTEM



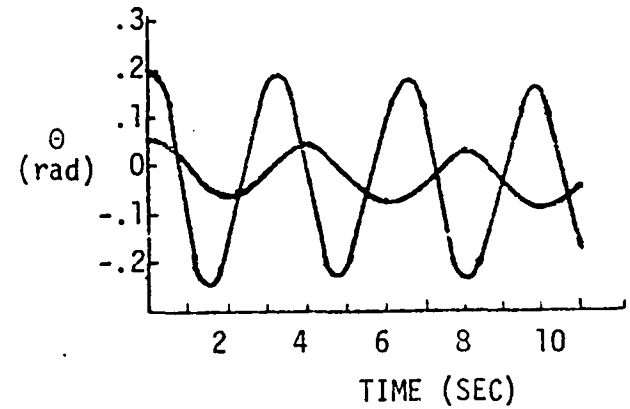
EQ. OF MOTION

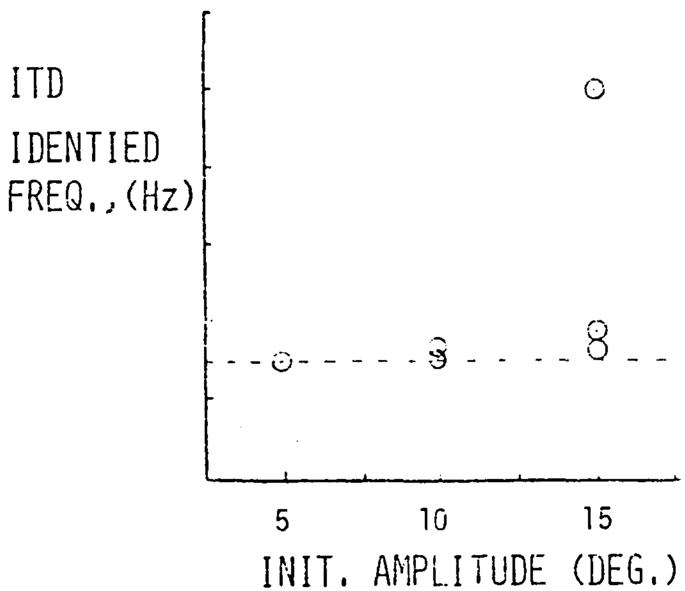
$$\ddot{\Theta}+D\dot{\Theta}+C_1\Theta^3+C_2\Theta=0$$

$$C1 = KR^4/_{2I}$$

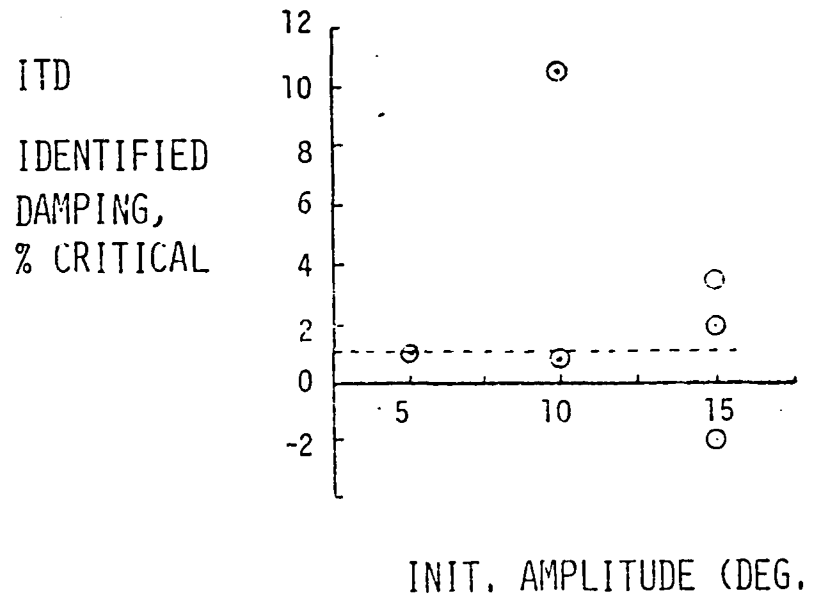
$$C2 = GJ/_{IL}$$

TYPICAL RESPONSE





C1/C2 = 5



C1/C2 = 5

NEW THERMAL CAPABILITY DEMONSTRATED FOR 16-METER VACUUM CHAMBER

R. Miserentino
Structural Dynamics Branch, SDD
Extension 2817
April 26, 1982
(RTOP 506-63-43)

A thermal capability has been added to the existing 16-meter vacuum chamber located in the Structural Dynamics Research Laboratory, Bldg. 1293B. Additions are ten quartz-lamp banks and ten liquid nitrogen coldplates mounted on scaffolding inside the chamber. The chamber has a flat floor, cylindrical side wall and hemispherical dome. Access is through a six-meter square service door.

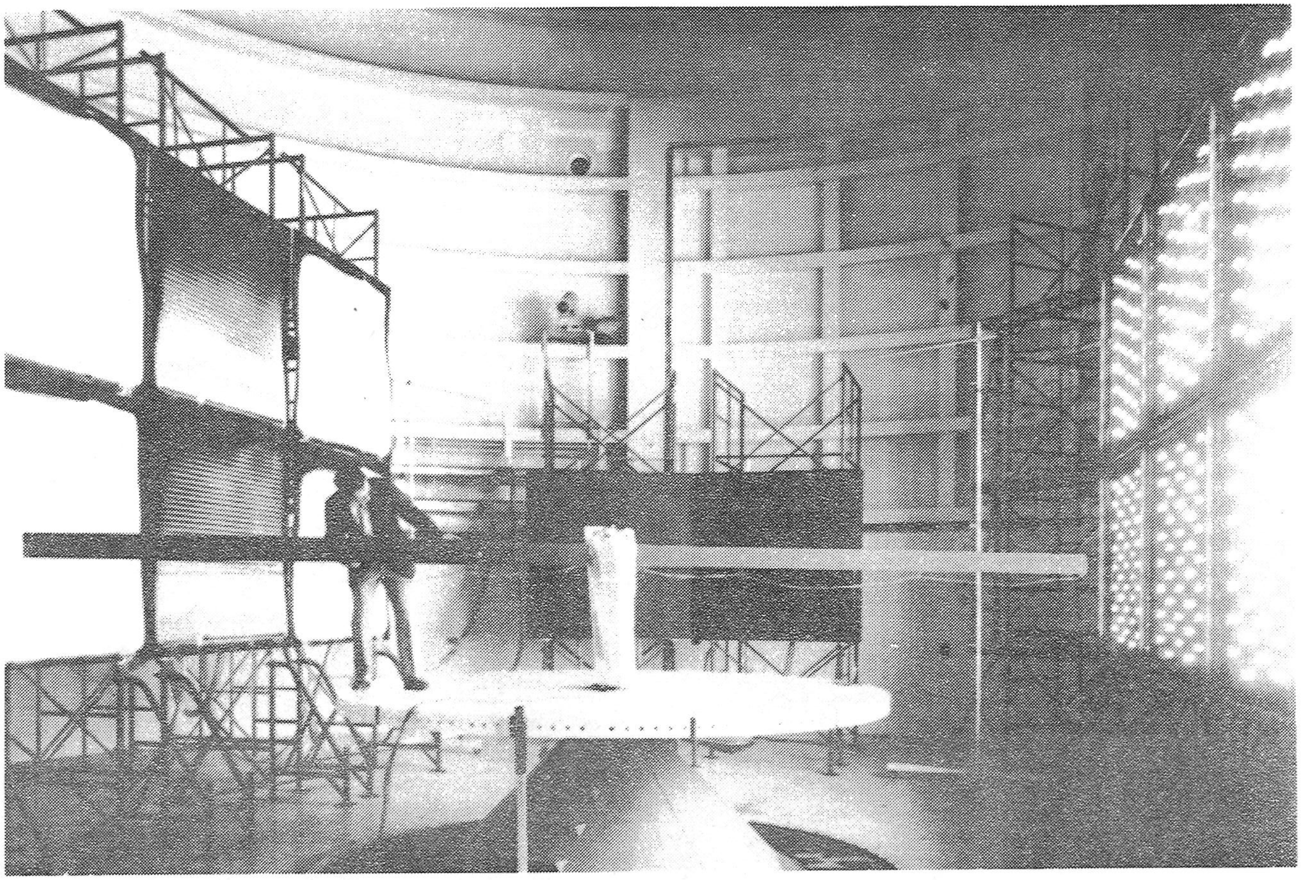
The attached figure lists major features and a photograph taken inside the chamber. The photograph shows six lamp banks and six coldplates in operation, while in the background, two of each were not operating. The long blade-like demonstration structure across the picture is attached to the center of a four-meter circular turntable.

During an acceptance test, all the lamps were run at full power while the ten coldplates were filled with liquid nitrogen and the chamber pressure was held at 3mm Hg. In addition, the turntable was spun at various speeds ranging down to 0.9 rpm.

Many arrangements of the 47 m^2 heat sources and 47 m^2 sinks can be made to obtain different heating rates. The design maximum heating rate is 1500 W/m^2. The first research studies will explore dynamic heating and distortions of linear and planar structures.

NASA
L-82-2,441

NEW THERMAL CAPABILITY DEMONSTRATED FOR 16-METER VACUUM CHAMBER



- ACCOMMODATES 11-METER STRUCTURES
- 5 MM HG VACUUM AVAILABLE
- Q= 1500 W/M^2 WITH VARIABLE ARRANGEMENT OF $47 M^2$ OF SOURCES AND SINKS
- FLAT FLOOR OR 4-METER TURNTABLE TO MOUNT TEST STRUCTURES

MECHANICAL ABSORBER CONTROLS VIBRATIONS IN SPACE BEAMS OF LIMITED LENGTH

Michael F. Card and Harvey G. McComb, Jr.
Structures and Dynamics Divison
Extension 3121

and

Susan W. Peebles
IPAD Project Office
Extension 3401
July 19, 1982

(RTOP 506-53-43)

Research Objective

Understand possible application of passive mechanical vibration absorbers to vibration control of space beam or mast structures.

Approach

A simplified analysis was performed of a typical space mast structural concept comprised of four graphite/epoxy longeron tubes laced together with a low-mass truss-work. This type of mast was studied by General Dynamics Convair for potential application to space antennas and in particular to the support of antenna feed equipment. Pertinent structural data are shown on the chart. An idealized space beam model of a feed mast was selected for study. The beam was assumed to be cantilevered from the shuttle orbiter and to support a feed mass at its free end. This arrangement is identical to the proposed Mast Space Flight Experiment. A two-degree-of-freedom analytical representation was developed. The vibration absorber theory in Den Hartog's textbook could then be applied to determine the required absorber mass, spring stiffness, and damping parameter to control the beam free-end deflections to within prescribed limits.

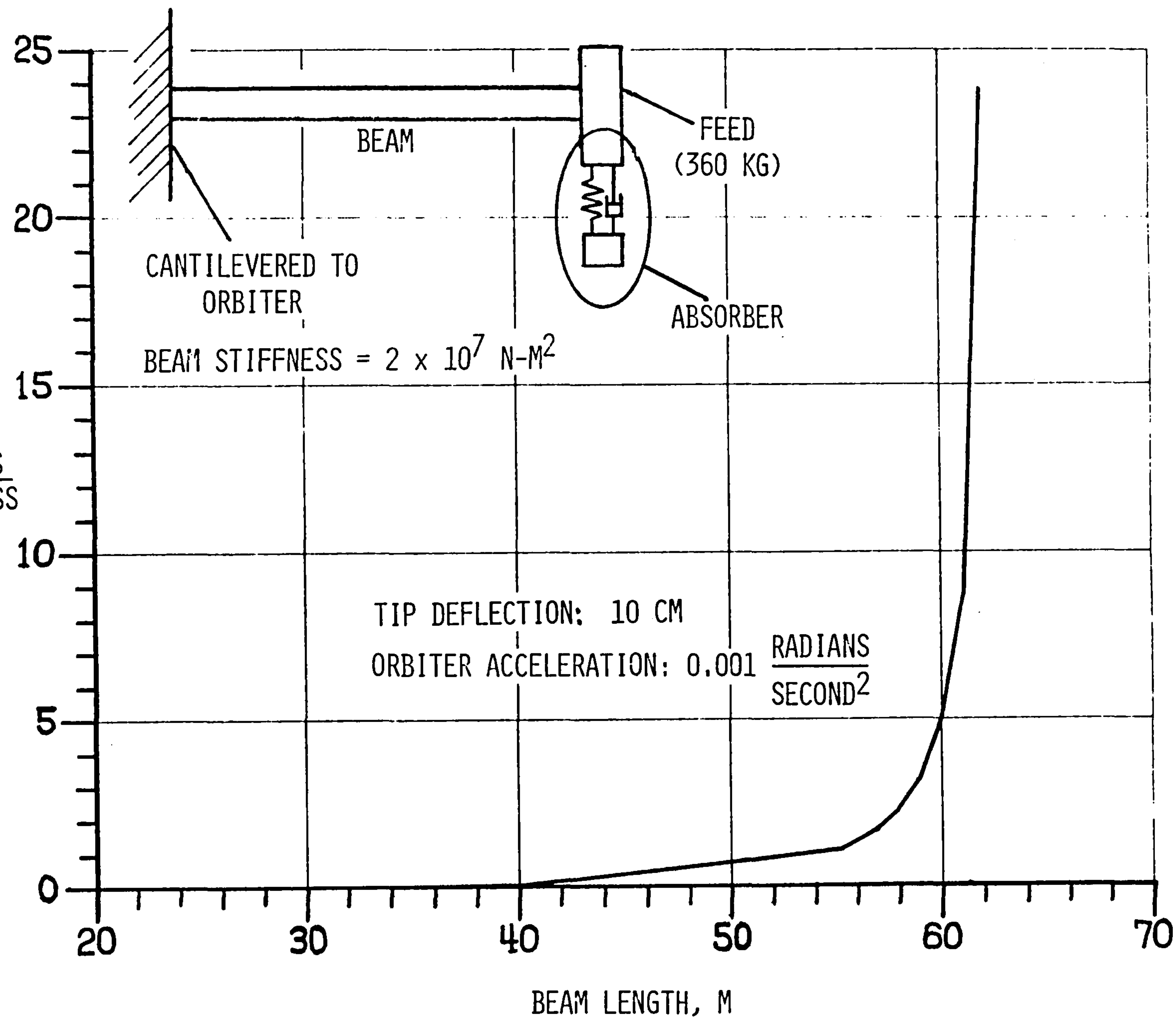
Accomplishment

Typical results for a feed mast beam are shown on the chart. The required ratio of absorber mass to beam plus feed mass is plotted as a function of beam length. Typical required tip deflection limits of ±10 cm and typical orbiter disturbance accelerations of 0.001 radians/second^2 are assumed. The required absorber mass is negligible for beam lengths less than 30 meters. The required absorber mass grows rapidly for lengths greater than 30 meters and at around 60 meters the absorber becomes prohibitively large for this particular example.

Future Needs

Because of the approximate nature of this analysis, more refined studies should be performed. Similar studies on other types of vibration controllers such as momentum wheels or paired gyros should reveal improved understanding of various approaches to vibration suppression in space antenna structures.

MECHANICAL ABSORBER CONTROLS VIBRATIONS IN SPACE BEAMS OF LIMITED LENGTH



ITD METHOD SURPASSES FFT FOR ANALYSIS OF SHORT FREE-RESPONSE DATA

Richard S. Pappa
Structural Dynamics Branch
Extension 3196
September 20, 1982
(RTOP 506-53-53)

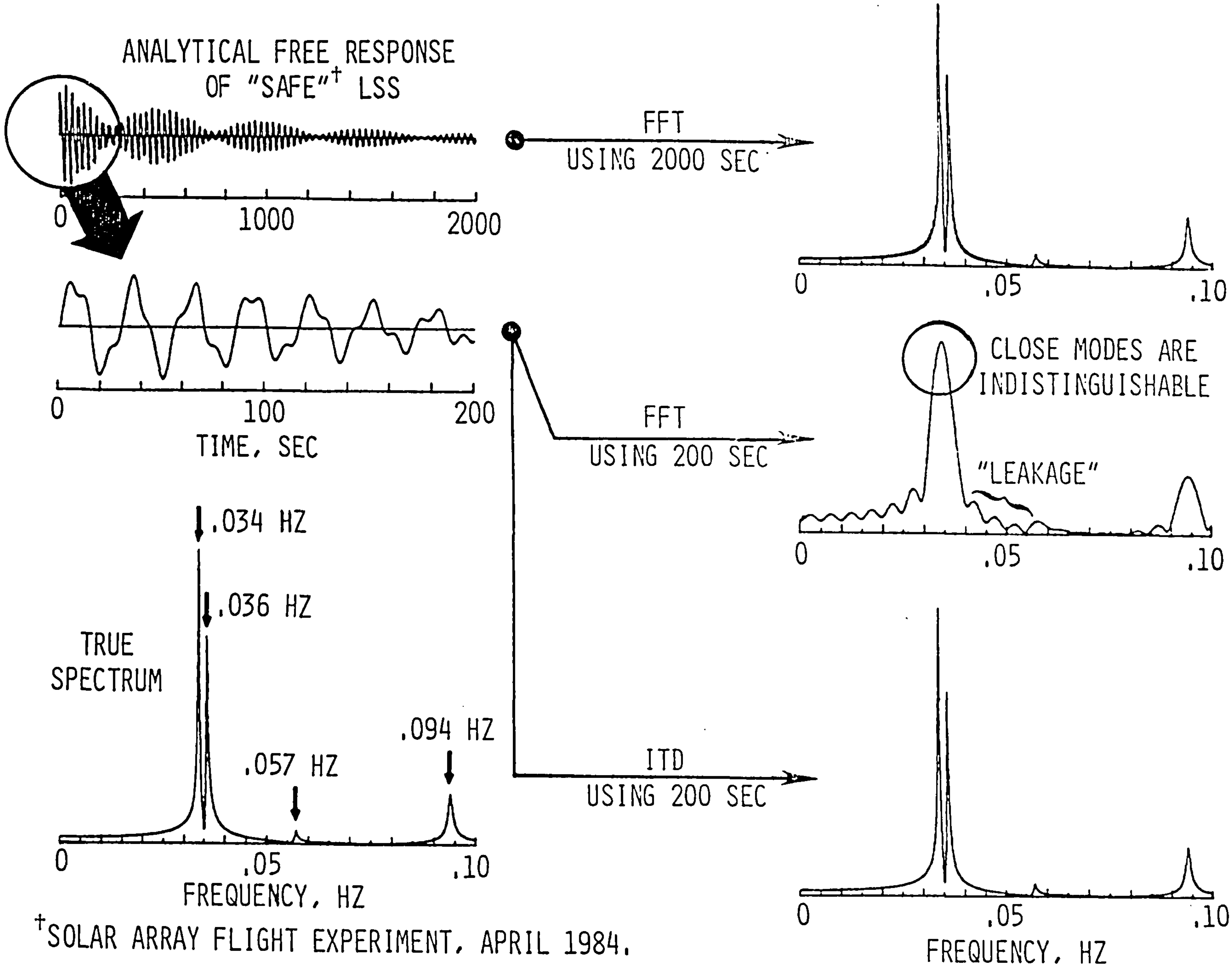
Research Objective: To optimize the performance of a modern modal identification technique--the Ibrahim Time-Domain (ITD) method.

Approach: The ITD technique uses free-response measurements to identify the modal parameters (natural frequencies, damping factors, and complex mode shapes) of a test structure. Although state-of-the-art performance has been demonstrated, significant changes can occur in the identification accuracy with changes in several user-selectable analysis parameters and in the characteristics of the data. Controlled numerical simulations are being conducted to understand these effects so that optimum results with quantifiable accuracy can be obtained in the analysis of experimental data.

Accomplishment Description: One important characteristic of the ITD technique is its ability to accurately identify the desired modal parameters using very short data records (i.e., consisting of only a few oscillation cycles of the frequency of interest). This ability is valuable for application of the technique to proposed orbital dynamics tests of low-frequency, large space structures (LSS) where test times need to be minimized. The accompanying figure compares the results of applying the ITD technique to a typical simulated free response of the "SAFE" (Solar Array Flight Experiment) structure with those obtained using the well-known fast Fourier transform (FFT) which is the basis of many other contemporary identification techniques. Although the FFT can be computed rapidly and produces results that are sufficiently accurate when "long" free-response data records are analyzed, such as the 2000-sec example shown in the figure, two inherent characteristics of the procedure limit the performance that can be achieved with shorter data records. The first is the inability to resolve frequency components spaced in hertz closer than roughly the reciprocal of the available data length in seconds. The other is an oscillatory distortion known as "leakage" that results from the mathematical effects of limiting data records to a finite time interval. These limitations of the FFT result in an extremely poor estimate of the true spectrum when only the first 200 sec of the simulated response data are used in the analysis, as shown in the center result. Using the ITD algorithm, on the other hand, the FFT is completely avoided and the modal parameters are identified from the time-domain data directly using a unique matrix eigensolution approach. The spectrum reconstructed from the ITD-identified parameters obtained when the same 200 sec of data are analyzed is indistinguishable from the true spectrum, as shown in the lower figure.

Plans: Results of this research are being used in-house and in industry to better understand and optimize ITD identification results. Controlled experimental tests are underway to substantiate the performance obtained with simulated data, including a pre-flight ground simulation of the "SAFE" dynamics test.

ITD METHOD SURPASSES FFT FOR ANALYSIS OF SHORT FREE-RESPONSE DATA



†SOLAR ARRAY FLIGHT EXPERIMENT, APRIL 1984.

STRUCTURAL CONCEPTS BRANCH

MULTI-PLY TRANSPARENT BIREFRINGENT COMPOSITE LAMINATES DEVELOPED FOR ANISOTROPIC PHOTOELASTIC STUDIES

Paul A. Cooper
Structural Concepts Branch, SDD
Extension 3787
October 16, 1981

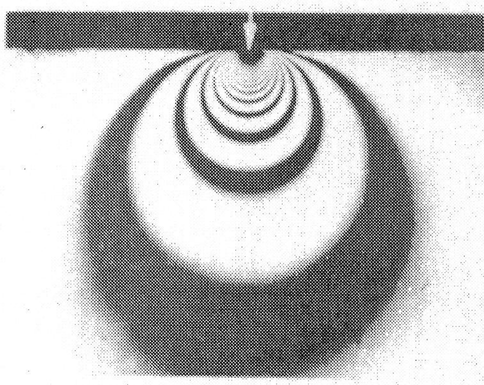
RTOPS: 506-53-53
506-53-23

Photoelastic stress analysis techniques use birefringent material and polarized light to determine the stress state in loaded structures and have been used successfully as an experimental alternative to finite element analyses, especially in regions with high stress gradients. Recently under NASA-Langley contract, I. Daniel from ITTRI has developed photoelastically sensitive cross-ply fibrous composite materials which can be used to extend photoelastic experimental techniques to include anisotropic structures. Simultaneously under a cooperative agreement with Langley, Prof. Prabhakaran from ODU has extended the usual photoelastic experimental procedures to encompass anisotropic structures.

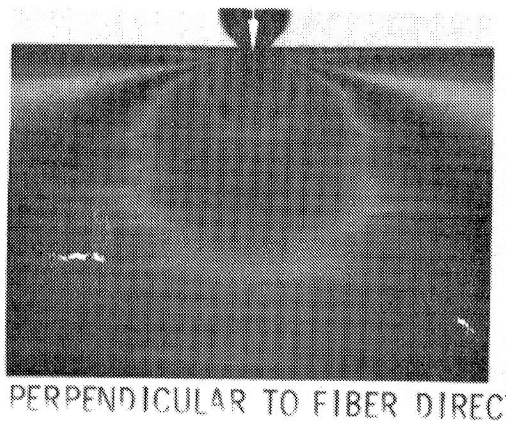
The figure shows an example of the different stress fields which occur because of material anisotropy. The classical problem of a point load on a semi-infinite isotropic plane gives a principal shear stress (isochromatic) pattern as shown at the top of the figure. The anisotropic material, in this case unidirectional fibers oriented parallel to the load on the right figure and perpendicular to the load on the left figure, exhibits a distinct distortion of the stress pattern. The stress patterns for the two composite material pictures were produced by the same load level. With the use of this material, global stress distributions may now be determined in anisotropic materials.

A quantity of sheets of various cross-ply orientations have been delivered and are being used by researchers at ODU to investigate experimental stress-separation techniques, at VPI&SU to investigate load flow in multi-fastener joining of composite laminates, and at IOWA State to investigate crack propagation in anisotropic media.

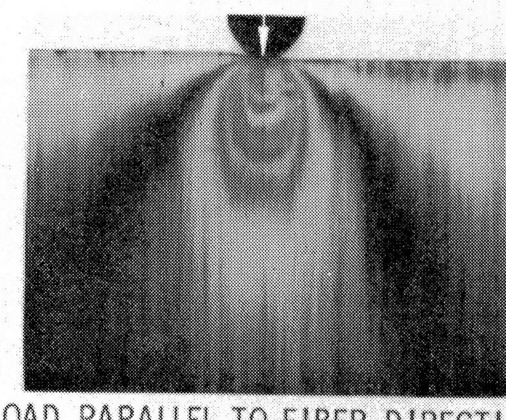
MULTI-PLY TRANSPARENT BIREFRINGENT COMPOSITE LAMINATES DEVELOPED FOR ANISOTROPIC PHOTOELASTIC STUDIES



LOAD ON ISOTROPIC PLATE



LOAD PERPENDICULAR TO FIBER DIRECTION



LOAD PARALLEL TO FIBER DIRECTION

FRINGE PATTERNS SHOW EFFECT OF LOAD ORIENTATION ON STRESS DISTRIBUTIONS IN COMPOSITE MATERIAL

TECHNICAL HIGHLIGHT

NOVEL FASTENER CONCEPT PERMITS USE OF LARGE CARBON-CARBON HOT STRUCTURES

L. R. Jackson, R. C. Davis, and A. H. Taylor
Structural Concepts Branch, SDD
Extension 2414
April 26, 1982
(RTOP 307-02-02)

Research Objective

To provide a metal fastener for joining structural components made of carbon-carbon, which has a much smaller coefficient of thermal expansion than the metal, that provides a snug fit at all temperatures (to effectively transmit shear) and that produces no thermal stress.

Approach

Conventional metal fasteners require a snug-fitting shank to effectively transmit shear. When heated, the shank wants to expand considerably more than the hole in the carbon-carbon; consequently, the carbon-carbon attempts to restrain the fastener and the resulting force is sufficient to break the carbon-carbon.

The Daze metal fastener is configured to expand thermally without restraint by the carbon-carbon while simultaneously maintaining continuous contact over sufficient area to permit shear transmission through the joint at an acceptable bearing stress in the carbon-carbon.

The Daze fastener concept consists of conical heads that have coincident vertices, as shown in the figure, and mating countersunk holes are provided in the carbon-carbon. As the joint is heated, the metal expands radially from the point of coincident vertices. Where the metal contacts the carbon-carbon, the snug fitting conical heads slide without interference. Since the fastener is free to expand, no thermal stress is produced in either the fastener or the carbon-carbon.

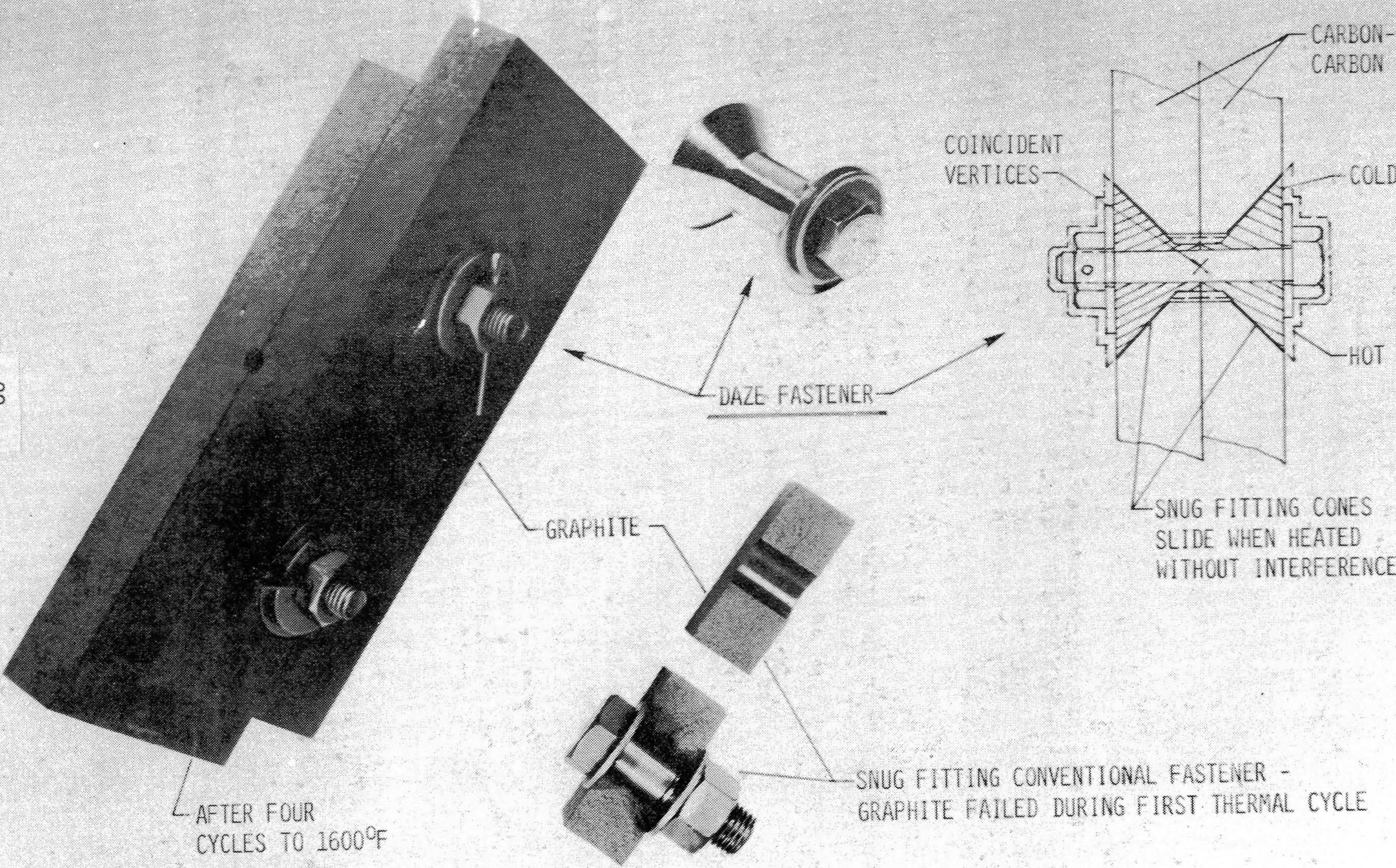
Accomplishment Description

Results include a test, see figure, wherein a snug fitting conventional metal fastener was installed in a graphite plate. During the first thermal cycle (simulated shuttle cycle), the graphite plate failed. Two Daze fasteners were installed in lapped graphite plates. This test element was tested for four thermal cycles without failure. Numerous variations of the Daze fastener have been conceived, and a patent disclosure has been submitted.

Future Plans

A contract is being negotiated with the Vought Corporation, Dallas, Texas, funded under the Director's Discretionary Fund, to study Daze fasteners as applied to a carbon-carbon body flap for the shuttle. Vought will make and test several Daze fasteners. Funding permitting, successful results will be applied to a study of the body flap. The body flap is too large to make as a one-piece layup, as the leading edges are now made; thus, a multielement structure must be used, which requires a suitable fastener. The Daze fastener and carbon-carbon for all control surfaces have the potential to reduce the shuttle weight by about 5000 lb.

FASTENER CONCEPT FOR LARGE CARBON-CARBON HOT STRUCTURES ACCOMMODATES DIFFERENTIAL EXPANSION WITHOUT STRESS



PREFERRED CONCEPT PROPOSED FOR NAVAL EMERGENCY VLF ANTENNA TOWER

Walter L. Heard, Jr.
Structural Concepts Branch
Extension 2608
May 10, 1982

(RTOP 506-53-43)

Research Objectives

The objective of this program is to devise a concept for a 1000-foot, emergency, very-low-frequency (VLF) antenna tower that can be compactly stowed for highway transportation to a remote site and erected in one-to-three days. The concept would be used by the U. S. Navy to reestablish VLF communications with its submarine fleet following loss of the fixed VLF stations due to nuclear attack.

Approach

Under funding from the U. S. Naval Electronics Systems Command, establish the tower design criteria and technical guidelines. Devise candidate tower structural configurations and methods of erection using deployable, erectable, and modular techniques. Develop design and analysis software and perform trade studies for comparison of cost, performance, risk, logistics, and complexity.

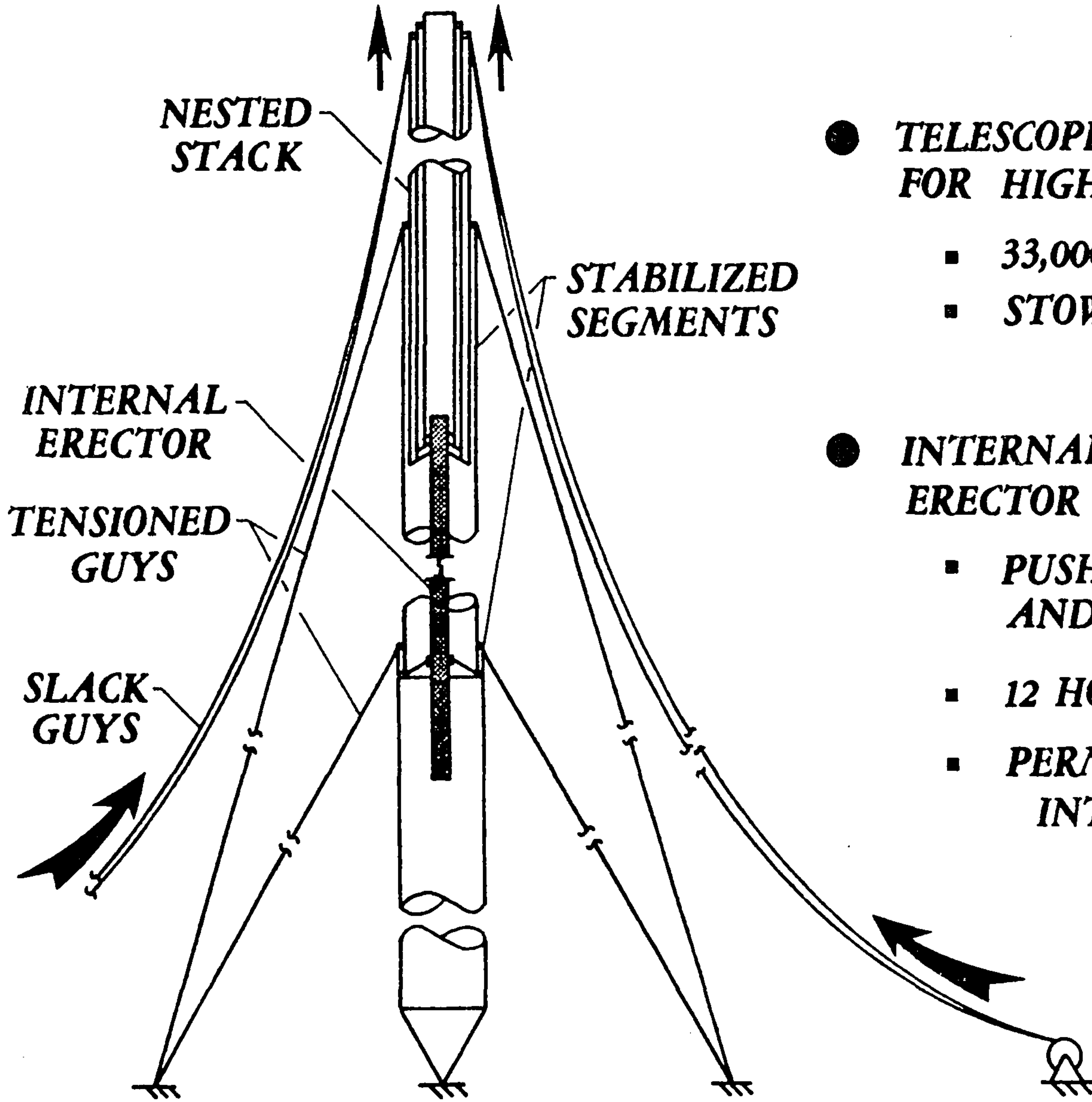
Accomplishment Description

Seven concepts were devised for which analysis verified structural feasibility. A preferred concept is proposed which is a guyed tower of telescoping aluminum cylinders that can be automatically extended to a height of 1,000 feet in less than twelve hours. Manufacturing feasibility studies indicate that the cylindrical segments of the tower can be fabricated using state-of-the-art techniques. The concept is light enough (approximately 33,000 lbs.) for highway transportation and can be packaged small enough to fit within a standard tractor-trailer truck. The tower and the preferred internal erector mechanism are shown schematically in the accompanying figure. The internal erector eliminates the need for controlling tower stability during erection with synchronized deployable guylines. The internal erector carries up the interior nested cylinders, leaving behind successive exterior cylinders which can be guyed off permanently. The tower design study has been documented as three separate NASA Contractor Reports which include the analysis and trade studies, the structural configurations and erection scenarios, and the preliminary specifications for the preferred concept.

Future Plans

As a result of these studies, the Navy has provided additional funding to extend the current contract (scheduled to conclude April 28, 1982) in order to plan electrical and structural hardware tests and further develop the internal erector concept and joint designs. A substantial increase in funding for this project has been requested by the Navy for FY 83. It is the Navy's desire for NASA-LaRC to continue managing the program.

1000 FOOT EMERGENCY VLF TOWER CONCEPT SELECTED



- *TELESCOPING CYLINDERS PACKAGE FOR HIGHWAY TRANSPORTATION*
  - *33,000 LB TOWER*
  - *STOWABLE IN ONE TRUCK*
- *INTERNAL "CARRY-UP-STACK" ERECTOR PERMITS:*
  - *PUSHBUTTON DEPLOYMENT AND RETRACTION*
  - *12 HOUR DEPLOYMENT*
  - *PERMANENT TENSIONING OF INTERMEDIATE GUYS*

TECHNICAL HIGHLIGHT

TAILORING MESH IMPROVES ACCURACY OF FACETED REFLECTORS

W. B. Fichter
Structural Concepts Branch, SDD
Extension 3179
July 19, 1982

(RTOP 506-53-43)

Research Objective

To improve the performance of faceted reflector antennas by minimizing the rms surface distortion relative to the ideal paraboloid.

Approach

Without lateral pressure, constant-tension membranes cannot assume the desired paraboloidal reflector shape. Whether the membranes are stretched over a planar or a paraboloidal frame, deviations from the desired surface are introduced. These deviations, which degrade antenna performance, can be quantified to provide a rational basis for design of a minimal-error configuration. In this study, expressions are being developed for rms deviation between the ideal reflector surface and its faceted-membrane approximation. For some representative facet shapes, the membrane deflection shapes and locations which minimize rms deviation are sought.

Accomplishment Description

Results to date are for equilateral triangles. For comparisons with flat facets, exact solutions have been obtained for uniform-tension membranes subjected to parabolic edge displacements, and rms deviations have been calculated for two doubly curved facet arrangements:

1. The membrane edges are matched to the paraboloidal surface, and
2. The membrane has both optimal parabolic edge deflection and placement relative to the paraboloid.

On the figure, results for two flat-facet and two curved-edge facet configurations are given. In the first flat-facet configuration, which serves as a baseline, the triangle vertices are in contact with the paraboloid. The dimensionless rms deviation is $\frac{W_{rms}}{D} = 0.0646 \frac{(\ell/D)^2}{F/D}$, where F is the reflector focal length, ℓ is the length of a facet edge, and D is the diameter of the shallow dish. Moving the flat facet into the paraboloidal surface to its minimal-rms location, the error is reduced by 75 percent. Making the facet edges congruent with the paraboloidal surface yields a slight additional improvement. Finally, moving the facet into the paraboloidal surface and giving it the optimum parabolic edge deflection yields a 90 percent reduction from the baseline rms deviation.

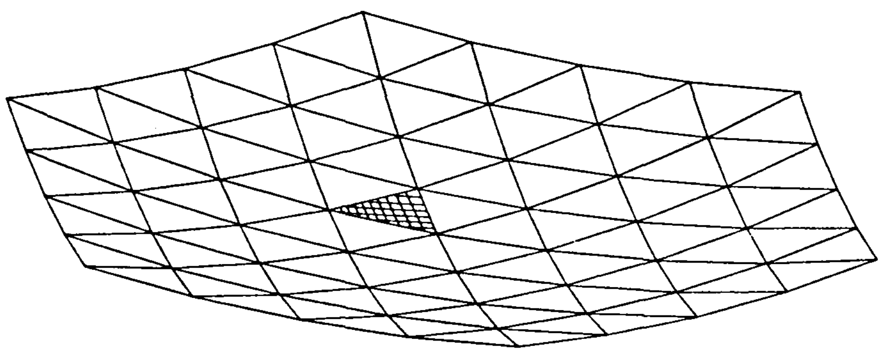
Future Plans

Similar analyses for rectangular facets have begun. Also underway is a study of the feasibility of incorporating these potential improvements in a deployable truss antenna.

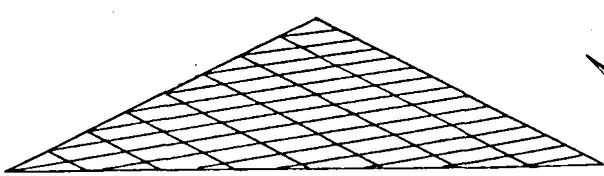
NASA
L–82–1,635

TAILORING SURFACE MESH IMPROVES ACCURACY OF FACETED REFLECTORS

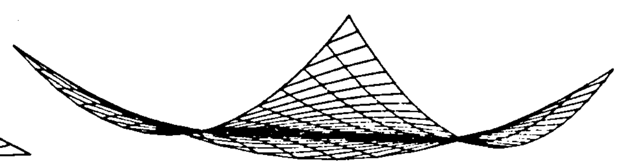
FACETED REFLECTOR



FLAT FACET



CURVED FACET



FACET CONCEPT	NORMALIZED RMS ERROR
FLAT	1
FLAT (BEST FIT)	0.25
CURVED	0.23
CURVED (BEST FIT)	0.10

LIMITS OF ACHIEVABLE ACCURACY DEFINED FOR TRUSS ANTENNA STRUCTURE

William H. Greene
Structural Concepts Branch, SDD
Extension 2841
September 17, 1982

RTOP 506-53-43

Research Objective

Tetrahedral trusses are currently being considered for forming a stiff, stable reflector surface for large antennas. Even with careful manufacturing procedures, the many struts which form the truss structure possess length errors which can contribute to a non-ideal reflective surface. The objective of this study is to assess the magnitude of surface distortion errors in truss antenna reflectors considering random strut length errors.

Approach

The length error of each strut in the truss is assumed to be random with a normal distribution, zero mean, and standard deviation, σ_ε. The structural deformations caused by the imperfect struts are calculated with an EAL finite element analysis. To calculate the statistical properties of this surface deformation, the analysis is performed a large number of times with different sets of randomly selected member errors.

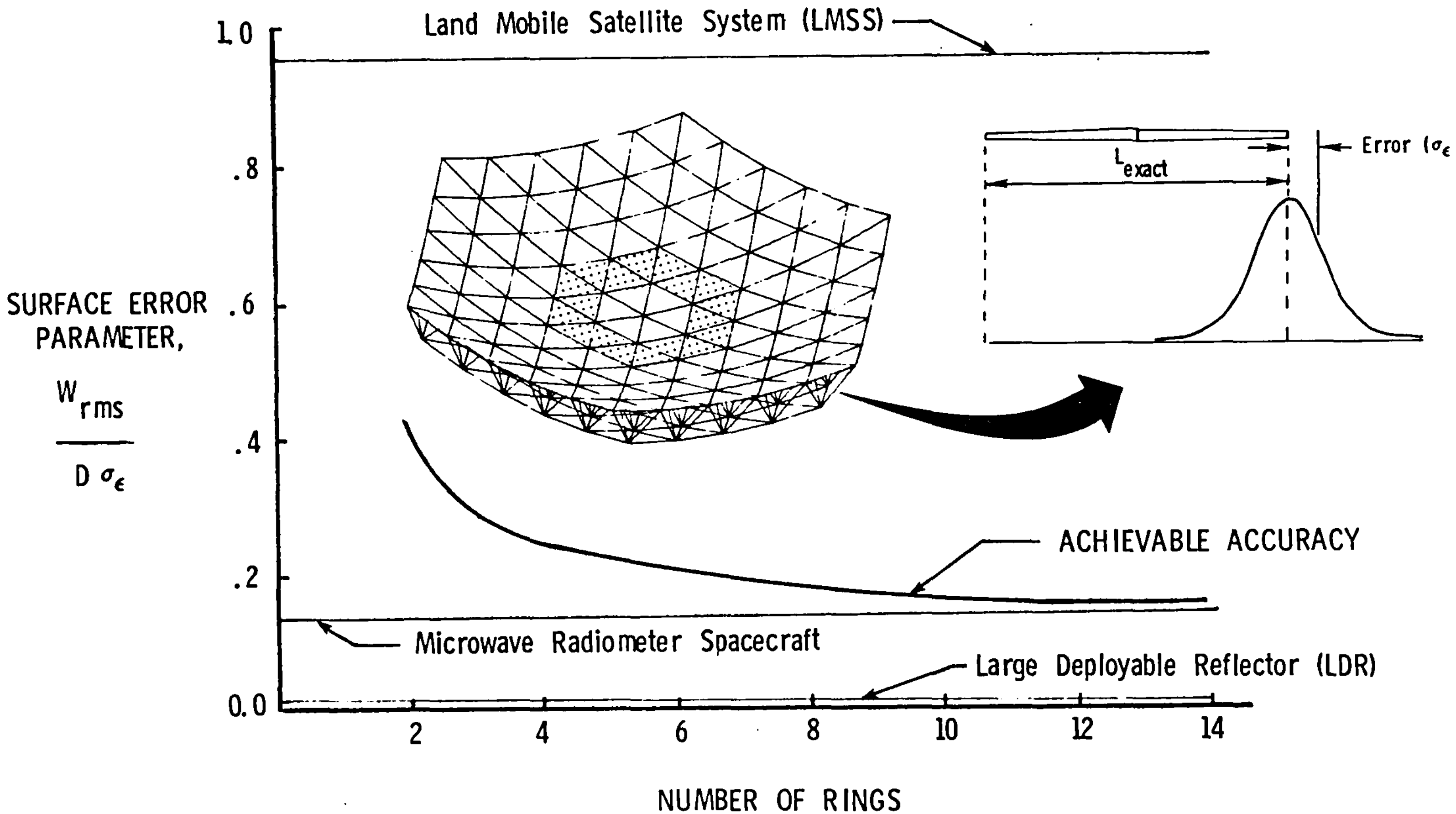
Accomplishment Description

In the figure, a surface error parameter consisting of the root mean squared normal surface error nondimensionalized by reflector diameter and member error standard deviation is plotted versus the number of rings in the truss. A typical ring is shown shaded on the five ring reflector in the figure. The heavy line denoted as "achievable accuracy" was obtained from the finite element results. The requirements for the three antennas shown in the figure are based on the rather common assumption of the rms surface error being equal to 1/20 of the operating wavelength. The struts in the reflectors are assumed to have an error standard deviation of 1×10^{-4} which should be possible with careful manufacturing techniques. The LMSS and the Microwave Radiometer have similar operating wavelengths but because the LMSS has a much smaller diameter (55m versus 750m) its surface accuracy requirement is much more easily met. The LDR has only a 20m diameter but because its operating wavelength is very small, (< 1mm) its surface acccuracy requirement cannot be met by the truss backup structure alone. For cases where the surface accuracy requirements cannot be met by the truss, the current analysis can be used to define the dimensional range that a control system will have to provide.

Future Plans

Feed location structure will be added to the model and focal point errors assessed.

LIMITS OF ACHIEVABLE ACCURACY DEFINED FOR TRUSS ANTENNA STRUCTURE



TECHNICAL HIGHLIGHT

PMR-15 POLYIMIDE/GRAPHITE FIBER COMPOSITE BONDED AND BOLTED JOINTS CARRY SPACECRAFT DESIGN LOADS AT 550°F

Paul A. Cooper and J. Wayne Sawyer
Structural Concepts Branch
Extensions 3787 and 3714
September 20, 1982

RTOP 524-71-03 (CASTS) and 743-01-03 (SCR)

Research Objective

The objective of this program is to provide a data base for the design of graphite/polyimide composite joints useful for service at elevated temperatures (550°F).

Approach

Determine with allowables and small specimen tests the materials and structural joining characteristics. Design, fabricate and test the strength and fatigue behavior at elevated temperature of both bonded and bolted attachment concepts for skin splices and rib-skin and spar-skin interfaces. The program includes over 1500 individual laboratory tests of composite elements and components.

Accomplishment Description

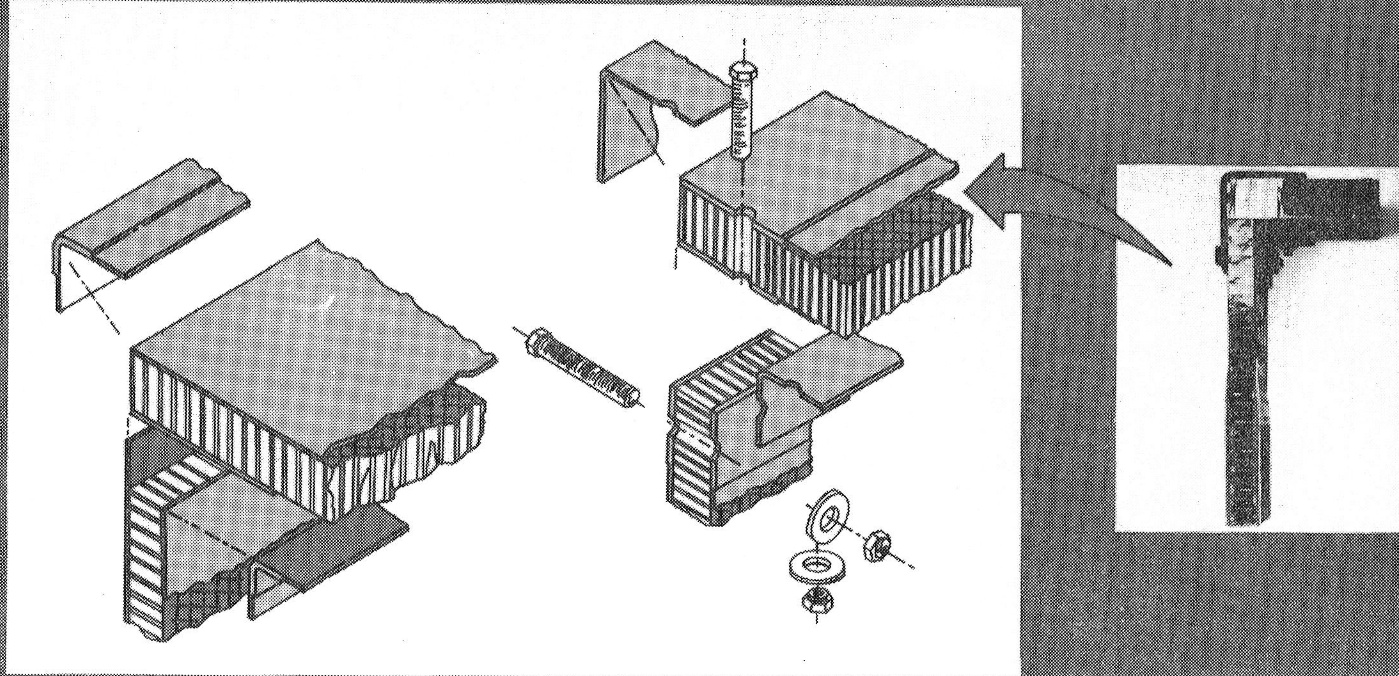
Static tests showed that seven types of joints successfully transferred required design loads at 550°F (as high as 10,000 lb/in for bolted splice joints). The bonded joints used an adhesive formulation based on the Langley developed high temperature adhesive LaRC-13. Room temperature tests of bolted concepts showed that the PMR-15/celion fiber composite had the same net tension and shearout capabilities at ambient temperature as corresponding graphite/epoxy joints so that there was no compromise of room temperature capabilities by using polyimides. The accompanying figure shows a schematic of the components of both a bonded and bolted corner joint and a picture of an assembled graphite/polyimide bolted corner joint test specimen. Results from the contract are supporting two programs at Boeing:

- Strong factor in influencing the decision to start in-house applications research program at Boeing Commercial with PMR-15/PI for possible use in -757 and -767 cowlings and nacelles (no production commitment as yet).
- Results were used in Air Force research study to configure a joint between a brittle ceramic radome and titanium missile body. The component was successfully tested at 800°F.

Future Plans

Static and fatigue tests of production quality joints underway. Contract was completed in June 1982.

PMR-15 POLYIMIDE/GRAPHITE FIBER COMPOSITE BONDED AND BOLTED JOINTS CARRY SPACECRAFT DESIGN LOADS AT 550°F



BONDED BOLTED

- LaRC-13 FORMULATION ADHESIVE RETAINED USEFUL STRENGTH AT 550°F
- BOLTED JOINTS EXHIBITED SAME STRENGTH AT ROOM TEMPERATURE AS EPOXY JOINTS
- RESULTS INFLUENCING BOEING DESIGN DECISIONS FOR COMMERCIAL AIRCRAFT AND MISSILES

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-85661		

4. Title and Subtitle	5. Report Date
Structures and Dynamics Division Research and Technology Plans for FY 1983 and Accomplishments for FY 1982	June 1983
	6. Performing Organization Code: 506-53-43-01
7. Author(s): Kay S. Bales	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address: NASA Langley Research Center, Hampton, VA 23665	11. Contract or Grant No.
	13. Type of Report and Period Covered: Technical Memorandum
12. Sponsoring Agency Name and Address: National Aeronautics and Space Administration, Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This paper presents the Objectives, Expected Results, Approach, and FY 1983 Milestones for the Structures and Dynamics Division's research programs. FY 1982 Accomplishments are presented where applicable. This information is useful in program coordination with other government organizations in areas of mutual interest.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Computer-aided design; IPAD; General aviation/transport crash dynamics; Aircraft ground performance; Composite structures; Failure analysis; Space vehicle dynamics; Large space structures	Unclassified - Unlimited Subject Category 39

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	112	A06

N-305