NASA/TM-1998-208714

Implementation Plan for the NASA Center of Excellence for Structures and Materials

Edited by
Charles E. Harris
Langley Research Center, Hampton, Virginia

August 1998

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National Aeronautics and
Space Administration

Langley Research Center
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Executive Summary

This report presents the implementation plans of the Center of Excellence (COE) for Structures and Materials. The plan documented herein is the result of an Agencywide planning activity led by the Office of the Center of Excellence for Structures and Materials at Langley Research Center (LaRC). The COE Leadership Team, with a representative from each NASA Field Center, was established to assist LaRC in fulfilling the responsibilities of the COE. The Leadership Team developed the plan presented in this report.

The Structures and Materials COE will provide the leadership for coordination, planning, advocacy, and assessment of the structures and materials research and technology development activities throughout the Agency. The COE will promote the development of new material systems and processes, innovative structural mechanics and dynamics design and analysis methods, experimental techniques, and advanced structural concepts through technology validation for aircraft, space transportation vehicles, science instruments and spacecraft. The COE will address technology challenges to enable more affordable, lighter weight, higher strength and stiffness, safer, and more durable vehicles for subsonic, supersonic, and sustained hypersonic flight, earth and other planetary atmospheric entry, and for spacecraft flight throughout the solar system.

The Structures and Materials COE will implement the following five specific functional responsibilities:

1. Conduct a periodic assessment of the current technical capabilities in relation to future Agency missions and technology requirements.
2. Maintain and enhance the preeminent technical capabilities distributed throughout the Agency.
3. Proactively participate in planning future Agency programs.
4. Serve as the primary point-of-contact for requests for structures and materials technical information and for requests to participate in urgent investigations of critical problems.
5. Build strategic alliances / partnerships with all NASA Field Centers, other COE's, industry, academia, other Government Agencies, and international partners.

The COE will be led by the COE Office at Langley Research Center with strategic partnerships established among the NASA Field Centers, forming the COE Community. The COE Office will provide the strategic leadership required to implement the functional responsibilities of the COE. The COE Community will be responsible for maintaining and enhancing the preeminent technical and programmatic expertise and ground test facilities and laboratories distributed throughout the Agency. The COE Community will develop and maintain partnerships with industry, academia, and other Government Agencies to leverage external programs and resources to achieve NASA strategic objectives. The COE Office will coordinate with the other COE's and key NASA Headquarters Offices, as appropriate, to effectively and efficiently meet the research and technology needs of all the NASA Strategic Enterprises.

Table of Contents

List of Figures

List of Tables

Implementation Plan for the NASA Center of Excellence for Structures and Materials

1.0 Introduction

This report presents the implementation plans of the Center of Excellence (COE) for Structures and Materials. The plan documented herein is the result of an Agencywide planning activity led by the Office of the Center of Excellence for Structures and Materials at Langley Research Center (LaRC). Under LaRC's leadership, a partnership has been established among the nine (9) NASA Field Centers, shown in Figure 1, with dedicated structures and materials capabilities. The COE Leadership Team, with a representative from each NASA Field Center, was established to assist LaRC in fulfilling the responsibilities of the COE. The Leadership Team developed the plan presented in this report.

2.0 Mission

The Structures and Materials COE will provide the leadership for coordination, planning, advocacy, and assessment of the structures and materials research and technology development activities throughout the Agency. The COE will promote the development of new material systems and processes, innovative structural mechanics and dynamics design and analysis methods, experimental techniques, and advanced structural concepts through technology validation for aircraft, space transportation vehicles, science instruments and spacecraft. The COE will address technology challenges to enable more affordable, lighter weight, higher strength and stiffness, safer, and more durable vehicles for subsonic, supersonic, and sustained hypersonic flight, earth and other planetary atmospheric entry, and for spacecraft flight throughout the solar system.

The COE will be led by the COE Office at Langley Research Center with strategic partnerships established among the NASA Field Centers, forming the COE Community. The COE Office will provide the strategic leadership required to implement the functional responsibilities of the COE. The COE Community will be responsible for maintaining and enhancing the preeminent technical and programmatic expertise and ground test facilities and laboratories distributed throughout the Agency. The COE Community will develop and maintain partnerships with industry, academia, and other Government Agencies to leverage external programs and resources to achieve NASA strategic objectives. The COE Office will coordinate with the other COE's and key NASA Headquarters Offices, as appropriate, to effectively and efficiently meet the research and technology needs of all the NASA Strategic Enterprises.

3.0 Vision

The COE Office is the Agencywide technical conscience for structures and materials technologies and fulfills a strategic leadership function. The Agency will benefit from the COE Community through the effective and efficient utility of the comprehensive inventory of technical capabilities distributed across the Agency, coordination of these capabilities, leading and participating in strategic planning, and maintaining and enhancing the preeminent Agency core competency in structures and materials.

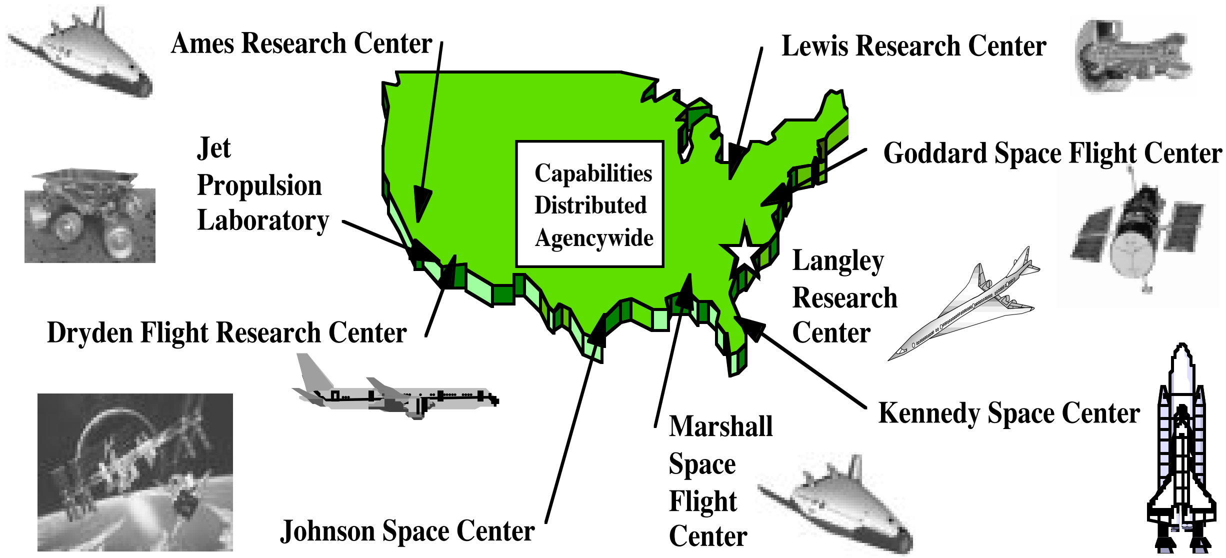


Figure 1. NASA Center Partners in the COE Community

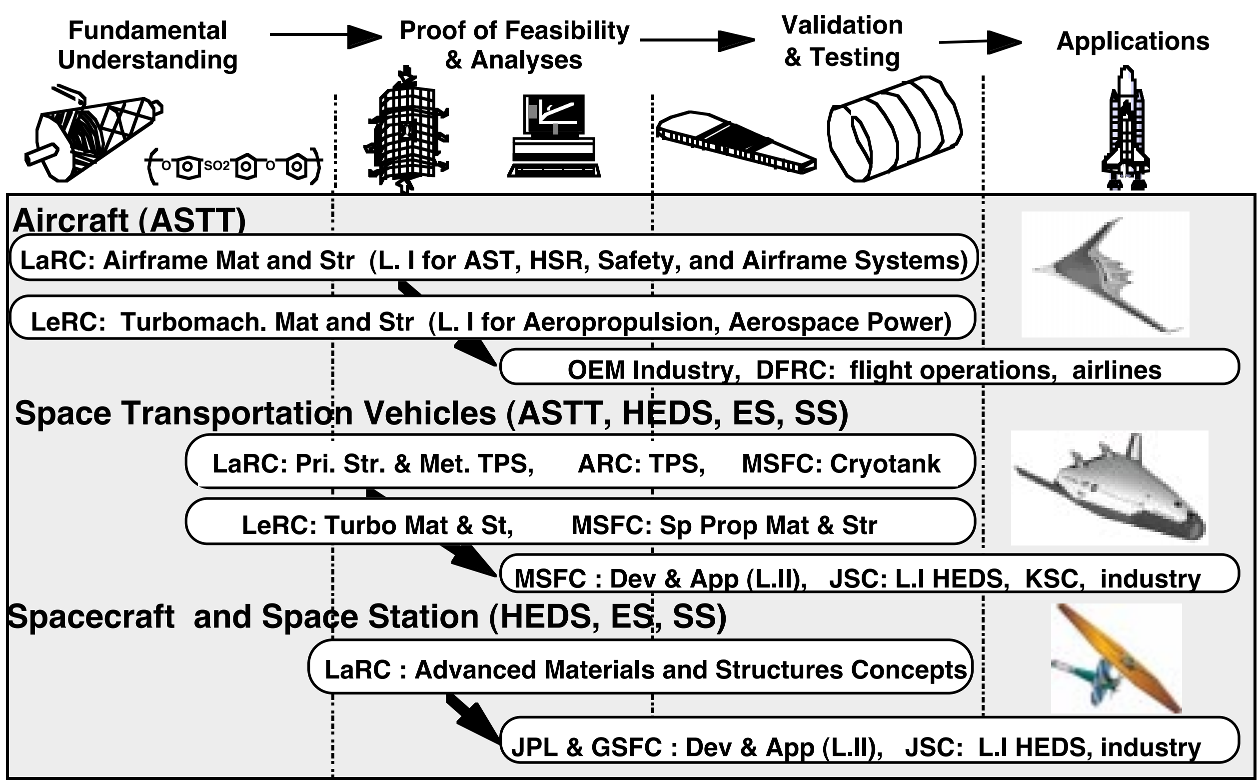


Figure 2. The COE Technology Scope

4.0 Authority

The Agency authority invested in the Structures and Materials COE is assigned to LaRC in the NASA Strategic Plan [1]. Further guidance and responsibilities are outlined in the NASA Strategic Management Handbook [2]. The COE is required to conduct periodic assessments of the status of the Agency technical capabilities with the expectation that the specific recommendations contained in these assessments will be acted on by the Center Directors, Enterprise Associate Administrators, Office of Chief Technologist, Office of the Chief Engineer, Technology Leadership Council, and the Capital Investment Council, as appropriate.

5.0 Technology Scope

The technology scope of the COE, illustrated schematically in Figure 2, includes research programs, technology development and demonstration programs; and the application of structures and materials technologies to NASA atmospheric flight missions, space launch operations, space and earth sciences missions, and the Space Station. (The Lead Center assignments for major Agency programs are designated by L.I or L.II in Figure 2.)

The technology scope encompasses the airframe and engine of subsonic, supersonic, and hypersonic aircraft; primary structure, cryotank, thermal protection systems, and propulsion systems of space transportation vehicles; space science instruments, and power and structural components of spacecraft; the Space Station; earth and other planetary atmospheric entry vehicles, and human space/planetary habitats.

The partnerships among the 9 NASA Field Centers is based on the following specific technology application focus at each Center:

Ames Research Center: thermal protection systems

Dryden Flight Research Center: atmospheric flight qualification, demonstration, and evaluation

Goddard Space Flight Center: space and earth science missions and technology development

Jet Propulsion Laboratory: spacecraft and space science instrument development and applications

Johnson Space Center (including the White Sand Test Facility): space shuttle, space station, and advanced spacecraft development and applications

Kennedy Space Center: materials characterization and failure analysis in support of space launch operations

Langley Research Center: airframe primary structure; primary structure, cryotank, and metallic thermal protection systems of space transportation vehicles; and advanced concepts for spacecraft and space science instruments

Lewis Research Center: turbomachinery for aircraft engines and space transportation vehicles; aerospace power; power for LEO, MEO, and GSO planetary spacecraft, and space experiments

Marshall Space Flight Center: primary and secondary structure, cryotanks, and TPS/insulation for integrated space transportation and propulsion system structure; and advanced space instruments, payloads, and subsystems

6.0 Inventory of Agencywide Technical Capabilities

A detailed inventory of the Agencywide structures and materials technical capabilities is given in the Appendix. The inventory includes a listing of the disciplinary technical skills relative to specific applications, description of the dedicated structures and materials facilities and laboratories, and the FY 98 Programs with the associated structures and materials civil service workforce for each Center in the COE Community. Over 300 disciplinary skills are listed in the inventory. A summary of these skills is given in Table 1. Over 100 dedicated facilities and laboratories are described in the inventory. A summary of these experimental capabilities are given in Table 2. The structures and materials workforce is supporting all 4 NASA Enterprises and 71 programs are listed in the inventory. A summary of the civil service workforce is given in Table 3. Examples of recent structures and materials technical accomplishments from each NASA Center is also given in the Appendix.

Table 1. Disciplinary Technical Skills

Technical Capabilities	LaRC	LeRC^T	ARC	DFRC	MSFC	JSC +WSTF	KSC	GSFC	JPL
New materials development	MPC R^f, R^a	MPC R^f, R^a	C R^f, R^a , D						
Materials processing & fabrication technology	MPC R^f, R^a	MPC R^f, R^a	C R^f, R^a D, S		MPC R^a, D, S	MPD, S		PD, S	PD, S
Materials characterization & failure analysis	MPC R^f, R^a,D, S	MPC R^f, R^a,D, S	C R^f, R^a D, S		MPC R^a, D, S	MPD, S	MPC R^a, D, S	MPD, S	PD, S
Materials durability & fatigue and fracture	MPC R^f, R^a	MPC R^f, R^a			MPC R^a, D, S	MPD, S	M R^a, D, S	MPD, S	
Tribology (coatings, lubricants, & bearings)		R^f, R^a			R^a, D, S	S		D, S	
Nondestructive evaluation sciences & NDE/I	R^f, R^a D, S	R^f, R^a D, S			R^a, D, S	R^a, D, S	S	D, S	D, S
Structural mechanics, strength, & design meth.	R^f, R^a D, S	R^f, R^a, D, S		D, S	R^a, D, S	S	D, S	S	S
Dynamics, vibration & modal analysis & tests	R^f, R^a D, S	R^f, R^a, D, S		R^a, D, S	R^a, D, S	S	D, S	D, S	D, S
Structural acoustics methodology & testing	R^f, R^a	R^f, R^a, D, S			D, S	S	D, S	D, S	D, S
Aeroelasticity analysis methods & testing	R^f, R^a, D	R^f, R^a, D, S		R^a, D, S					
Flight hardware design, fabrication, & testing	D, S	D, S	D, S	D, S	D, S	D, S	S	D, S	D, S

Capability Code:
M = metallic alloys and composites
P = polymers and composites
C = high temperature ceramic and refractory materials and composites
R^f = fundamental research, and R^a = applied (focused) research
D = technology development and demonstration
S = innovative engineering for mission support
x^T = high temperature propulsion materials and structures

Table 2. Facilities and Laboratories

Laboratories and Facilities	LaRC	LeRC	ARC	DFRC	MSFC	JSC +WSTF	KSC	GSFC	JPL
Polymers and composites	R&D	R&D			D, S	D, S		D, S	D, S
Metals and composites	R&D	R&D			R&D, S	D, S		D, S	D, S
Ceramics, refractory mat'l and composites	R&D	R&D	R&D		D, S			D, S	
Mat'ls characterization, analysis, and properties	R&D, S	R&D, S	R&D		R&D, S	D, S	R&D, S	R&D, S	D, S
Durability and mission simulation	R&D	R&D			R&D, S			D, S	D, S
Fatigue and fracture	R&D	R&D			R&D, S	D, S	R&D, S	D, S	D, S
Tribology (coatings, lubricants, & bearings)		R&D			R&D, S			D, S	
Nondestructive evaluation sciences and NDE/I	R&D, S	R&D, S			R&D, S	D, S	S	D, S	D, S
High temperature, high heat flux facilities	R&D	R&D	R&D	R&D	D, S	D, S			
Large component structural test facilities	R&D	R&D			D, S	D, S		D, S	D, S
Structural dynamics, vibration, and acoustics	R&D,S	R&D,S		R&D, S	D, S	D, S		D, S	D, S
Thermal vacuum and space simulator facilities		R&D,S			R&D, S	D, S	D, S	D, S	D, S
Electromechanical, MEMS/MOMS, & actuators	R&D	R&D		R&D, S	D, S	D, S	D, S	D, S	R&D, S
Aerothermodynamic structures facilities	R&D		R&D		D, S				
Spacecraft / instrument fab, assembly & testing	D, S	D, S			D, S	D, S		D, S	D, S
Unique facilities with specialized capability	TDT, IDRF ALDF COLTS	Turbomac Comp Test Complex	Arc Jet Complex	Flight Loads Lab	Large tests, Turbopump LOX & LH_2	Arc Jets, Mat Testing in Haz. Env.	Beach Site Corrosion, LETF	Centrifuge, Outgassing 6 DOF	13'& 27' Space Simulator

R = research **D = technology development and demonstration** **S = support of flight hardware**

Table 3. FY 98 Programs and Civil Service Workforce

By Technical Function	LaRC	LeRC	ARC	DFRC	MSFC	JSC +WSTF	KSC	GSFC	JPL	Totals
Research and Technology Development	236	183	31	11	119	0	13	30	49	**672**
Facility & Laboratory Operations	184	117	16	15	0	22	53	18	42	**455**
Flight Hardware Design and Fabrication	20	26	2	1	210	47	3	259	149	**729**
By Enterprise	**LaRC**	**LeRC**	**ARC**	**DFRC**	**MSFC**	**JSC +WSTF**	**KSC**	**GSFC**	**JPL**	**Totals**
Aeronautics and Space Transportation Technology	368	294	43	26	106	2	17	0	0	**856**
Human Exploration and Development of Space	9	5	0	0	150	67	52	0	0	**283**
Earth Science	8	1	0	0	5	0	0	53	107	**174**
Space Science	29	18	6	0	30	0	0	162	130	**375**
Other programs	26	8	0	1	38	0	0	92	3	**168**
Total Workforce, CS FTE's	**440**	**326**	**49**	**27**	**329**	**69**	**69**	**307**	**240**	**1856**

7.0 Functional Responsibilities and Implementation Plans

Using the guidance provided in the NASA Strategic Management Handbook, the Center of Excellence for Structures and Materials has adopted the following five (5) specific functional responsibilities:

1. Conduct a periodic assessment of the current technical capabilities in relation to future Agency missions and technology requirements.

2. Maintain and enhance the preeminent technical capabilities distributed throughout the Agency.

3. Proactively participate in planning future Agency programs.

4. Serve as the primary point-of-contact for requests for structures and materials technical information and for requests to participate in urgent investigations of critical problems ("911 calls").

5. Build strategic alliances / partnerships with all NASA Field Centers, other COE's, industry, academia, other Government Agencies, and international partners.

The tasks required to implement each functional responsibility are described in the following sections.

7.1 Conduct a periodic assessment of the current technical capabilities in relation to future Agency missions and technology requirements.

A process has been developed for conducting the periodic assessment of the current technical capabilities distributed throughout the COE Community. This process is outlined in the process flow diagram shown in Figure 3. The COE will implement the following specific tasks:

1. The COE Office will compile and publish an inventory of the Agency's structures and materials capabilities. Each Center will provide the following data:
   - technical capabilities,
   - description of facilities and laboratories,
   - current FY programs and associated civil service workforce (FTE's),
   - recent accomplishments and problems solved,
   - identify future Agency missions/needs and technical requirements,
   - identify examples of a "technology push" that enables a future Agency mission.

2. Each Center will conduct a self-assessment of strengths, weaknesses, and gaps with respect to Enterprise goals and objectives.

3. The COE Office will coordinate the Center self-assessments, identify overarching themes, develop list of deficiencies, and benchmark NASA capabilities to those of outside organizations, as appropriate.

4. The COE Office will lead the development of recommendations to address deficiencies, and proactively advocate appropriate implementation of the recommendations.

5. Each Center will develop a Structures and Materials Facilities and Laboratories Brochure suitable for public dissemination.

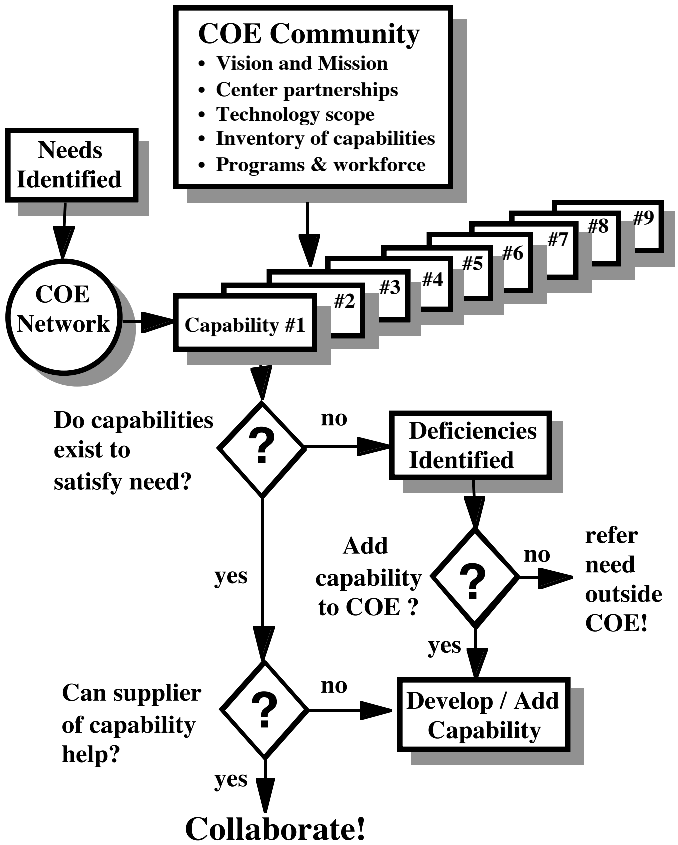


Figure 3. Periodic assessments of the current technical capabilities

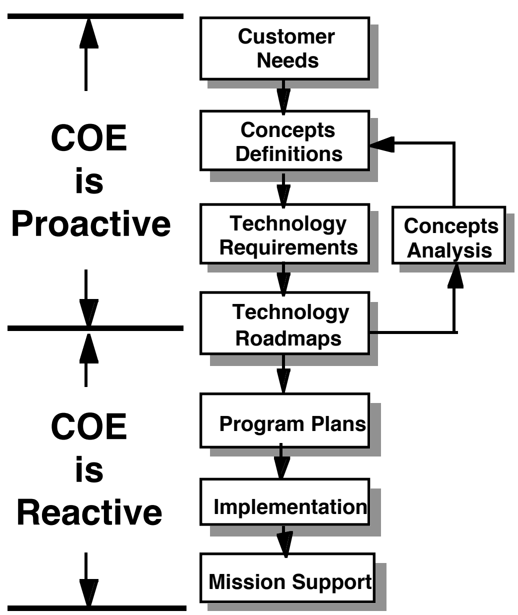


Figure 4. Notional diagram of the process for program development

7.2 Maintain and enhance the preeminent technical capabilities distributed throughout the Agency.

The responsibility to maintain and enhance the preeminent technical capabilities distributed throughout the Agency resides with the line management at each participating Center. The COE will establish Working Groups in specific technical areas that cross-cut the structures and materials community. The purpose of these Working Groups will be to discuss common problems, share experiences, and form partnerships where cooperative activities are mutually beneficial. It is anticipated that several Working Groups will be established as standing committees to address the maintenance and enhancement of technical skills and expertise. However, Working Groups to address the enhancement of Facilities and Laboratories will only be established when the need arises from the periodic assessment of current technical capabilities. The COE will implement the following specific tasks:

1. The COE Office will coordinate the establishment of Working Groups by conducting a canvas of the COE Community to obtain a list of existing relevant Working Groups, identify candidate technical areas for new Working Groups, and gage the interest in participating. (Table 4 contains a list of some of the existing NASA Working Groups.)

2. The COE Office will initiate a discussion with existing Working Groups that may be appropriate to facilitate the objectives of the COE.

3. Where sufficient interest exists to create a new Working Group, the COE Office will lead the development of a charter, solicit names of the members from the interested Centers, and a kick-off meeting will be organized.

4. The COE Community will voluntarily participate in those Working Groups that directly benefit the participating Centers.

7.3 Proactively participate in planning future Agency programs.

A notional diagram of the NASA process for program creation, implementation, and mission support is shown in Figure 4. The COE will be proactive in planning future programs and Agency missions. This proactive role will help insure that all future programs are planned with an appropriate structures and materials content. Also, visionary plans for long-term developments in structures and materials will be advocated as examples of technologies that can enable future Agency missions that are not currently conceived. The COE will implement the following tasks:

1. The COE Office will coordinate the support for planning future programs as requests are received and opportunities identified.

2. The COE Community will voluntarily participate in the planning activities as requests/opportunities arise.

3. The responsibility to communicate throughout the COE Community the information regarding requests and opportunities is jointly shared by the COE Office and the COE Community members.

4. The COE Office will engage in regular discussions with key personnel in Enterprise and Program Offices. These discussions are intended to be informational in content. (Advocacy for implementing recommendations is part of the responsibility for conducting periodic assessments of current technical capabilities.)

5. The COE will organize and participate in workshops of specific technical issues of interest to the COE Community. Emphasis will be given to the long-term view, especially where structures and materials has an opportunity to provide a “technology push” that enables a future Agency mission. (Participation on the organizing committee and in the workshop is voluntary.)

Table 4. Existing Disciplinary Working Groups

- NASA NDE Working Group
- NASA Materials and Processes Working Group
- NASA Fracture Control Panel
- NASA Design, Analysis, Test, and Verification Working Group
- Engineering Standards Steering Committee
- NASA Reliability Board
- Vibroacoustics Standards Panel
- NASA Space Mechanisms Working Group
- NASA Microdynamics Working Group
- NASA Structural Dynamics Working Group
- Telerobotic Intercenter Working Group
- NASA Structures Probabilistics Working Group
- Loads Standards Panel
- Life Prediction of Ceramic Matrix Composites for RLV Applications
- Fracture Toughness Testing of Lithium-Aluminum Shuttle Tank Replacement Materials
- Characterization of NASA-derived Advanced Polymeric Materials
- Space Environments and Effects Program: Meteroid & Orbital Debris, Materials & Processes, and Ionizing Radiation Technical Working Groups
- Headquarters S&MA Structures Probabilistics Working Group
- Shuttle Replacement Technology Team
- NASA Operational Environment Team
- ECoA Intercenter Planning Team for the Environmental Initiative
- EOS Structural/Mechanical/Dynamic Loads and Environment Integration of Launch Vehicles
- Structural Stability Research Council
- Synthetic Thinned-Aperture Radiometer (STAR) Development Team
- Structural Stability Research Council
- Langley Smart Structures Technical Committee
- The Technical Cooperation Program on Structures & Dynamics of Aeronautical Vehicles
- Gust Specialists Committee

7.4 Serve as the primary point-of-contact for requests for structures and materials technical information and for requests to participate in urgent investigations of critical problems ("911 calls").

In order to fulfill the reactive role illustrated notionally in Figure 4, the COE will implement the following specific tasks:

1. The COE Office will respond to requests for technical information as the need arises. The COE Office will use the Directory of Key Personnel (points-of-contact included in the Capabilities Inventory) provided by each Center as a source of referrals when the Office cannot fulfill a request.

2. The COE Office will assign action items to appropriate Centers when requests to participate in urgent investigations of critical problems ("911 calls") are received.

3. The COE Community will voluntarily participate in "911 calls" at a level judged to be appropriate by the Center(s) receiving the request from the COE Office.

4. Those requests for technical information or "911 calls" that involve multiple Centers will be communicated throughout the COE Community by the COE Office and/or the members of the Community.

7.5 Build strategic alliances / partnerships with all NASA Field Centers, other COE's, industry, academia, other Government Agencies, and international partners.

The foundation of the Center of Excellence for Structures and Materials is the partnership established among the NASA Field Centers. The voluntary participation of all NASA Field Centers in the COE partnership is viewed to be essential for success. The NASA community of excellence in structures and materials will benefit from alliances with external organizations. Numerous alliances and partnerships already exist between members of the COE Community and external organizations.

In the context of the COE Implementation Plan, an alliance will be defined as an enduring relationship, connecting parties with common interests (needs), that does not disappear with specific programs. The COE will implement the following specific tasks:

1. The COE Office will canvas the COE Community, compile, and distribute a list of existing structures and materials alliances. (Table 5 contains a list of some of the existing alliances.)

2. The COE Community will identify opportunities for other community partners to join existing alliances.

3. The list of alliances will be evaluated by the COE Office and Community to identify needs not currently fulfilled by the existing alliances.

4. The COE Office will inform the COE Community of opportunities to form new alliances.

5. The specific actions to form new alliances will be the voluntary initiative of the individual members of the COE Community.

Table 5. Existing Disciplinary Alliances

- Life Prediction of Metal Matrix Composite Ring Structure (NASA LeRC, and DoD)
- Life Prediction of Toughned Ceramics for Heat Engines (NASA LeRC, and ORNL)
- T700 Engine Lfie Management Program (NASA LeRC, and DoD)
- Guide Consortium on Turbomachinery Forced Response (NASA, DoD, and industry)
- High Cycle Fatigue Program (NASA LeRC, and DoD)
- Interagency Advanced Power Group, Thermal Management Subgroup (NASA, DoD, and DoE)
- Carbon-Carbon Spacecraft Radiator Partnership (NASA, DoD, and Industry)
- Shock and Vibration Information and Analysis Center (SAVIAC), Technical Advisory Group (NASA, DoD, DoE, and industry)
- International Structural Optimization Workshop (NASA, ESA, academia, and industry)
- Government Flight Flutter Test Council (NASA, DoD)
- DFRC Flight Test Center Alliance for Flutter Testing (NASA DFRC, and USAFFRC)
- Corrosion Technology (NASA KSC, NRL)
- Advanced Materials Processing & Analysis Center (NASA KSC, UCF)
- Advanced Composites Working Group Steering Committee (NASA, DoD)
- Mil Handbook 17 Working Group to develop the Specification for SiC/Al MMC (NASA, DoD, FAA, and Industry)
- Mil Handbook 17 Working Group on Specialized Data Development (NASA, DoD, FAA, and industry)
- MMC Working Group for Versailles Project on Advanced Materials and Standards (consortium of laboratories in 8 countries)
- JANNAF Material Properties and Processing Panel (NASA, DoD)
- Integrated High Payoff Rocket Propulsion Technology Materials Working Group (NASA, DoD)
- ISS Materials and Processes Analysis and Integration Team (NASA, industry)
- NASA/USAF Wind Tunnel Alliance: facilities with arc heaters (NASA ARC, JSC, LaRC, and the USAF AEDC)
- NATO Research Test Orginization: for TPS and arc jet testing (NATO members)
- Rotorcraft Leadership Team (NASA, Army)
- Rotorcraft HUMS Team (NASA, Army)
- Civil Tilt Rotor Capacity Planning Team (NASA, industry)
- Lower Density Higher Temperature Polymer Matrix Composite Partnership (JPL, USAFRL)
- Composite Structures Design Working Group (NASA, DoD, FAA, and industry)
- Airframe Structural Integrity Working Group (NASA, DoD, FAA, and industry)
- Composite Armor Group (NASA, Army)
- Transportation Research Board: Pavement Surface Properties Committee (NASA, DOT, DoD, and industry)
- AGARD Working Group on experimental steady and unsteady aerodynamic data (AGARD member countries)
- IHPTET Steering Committee (NASA LeRC and DoD)
- IHPTET Fiber Consortium (NASA LeRC, DoD, and engine companies)

8.0 COE Leadership Team

The Director of each participating Center has appointed a member to serve on the COE Leadership Team. The designated member will serve as the single-point-of-contact for coordinating all tasks that are the responsibility of each Center, listed in Section 9.2 below. The Leadership Team will meet annually to review the COE progress, prioritize recommendations, and provide guidance for future activities. The members of the current Leadership Team are:

- Charles E. Harris, Chief Technologist for Structures and Materials, COE Office, Langley Research Center, Leadership Team Chairperson

- Mark J. Shuart, Chief, Materials Division, and in alternating years, Woodrow Whitlow, Jr., Chief, Structures Division, Langley Research Center

- Hugh R. Gray, Chief, Materials Division, Lewis Research Center

- Ann F. Whitaker, Director, Materials and Processes Laboratory, and in alternating years, W. Randy Humphries, Director, Structures and Dynamics Laboratory, Marshall Space Flight Center

- Michael V. DeAngelis, Ast. Director, Research Engineering Directorate, Dryden Flight Research Center

- Michael C. Lou, Member Techncial Staff, Jet Propulsion Laboratory

- Steven J. Brodeur, Ast. Chief, Mechanical Systems Center, Goddard Space Flight Center

- James O. Arnold, Chief, Space Technology Division, Ames Research Center

- Edward T. Chimenti, Chief, Structures and Mechanics Division, Johnson Space Center

- Timothy R. Bollo, Chief, Materials Science Division, Kennedy Space Center

9.0 Summary of Responsibilities

9.1 Specific Responsibilities of the COE Office

The COE Office at Langley Research Center is responsible for the following specific tasks:

1. Compile and publish an inventory of the Agency's structures and materials capabilities.

2. Coordinate the Center self-assessments, identify overarching themes, develop list of deficiencies, and benchmark NASA capabilities to those of outside organizations, as appropriate.

3. Lead the development of recommendations to address deficiencies, and proactively advocate appropriate implementation of the recommendations.

4. Coordinate the establishment of Working Groups, as needed.

5. Initiate a discussion with existing Working Groups that may be appropriate to facilitate the objectives of the COE.

6. Lead the development of the charter for new Working Groups, solicit names of the members from the interested Centers, and organize a kick-off meeting.

7. Coordinate the support for planning future programs as requests are received and opportunities identified.

8. Communicate throughout the COE Community the information regarding requests and opportunities to participate in planning activities.

9. Engage in regular (informational) discussions with key personnel in Enterprise and Program Offices.

10. Organize and participate in workshops of specific technical issues of interest to the COE Community.

11. Respond to requests for technical information using the Directory of Key Personnel as a source of referrals when the Office cannot fulfill a request.

12. Assign action items to appropriate Centers when requests to participate in urgent investigations of critical problems ("911 calls") are received.

13. Communicate throughout the COE community those requests for technical information or "911 calls" that involve multiple Centers.

14. Canvas the COE Community, compile, and distribute a list of existing structures and materials alliances.

15. Evaluate the list of alliances to identify needs not currently fulfilled by the existing alliances.

16. The COE Office will inform the COE Community of opportunities to form new alliances.

9.2 Summary of the Specific Responsibilities of each Center

Each Center in the COE Community is responsible for the following specific tasks:

1. Provide the data for the inventory of the Agency's structures and materials capabilities.

2. Conduct a periodic self-assessment of strengths, weaknesses, and gaps with respect to Enterprise goals and objectives.

3. Develop a Structures and Materials Facilities and Laboratories Brochure suitable for public dissemination.

4. Voluntarily participate in those Working Groups that directly benefit the participating Center.

5. Voluntarily participate in the planning activities as requests and opportunities arise.

6. Communicate throughout the COE Community the information regarding requests and opportunities to participate in planning activities.

7. Voluntarily participate in workshops of specific technical issues of interest to the COE Community.

8. Voluntarily participate in "911 calls" at a level judged to be appropriate by the Center(s) receiving the request from the COE Office.

9. Communicate throughout the COE Community those requests for technical information or "911 calls" that involve multiple Centers.

10. Provide a list of existing structures and materials alliances.

11. Identify opportunities for other community partners to join existing alliances.

12. Evaluate the list of alliances to identify needs not currently fulfilled by the existing alliances.

13. The specific actions to form new alliances will be the voluntary initiative of the individual members of the COE Community.

14. Appoint a member to serve on the COE Leadership Team. The Member will attend the annual Leadership Team Meeting to review the COE progress, prioritize recommendations, and provide guidance for the next year.

10.0 Agencywide Collaborative Activity Leads to Revolutionary New Technology

It is interesting to note that one of NASA's most significant and lasting technical contributions in the field of structures and materials was a direct result of a collaborative effort among all the NASA Field Centers. In January 1964, key personnel from all NASA Field Centers gathered at Headquarters in Washington to discuss efforts underway to improve structural analysis methods, particularly as it applied to the shell configurations commonly used in aerospace structure. Each representative described how his group had written special-purpose computer programs to analyze particular shell configurations. After this meeting, NASA Headquarters commissioned an ad hoc committee, with a representative from each NASA Center, to investigate the state of analysis methods in the aerospace industry. The first action taken by the committee was to visit the aircraft companies which were doing prominent work in developing computer-based advanced structural analysis methods. The committee's visits to the aircraft companies revealed that no single computer program incorporated enough of the best analysis features desired by NASA. Therefore, the committee recommended to Headquarters that NASA sponsor the development of its own computer program as a means to upgrade the analytical capability of the whole aerospace industry. Headquarters endorsed the recommendation and selected Goddard Space Flight Center (GSFC) to manage the development of the computer program. Under the leadership of GSFC, the ad hoc committee developed a visionary and thorough technical specification for the computer program and released a Request for Proposals in July of 1965. Much of the eventual success of the project was directly attributed to the initial work of the NASA committee in developing the thorough specification for the computer program [3]. In December 1965, NASA awarded two Phase I contracts for preparation of a Technical Evaluation Report, one to a team led by the MacNeal-Schwendler Corporation (MSC) and one to the team led by Douglas Aircraft Company. After an evaluation of the two competing Phase I Reports and the associated Phase II proposals, MSC was selected as the recipient of the Phase II contract and began development of the computer program in July 1966. Shortly thereafter, NASA designated the name of the computer program to be the NASA STructural ANalysis (NASTRAN) Computer Program. The contracting team completed the computer program in 1969 and delivered it to all the NASA Field Centers. In February 1970, the Program Office at Goddard was disbanded. Later that year, NASA Headquarters established the NASTRAN Systems Management Office (NSMO) at Langley Research Center. The NSMO had the dual mission of maintaining NASTRAN and developing new capabilities for the program. A NASTRAN Advisory Group was set up to provide guidance to the NSMO. This Advisory Group consisted of members from each of the NASA Centers and was, in effect, a continuation of the ad hoc committee which drafted the initial NASTRAN specification in 1964. In November 1970, NASTRAN was released to the public through the COSMIC Distribution Center at the University of Georgia for the price of $1750. Less than a year later in September, the first NASTRAN Users Conference held at Langley Research Center was attended by about 200 representatives of the rapidly growing user community. Thus were the origins of the most successful finite element structural analysis computer code used throughout the world and in virtually all industrial sectors.

11.0 Concluding Remarks: Keys to Success

The implementation plan documented herein relies on three fundamental keys to success. These keys to success are building the COE community, a commitment of resources by the participating Centers, and developing high-payoff advanced technologies. First, the Structures and Materials COE Community is built on the voluntary partnership among 9 NASA Field Centers. Strategic alliances with external organizations will expand the Community. Collaborative activities among the Community partners will evolve from the thorough knowledge of the technical capabilities of each Community member. The COE communications network will foster collaboration. Second, the COE Community does not anticipate that the COE Office will be a source of funding to support research, technology development, or mission support. However, membership in the COE Community requires that each Center provide those resources necessary to implement the responsibilities listed in section 9.2 above. Third, it is encumbent upon the COE Community to identify and develop those high-payoff advanced technologies that enable future Agency missions. Each of these three "keys to success" are essential to achieving a meaningful fulfillment of the requirements set forth in this implementation plan.

12.0 References

1. *NASA Strategic Plan*, NASA Policy Directive (NPD)-1000.1, National Aeronautics and Space Administration, Washington, D. C., 20546, 1998, page 15.

2. *NASA Strategic Management Handbook*, National Aeronautics and Space Administration, Washington, D. C., 20546, 1996, pages 14-15.

3. The MacNeal-Schwendler Corporation, The First Twenty Five Years, by Dr. Richard H. MacNeal, The MacNeal-Schwendler Corporation, Major Aerospace and Defense Accounts, 1000 Howard Blvd., Suite 105, Mount Laurel, NJ 08054, 1988.

Appendix: Inventory of Technical Capabilities

This Appendix contains the Agencywide inventory of structures and materials technical capabilities. The inventory contains the following data for each Center:

- summary of technical capabilities
- directory of technical points of contact
- FY 98 programs and the associated structures and materials civil service workforce
- brief summaries of recent technical accomplishments
- technical skills mapped against specific applications
- descriptions of the dedicated structures and materials facilities and laboratories.

Some of the data in the inventory, such as the listing of programs and the associated civil service workforce, may only be valid for the year in which it was compiled, FY 98. The COE expects to update and publish the inventory on a periodic basis.

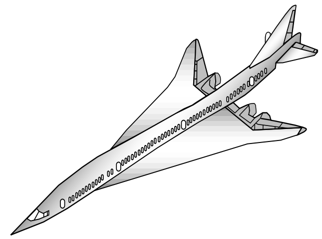
Table of Contents:

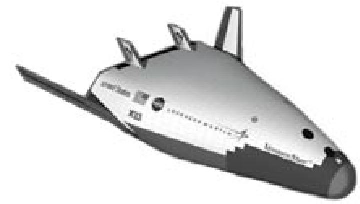
Langley Research Center

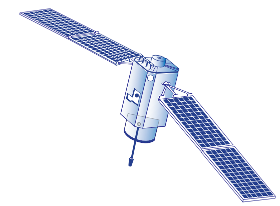
Structures and Materials Center of Excellence

Technology Applications

- Aircraft primary structure
- Primary structure, cryotank, and metallic TPS for space transportation vehicles
- Advanced concepts for spacecraft







Technical Capabilities

- Synthesis of polymeric resins, adhesives, and film; composites processing technology; and characterization
- Development of light metal alloys, processing, and joining technology; and microstructure-property characterization
- Development of ceramic-based materials, multifunctional materials, flight mission simulation, radiation physics, and flight experiments
- Mechanics of nonlinear stress-strain behavior, fatigue and fracture mechanics, and computational materials
- Development of ultrasonics, thermography, radiography, optics, and electromagnetics for nondestructive evaluation
- Experimental aeroelasticity, aeroservoelastic analysis, and applications of CFD methods
- Aircraft landing dynamics, spacecraft dynamics, and control of dynamic response
- Mechanics of thermal protection systems, hot structures, and cyrogenic tanks
- Mechanics of composite structures, structural concepts, and vehicle crashworthiness
- Advanced computational methods, multidisciplinary optimization, and methods for next generation computers
- Development of structural acoustic models, sonic fatigue models, prediction methodology, and interior noise supression concepts
- Design, analysis, fabrication, and assembly of science instruments and spacecraft flight hardware

Facilities and Laboratories:

- Transonic Dynamics Wind Tunnel
- Aircraft Landing Dynamics Facility
- Impact Dynamics Research Facility
- Structures and Materials Laboratory
- Combined Loads Test Facility
- Bi-axial curved panel pneumatic test facility
- Structural Dynamics Laboratory
- 8-Foot High Temperature Tunnel
- Thermal Structures Laboratory
- Helicopter Hover Facility
- Spacecraft and instrument fabrication and assembly facilities
- Structural acoustics test facilities
- Fatigue and fracture laboratory
- Durability and mission simulation facilities
- Polymer synthesis and composites fabrication laboratory
- Carbon-carbon and ceramic composites research laboratory
- Light alloy synthesis, forming, and joining technology lab
- Smart materials and superconductivity laboratory
- Materials characterization and dimensional stability labs
- Nondestructive examination sciences laboratory

Directory of Technical Points of Contact at LaRC

COE Leadership Team:

Charles E. Harris	Chief Technologist, COE Office	757-864-3408
Mark J. Shuart	Chief, Materials Division	757-864-3492
or, in alternating years,		
Woodrow Whitlow, Jr	Chief, Structures Division	757-864-2934

Technical Points-of-Contact:

Terry L. St. Clair	Head, Composites and Polymers Branch	757-864-4273
Dennis L. Dicus	Head, Metallic Materials Branch	757-864-3137
Howard G. Maahs	Head, Environmental Interactions Branch	757-864-3498
Ivatory S. Raju	Head, Mechanics of Materials Branch	757-864-3449
Edward R. Generazio	Head, Nondestructive Evaluation Scs. Branch	757-864-4970
Thomas E. Noll	Head, Aeroelasticity Branch	757-864-1207
Howard M. Adelman	Head, Structural Dynamics Branch	757-864-2257
Stephen J. Scotti	Head, Thermal Structures Branch	757-864-9393
James J. Starnes, Jr.	Head, Structural Mechanics Branch	757-864-3168
Jerrold M. Housner	Head, Computational Structures Branch	757-864-2907
Kevin P. Shepherd	Head, Structural Acoustics Branch	757-864-3575
Carl E. Gray, Jr.	Chief, Facility Systems Engineering Division	757-864-7291

LaRC Programs and Workforce (FY 98)

Structures & Materials
Center of Excellence

Programs and Projects	Workforce CS FTE's
Aeronautics and Space Transportation Technology Enterprise	
509 High Performance Computing and Communication	2
522 Airframe Systems Program	137
537 High Speed Research Program	102
538 Advanced Subsonic Technology Program	63
581 Rotorcraft	19
242 Reusable Launch Vehicles (X-33 Program)	25
242 Advanced Space Transportation Program	20
Human Exploration and Development of Space Enterprise	
199 Space Radiation Effects and Protection	5
547 Flight Technology Demonstration	4
Earth Science Enterprise	
233 Sensors and Detectors (Remote Sensing Technology)	8
Space Science Enterprise	
632 Spacecraft Technology	29
Other Programs	
DDF, Code AE/Q, Non-Aerospace Technology Transfer	26
Structures and Materials Workforce, LaRC CS FTE Total	**440**

Notes: 1. Workforce includes civil service S&E's, program managers, and technicians assigned to the specific programs.
2. Does not include "indirect/overhead" civil servants or other Government Agency personnel co-located at the Center.
3. Does not include on-site personnel such as contractors, students and professors, or NRC Post-Doctoral Fellows.

Environmental Interactions
Point-of-Contact: Howard G. Maahs, Head, Environmental Interactions Branch

The Environmental Interactions Branch has completed a fundamental study of ionizing radiations from space and the transport of these radiations through and interaction with materials which led to the development of the HZETRN computer code plus several related and supporting codes. The purposes of these codes are to predict radiation environments internal to spacecraft and high-altitude aircraft thereby enabling risk assessments to humans and electronic devices, and to guide the development of light-weight shield materials that provide effective protection. These codes, which are 1000 times computationally faster than traditional Monte Carlo methods, have been employed widely in support of numerous NASA missions including Space Shuttle dosimetry, Space Station design studies, Mir exposure estimates, and many others. In addition, these codes have also been employed by the medical community for cancer therapy and by the Department of Energy.

Composites and Polymers
Point-of-Contact: Terry L. St. Clair, Head, Composites and Poymers Branch

The Composites and Polymers Branch has been involved in R&D on advanced polymers for over 25 years. During that period they have been able to maintain a good balance of focused and basic research which has led to the development of technologically significant composite matrx resins and structural adhesives while at the same time exploring fundamental structure/property relationships. This latter activity has allowed the branch to become recognized around the World through the writing of technical papers and participation in technical meetings. The branch has over 100 patents in this technology field and many have been licensed with commercial products resulting. In recent years such breakthroughs as the development of the matrix resin and adhesive for the High Speed Research Program, PETI-5, as well as LARC-SI, LARC-IA, THUNDER, Atomic Oxygen Resistant Films, Colorless Polyimides, etc. has resulted from the strength of that fundamental R&D.

Nondestructive Evaluation Sciences
Point-of-Contact: Edward R. Generazio, Head, Nondestructive Evaluation Sciences Branch

The Nondestructive Evaluation Sciences Branch has developed several advanced inspection systems for aircraft damage detection. Commercial and military aircraft are being operated well beyond their original design life. This has presented an ever growing inspection problem where the presence of disbonds, corrosion and cracks in aging airframe structures have resulted in loss of human life. In a concentrated effort, several advanced NDE systems have been developed for the inspection of these aging aircraft. A rotating self-nulling eddy current probe was developed that has exceeded the hidden crack detection capabilities of all commercially available systems for airframe structures. Detection of disbonds and loss of wall thickness due to corrosion can now be done rapidly with newly developed thermal and ultrasonic inspections systems for large and small areas, respectively. These three technologies, together, meet the challenge of inspection of aging airframe fuselages. The increased inspection capability provides for a overall increase in safety for air travelers. The commercially available product, “Crack Finder”© , produced by Krautkramer Branson is based on the licensed self-nulling concept, and the rotating self-nulling probe is being developed under a license with Foerster Instruments International.

Mechanics of Materials
Point-of-Contact: Ivatory S. Raju, Head, Mechanics of Materials Branch

The Mechanics of Materials Branch has led the development of several major improvements in the design and manufacturing of more damage tolerant airframe structure. An innovative through-the-thickness stitching concept that improved damage tolerance of composite materials by 100-percent was developed for application to primary airframe structures. A high speed stitching machine was developed to fabricate one-piece integrally stiffened composite wing skins that weigh 25-percent less and cost 20-percent less than equivalent metal wings. A new computer code, FASTRAN, has been developed to predict the fatigue crack growth and life of metallic structure. This code predicts the crack growth and life under complicated spectrum loadings. The code is recently used by several airframe and engine manufacturers; Hamilton Standard used FASTRAN to explain in-service propeller blade failures from small corrosion pits and helped to establish inspection intervals before blade replacement, Boeing - Long Beach used FASTRAN to predict crack growth under a C-17 tension-compression spectrum, where other codes were unable to predict the crack growth behavior, and Lockheed - Georgia used the small-crack behavior predicted from FASTRAN to update their in-house fatigue life prediction code.

Metallic Materials
Point-of-Contact: Dennis L. Dicus, Head, Metallic Materials Branch

A team of researchers in the Metallic Materials Branch was requested by Super Light Weight Tank (SLWT) Program offices at MSFC and Michoud Assembly Facility to support the program by materials testing and metallurgical analysis of alloy 2195. The new SLWT is constructed from aluminum-lithium alloy 2195 which has lower density and higher strength than the aluminum alloy 2219 currently used to fabricate the External Tank. The team supported materials data base generation for 2195 by conducting precision elastic modulus tests at ambient and cryogenic temperatures at LaRC. The results indicated the both the ambient and cryogenic elastic moduli of Al-Li alloy 2195 are higher than those of Al alloy 2219, thereby contributing to the reduced weight of the SLWT design. In addition, the unique test capabilities which exist at LaRC were used to conduct biaxial loading tests on alloy 2195. These tests demonstrated that 2195 exhibits a significantly higher yield strength than 2219 over a range of biaxial stress states under simulated service conditions. Currently, the LaRC team is conducting biaxial tests and metallurgical analyses on 2195 welded and weld repaired panels in support of the SLWT program. The first launch of a SLWT is scheduled for STS-91 in June 1998.

On-Orbit Structural Dynamics Experiment Enhances Spacecraft Engineering Database
Point-of-Contact: Howard M. Adelman, Head, Structural Dynamics Branch

The Photogrammetric Appendage Structural Dynamics Experiment (PASDE) was developed to demonstrate the use of photogrammetric techniques for structural dynamic response measurements of spacecraft solar arrays and similar structures. PASDE was flown on STS-74. Development and demonstration of passive, on-orbit structural response measurement methods increase the amount of spacecraft engineering data at lower cost than typical hard-wired instrumentation systems. The availability of low-cost, on-orbit engineering data for the International Space Station is essential for mathematical model and design load verification and subsequent determination of proper operational procedures and constraints.

Runway Research Enhances the Safety of Spacecraft and Aircraft
Point-of-Contact: Thomas J. Yager, Sr Researcher, Structural Dynamics Branch

Modification of the Shuttle Landing Facility runway surface at the Kennedy Space Center (KSC) was completed on September 22, 1994. This treatment was a major modification to the runway and was based on Langley-led research in which a large number a candidate treatments were evaluated experimentally. A "shot-peening" approach was found to be the preferred approach and was used. The first Shuttle landing on this modified surface occurred February 11, 1995 at conclusion of Mission STS-63. All reports indicate significant reduction in tire tread wear compared to earlier Shuttle landings at KSC. Increasing the current Shuttle crosswind landing limit from 15 to 20 knots (which is critical to the role of Shuttle for Space Station assembly) is made possible by the modification. Runway friction was measured in temperature range where data previously was unavailable. The primary objective of this effort is to perform instrumented aircraft and ground vehicle tests aimed at improving the safety of aircraft ground operations and help relieve airport congestion during bad weather. Several studies will be performed including effects of contaminant type on impingement drag on aircraft, harmonization of ground vehicle friction data with aircraft braking friction data, effectiveness of various chemical types, and effects on runway friction of treatment application rates.

Interface Technology Developed for Structural Design and Analysis
Point-of-Contact: Jerrold M. Housner, Head, Computational Structures Branch

New comprehensive design paradigms must account for critical design details which, if ignored in the early design phases, can lead to expensive redesign manufacturing rework and compromised performance. Interface technology, developed at NASA Langley Research Center, promises to revolutionize structural design and analysis by dramatically reducing model development time and enabling detail design in the conceptual design phase. The methodology uses hybrid variational principles of mechanics to enforce compatibility of deformations and stresses at the common interface between independently discretized finite element models. The technology allows designers to consider and determine the impact of various modeling and geometric alternatives for local details without changing the bulk of the existing finite element model. Interface technology is an enabling technology for a Smart Assembly Modeler (SAM) developed as part of the interagency NEXTGRADE (Next Generation Revolutionary Analysis and Design Environment) Program. In addition, through a cooperative agreement between MacNeal-Schwendler Corporation (MSC) and NASA, the interface technology has been implemented in the commercial general-purpose code, MSC/NASTRAN, which is indicative of industry investment in the technology.

Technologies Developed to Reduce the Weight of Reusable Launch Vehicles
Point-of-Contact: Stephen J. Scotti, Head, Thermal Structures Branch

Langley leads development of metallic thermal protection systems (TPS) that would replace the ceramic, shuttle-type tiles on a reusable launch vehicle (RLV) to significantly reduce the need for maintenance between RLV flights. Analysis and testing is performed on the TPS, warm/hot fuselage and wing structures, and cryogenic propellant tanks. This research will result in reduced structural weight and reduced vehicle service requirements. Thus, these technologies will enable significant reduction in RLV development and operations costs and drastically reduce the cost of placing payloads in orbit.

LaRC Recent Technical Accomplishments

Aeroelastic and Advanced Controls Enhance Military Aircraft Performance
Point-of-Contact: Thomas E. Noll, Head, Aeroelasticity Branch

The Advanced Controls/Active Aeroelastic Wing (AAW) effort will result in more effective military aircraft. The objectives are to demonstrate smart aircraft design that minimizes wing weight while providing safety through the transonic flight regime and to demonstrate in-flight roll-control capability through active-controlled twisting of main wing box using leading- and trailing-edge surfaces. An active aeroelastic wing for a wind-tunnel investigation is being designed. The AAW concept will be assessed in flight on a modified and instrumented F-18 testbed aircraft.

Structural Acoustics
Point-of-Contact: Kevin P. Shepherd, Head, Structural Acoustics Branch

The Structural Acoustics Branch is involved in R&D aimed at the prediction and control of aircraft interior noise and sonic fatigue. Current efforts span the full range of vehicle classes from general aviation propeller and subsonic transports through supersonic and hypersonic aircraft. Interior noise problems due to both the propulsion system and the fuselage turbulent boundary layer are being addressed through modeling, both analytical and numerical, and the application of noise control technologies. The latter include both active and passive techniques. The Branch continues to be a pioneer in the development and application of active structural acoustic control methods to interior noise problems. This technology has progressed beyond the laboratory and first-generation systems are beginning to achieve commercial viability. Sonic fatigue efforts have focused on supersonic and hypersonic vehicles, and utilize in-house analytical and experimental capability. Codes developed through these programs have found widespread use by the manufacturers of military aircraft to assess and mitigate structural fatigue problems.

Structural Mechanics
Point-of-contact: James H. Starnes, Jr., Head, Structural Mechanics Branch

New solid and sandwich elements have been developed within the STructural Analysis of General Shells (STAGS) finite element analysis code to expand the analysis capability to thick structures with through-the-thickness stress gradients. The sandwich elements are specifically designed to simulate the response of composite sandwich structures with facesheet cracks and/or delaminations. The residual strength analysis capability of the STAGS code was also modified to include elasto-plastic crack growth in ductile metal structure. The Crack Tip Opening Angle (CTOA) crack growth criterion and geometric nonlinearities were included to represent accurately the stress and displacement gradients associated with a propagating crack. The effects of local stiffener and frame distortions are properly represented, and the effects of fastener and structural element yielding and failure are included in the analysis code. This advanced finite element analysis capability was used to conduct in-depth structural analyses of the Space Shuttle Superlightweight liquid-oxygen tank for two critical flight loading conditions, as part of the MSFC structural verification criteria. The analyses represent possibly the most complex, high fidelity nonlinear analyses ever conducted on a large-scale flight vehicle The results indicate that the liquid-oxygen tank is able to sustain load levels well in excess of the design limit loads. Buckling and nonlinear analyses were also conducted on the first production liquid-oxygen barrel section to assess the significance of large initial geometric imperfections. The results of the analyses show that the actual measured imperfections do not excessively degrade the load carrying capacity of the barrel section.

LaRC Capabilities: Research

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
polymer synthesis and processing	LARC		LARC	LARC			LARC	LARC	
PMC curing process dev	LARC		LARC	LARC			LARC	LARC	
PMC structure-property char.	LARC		LARC	LARC			LARC	LARC	
aluminum alloy synthesis & processing	LARC		LARC	LARC					
titanium alloy synthesis & processing	LARC		LARC	LARC					
metal forming and joining process dev	LARC		LARC	LARC	LARC				
metallic alloy structure-property char.	LARC		LARC	LARC	LARC				
refractory composite dev. & processing					LARC		LARC	LARC	
refractory composite struc-prop. char.					LARC		LARC	LARC	
mechanics of nonlinear material beh.	LARC		LARC	LARC				LARC	
mechanics of nonlinear structural beh.	LARC		LARC	LARC	LARC			LARC	
damage mechanisms and modeling	LARC		LARC	LARC	LARC		LARC	LARC	
fatigue and fracture mechanics methods	LARC		LARC	LARC					
damage tolerance struc. an. methods	LARC		LARC	LARC	LARC				
aeroelasticity computational methods	LARC		LARC						
struc. dynamics test & analysis methods	LARC		LARC	LARC			LARC	LARC	
sensor & measurement physics	LARC		LARC	LARC	LARC			LARC	
NDI system & signal processes algorthm	LARC		LARC	LARC	LARC				
smart materials and structures	LARC						LARC	LARC	
radiation physics & transport code dev.	LARC		LARC					LARC	
radiation protection materials	LARC		LARC					LARC	
multidisciplinary optimization methods	LARC		LARC					LARC	
sonic fatigue models and pred. methods	LARC		LARC					LARC	
structural acoustic models	LARC		LARC					LARC	
textile preform PMC mat & str	LARC		LARC	LARC				LARC	
computational and design methodology	LARC		LARC	LARC	LARC			LARC	
structural analysis algorithms	LARC		LARC	LARC				LARC	
structural response and failure mechanisms	LARC		LARC	LARC				LARC	
NDE methods for mechanical prop char	LARC		LARC	LARC				LARC	
Active control of structural response	LARC		LARC					LARC	

LaRC Capabilities: Technology Development

Structures and Materials
Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
polymer & composite fabrication scale-up	LARC		LARC	LARC				LARC	
refractory composite fabrication scale-up					LARC			LARC	
metal forming process and fabr. scale-up	LARC		LARC	LARC	LARC				
durability, environmental effects, mis. sim.	LARC		LARC	LARC	LARC		LARC	LARC	
validation of structural concepts	LARC		LARC	LARC			LARC	LARC	
computational methods & design tools	LARC		LARC	LARC				LARC	
fatigue and fracture mechanics methods	LARC		LARC	LARC			LARC	LARC	
structural damage tolerance & durability met.	LARC		LARC	LARC					
structural concepts, dynamics, & design met.	LARC		LARC				LARC	LARC	
aeroelasticity	LARC		LARC						
NDI measurement systems & field demo	LARC		LARC				LARC		
in-situ health monitoring systems	LARC		LARC	LARC			LARC	LARC	
test methods for design allowables	LARC		LARC				LARC	LARC	
"subcomponent" design & manufacturing	LARC		LARC				LARC	LARC	
experimental methods & verification tests	LARC		LARC				LARC	LARC	
smart materials and structures	LARC		LARC				LARC	LARC	
multifunctional materials							LARC	LARC	
radiation protection materials	LARC		LARC				LARC	LARC	
vehicle / mission systems analysis	LARC		LARC					LARC	
thermal management	LARC		LARC		LARC		LARC	LARC	
multidisciplinary optimization applications	LARC		LARC					LARC	
control of sonic fatigue	LARC		LARC					LARC	
interior noise supression	LARC		LARC					LARC	
NDE methods for mission assurance	LARC		LARC	LARC				LARC	
materials characterization	LARC		LARC	LARC				LARC	

LaRC Facilities and Laboratories

- **Transonic Dynamics Wind Tunnel**
  Only facility in the world capable of performing tests of scaled aeroelastic models at transonic speeds. Operating characteristics and use of heavy gas as a test medium unique in the world. Used in U.S. to clear aircraft for flutter.

- **Aircraft Landing Dynamics Facility**
  Unique facility uses high pressure waterjet to accelerate a test carriage to maximum speeds of 220 knots for testing tires, braking systems, and runway surface treatments. Facility also includes a research laboratory with specialized test capability for the study of landing gear, tires, and runway friction. Most major airframers and tire manufacturers use test results to optimize ground performance.

- **Impact Dynamics Research Facility**
  Unique facility and drop towers are used for testing the crashworthiness and crash response of aircraft structures.

- **Structures and Materials Laboratory**
  Specially designed 120 Kip, 300 Kip, and 1,200 kip test machines for precision compression testing; high bay area with large platen for testing structural components

- **Combined Loads Test Facility**
  Combined mechanical, pressure, and thermal loading capability that simulates subsonic and supersonic flight load conditions on transport wing and fuselage structures

- **Bi-axial curved panel pneumatic test facility**
  Pressure box fixture for testing large-scale curved stiffened panels with pneumatic internal pressure to simulate actual flight loads, including elevated and cryogenic temperatures.

- **Structural Dynamics Laboratory**
  Three laboratories specifically designed for structural dynamics and pointing control research on aerospace structures and components.

- **8-Foot High Temperature Tunnel**
  The 8-FT high temperature tunnel is a combustion-heated hypersonic blowdown-to-atmosphere wind tunnel that provides simulation of flight enthalpy for Mach numbers of 4, 5, and 7 through a range of atlitude from 50,000 to 120,000 feet. The open-jet test section is 8-feet in diameter and 12 feet long. Stable wind tunnel test conditions can be provided up to about 60 seconds achieving temperatures up to 3650 R at a dynamic pressure to 1900 psf.

LaRC Facilities and Laboratories, continued

- **Thermal Structures Laboratory**
  Conducts a broad range of tests to characterize the behavior of advanced thermal structures subjected to combined thermal and mechanical loading conditions.

- **Helicopter Hover Facility**
  The Helicopter Hover Facility (HHF) is a dedicated rotorcraft model aeroelasticity test facility. The HHF has 2 large test cages; one dedicated to hover testing of a tiltrotor model and the other for a helicopter model. The HHF has a unique data acquisition system for 64 channels of data at up to 3000 samples per second per channel. Once the models have completed ground and hover testing in the HHF they are transported into the Transonic Dynamics Tunnel for forward flight testing.

- **Spacecraft and instrument fabrication and assembly facilities**
  Full spectrum of metal, composite, and ceramics component fabrication and assembly facilities; and development of advanced materials processing and manufacturing technology

- **Structural acoustics test facilities**
  The Structural Acoustics Loads and Transmission facility consists of a reverberation chamber (6.1m x 8.5m x 4.3m) connected to an anechoic chamber (7.9m x 9.7m x 4.5m) by a window which can accommodate panel-type structures up to 1.4m x 1.4m. The Thermal Acoustic Fatigue Apparatus is a progressive wave tube facility which can accommodate test panels as large as 1.5m x 1.5m and can subject them to sound pressure levels up to 172 dB over a bandwidth from 40 to 500 Hz. A 360 kW quartz lamp bank provides radiant heat with a peak heat flux of 54 W/cm2. Other structural acoustic facilities include a small transmission loss suite, several anechoic chambers, and numerous test articles ranging from aircraft sub-structures to full-scale fuselages.

- **Fatigue and fracture laboratory**
  Capability to characterize materials nonlinear stress-strain behavior; yield and ultimate strength of metals for uniaxial and biaxial stresses; fatigue life, fatigue crack growth, thermomechanical fatigue, and crack growth in ultra-high vacuum, inert gases, and salt water; fracture toughness; damage mechanisms and progressive failure of composites; elevated temperature creep, mechanical testing for combined tension/torsion, tension/bending, and in-plane biaxial loading condition.

- **Durability and mission simulation facilities**
  Long-term and accelerated durability testing at elevated temperature to 3000 F; combined environmental conditions including temperature, humidity, mechanical loads, partial pressure, high vacuum, and inert gases; thermal expansion measurements, oxidation effects by thermogravimetric analysis to 3100 F, partial pressure atmospheric chambers for isothermal aging; characterization laboratories include corrosion and environmental degradation equipment.

LaRC Facilities and Laboratories, continued

- **Polymer synthesis and composites fabrication laboratory**
  Synthesis and processing of novel polymers, adhesives, functional and smart polymers; computational materials, and polymer matrix composites; advanced composite fabrication including tape layup prepreg, powder coated towpreg, textile preforms and resin film infusion; and adhesives development and characterization.

- **Carbon-carbon and ceramic composites research laboratory**
  Complete processing capabilities for fabricating carbon-carbon composites and ceramic-composites, coatings deposition by chemical vapor deposition, pack cementation conversion, sol gel processing, graphitization and high-temperature heat treating to 2900 F, isothermal oxidation exposure testing of materials, mechanical property measurements, and ultra-high temperature materials exposure in high heat flux facility with black-body source to 6500K

- **Light alloy synthesis, forming, and joining technology laboratory**
  Alloy synthesis, processing, and joining and comprehensive physical, chemical, and metallurgical analysis capabilities to develop advanced aluminum, aluminum-lithium, titanium, and metal matrix composites; facilities include metallography, optical microscopy, and electron optics for transmission, scanning, and microprobe analysis and crystallography; x-ray diffraction lab for phase identification, texture, and residual stress; synthesis and processing labs include vacuum hot press, hot isostatic press, plasma deposition, and physical and chemical vapor deposition.

- **Smart materials and superconductivity laboratory**
  Ceramics and ceramic thin-film processing, piezoelectric materials development and characterization, piezoelectric actuator device development and performance testing, superconductivity materials development and characterization (current density vs. temperature, durability), class 100 clean room

- **Materials characterization and dimensional stability laboratories**
  Cabilities include ultraviolet, visible, and infrared spectroscopy, outgassing measurements, mass spectrometers for analysis of volatile products from materials, glass transition temperature measurements, electron paramagnetic resonance spectroscopy for characterizing degradation mechanisms, specimen conditioning ovens, mechanical property measurements, cryogenic exposures, thermal expansion measurements with resolution to 0.5 ppm, and surface accuracy measurements on reflector panels.

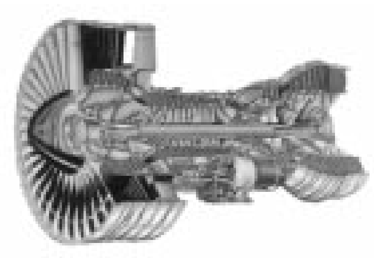
- **Nondestructive evaluation sciences laboratory**
  Advanced sensor technologies and signal processing software are being developed for ultrasonics, thermal, optical, electromagnetic, acoutic emission, x-ray radiography, computer aided tomography, and fiber optics with a fiber draw tower.

Lewis Research Center

Structures and Materials
Center of Excellence

Technology Applications

- Turbomachinery for aircraft engines and space transportation vehicles
- Aerospace Power, Power for LEO, MEO, and GSO planetary spacecraft, and space experiments



Technical Capabilities

- Development of superalloys, titanium, copper, and refractory metal alloys and composites; processing; and characterization
- Development of functional ceramics and composites, fibers and fiber coatings, processing technologies, and characterization
- Development of solid and liquid lubricants; thin film, wear resistant coatings; surface chemistry and topographical analysis; fiber-interface science; and computational materials modeling
- Development of high temperature polymeric composites, advanced processing concepts, long term durability, and characterization
- Development of protective high-temperature interface, overlay and thermal barrier coatings to enhance stability and durability in high velocity and pressure environments, and methods to assess, extend and predict life and durability
- Computational and experimental methods to assure life, durability, and integrity of high temperature aeropropulsion and power systems
- Structural concepts and design/optimization tools; aeromechanical response of fans, compressors, and turbines; and active/passive vibration and instability control
- Computational and experimental acoustics and aerodynamics for reducing fan, propeller, and jet noise
- Aeropropulsion mechanical component technologies including transmissions, gears, bearings, seals, health monitoring and lubrication
- Structural design, certification, and verification of aerospace flight hardware
- Prediction and verification of flight dynamic environments (shock acoustics, transient dynamics, and random)
- Development and evaluation of optical, radiative, atomic oxygen protective and thermal control materials and surfaces for space power

Facilities and Laboratories

- Polymeric materials processing and testing laboratory
- Metallic materials processing and testing laboratory
- Ceramic materials processing and testing laboratory
- Structural mechanics laboratories
- Environmental durability laboratories
- Life prediction complex (fatigue and fracture laboratory)
- Space environmental durability evaluation laboratory
- Martian atmospheric chemistry simulation facility
- Materials Characterization and analysis laboratories
- Propulsion structural dynamics laboratories
- Magnetic suspensions laboratories
- Propulsion component NDE laboratories
- Propulsion mechanical components laboratories
- Tribology facilities
- Vibration test laboratory
- Structural static test laboratory

Directory of Technical Points of Contact at LeRC

COE Leadership Team:

Hugh R. Gray	Chief, Materials Division	216-433-3230

Technical Points-of-Contact:

L. James Kiraly	Chief, Structures and Acoustics Division	216-433-6023
Michael V. Nathal	Chief, Advanced Metallics Branch	216-433-9516
Stanley R. Levine	Chief, Ceramics Branch	216-433-3276
Mary V. Zeller	Chief, Tribology and Surface Science Branch	216-433-2061
Michael A. Meador	Chief, Polymers Branch	216-433-9518
Leslie Greenbaur-Seng	Chief, Environmental Durability Branch	216-433-6781
John J. Gyekeneysi	Chief, Life Prediction Branch	216-433-3210
George L. Stefko	Chief, Structural Mechanics and Dynamics Br	216-433-3920
Dennis L. Huff	Chief, Acoustics Branch	216-433-3913
John J. Coy	Chief, Mechanical Systems Branch	216-433-3915
Richard T. Manella	Chief, Structural Systems Dynamics Branch	216-433-2590
Mei-Hwa Liao	Chief, Structural Analysis Branch	216-433-3787
Bruce A. Banks	Chief, Electro-Physics Branch	216-433-2308

LeRC Programs and Workforce (FY 98)

Programs and Projects	Workforce CS FTE's
Aeronautics and Space Transportation Technology Enterprise	
509 High Performance Computing and Communication	2
522 Airframe Systems Program	5
523 Propulsion Systems Program	121
537 High Speed Research Program	49
538 Advanced Subsonic Technology Program	108
581 Rotorcraft	6
242 Reusable Launch Vehicles (X-33 Program)	3
Human Exploration and Development of Space Enterprise	5
Earth Science Enterprise	1
Space Science Enterprise	
632 Spacecraft Technology	18
Other Programs	
DDF, Code AE/Q, Non-Aerospace Technology Transfer	8
Structures and Materials Workforce, LeRC CS FTE Total	**326**

Notes: 1. Workforce includes civil service S&E's, program managers, and technicians assigned to the specific programs.
2. Does not include "indirect/overhead" civil servants or other Government Agency personnel co-located at the Center.
3. Does not include on-site personnel such as contractors, students and professors, or NRC Post-Doctoral Fellows.

LeRC Recent Technical Accomplishments

Life Prediction
Point-of-Contact: John J. Gyekeneysi, Chief, Life Prediction Branch

The Life Prediction Branch has pioneered the award winning Ceramics Analysis and Reliability Evaluation of Structures (CARES) integrated design computer software for evaluating the reliability and life of advanced brittle material components for a wide variety of 2lst century applications. As cited in the March 1998 issue of NASA Tech Briefs, CARES has been recognized as one of the foremost examples of structural design software developed at NASA in the past 40 years. Today over 350 organizations within the United States use the CARES software to enable the design of reliable, efficient environmentally conscious products. In recognition of their exemplary technical accomplishments, members of the NASA LeRC CARES Team became the first recipients to win the NASA Software of the year Award in 1994. Several other awards for developing and transferring this innovative software and underlying technology, including the Federal Laboratory Consortium Technology Transfer Award (1994) and an R&D 100 Award (1995) were also received. The Life Prediction branch has also developed the micromechanics analysis code (MACIGMC), a 1997 NASA Software of the Year finalist, as an established tool for deformation and damage analysis of composite materials, in particular metal matrix composites. This code predicts the elastic and inelastic thermomechanical response of multiphased composite materials based on the hilly analytical, continuum-based, generalized method of cells micromechanics model. This unique software is ideally suited for conducting "what-if" scenarios in the design/analysis of advanced composite materials; including metal, intermetallic, ceramic, and polymer matrix composites and has been widely used by over twenty organizations.

Structural Mechanics
Point-of-Contact: George L. Stefko, Chief, Structural Mechanics and Dynamics

Over the past five years, the former Structural Mechanics Branch has established a broad-based research and technology development activity in the area of engine blade-out containment and hazard mitigation. The major goals are: to enable safety-assured, lighter weight, lower cost structural systems to more effectively meet engine blade-out requirements for aircraft turbine engines; to reduce the time, cost and risk of the design-development-certification process. Some key recent accomplishments include: implementation of facilities for materials high-strain-rate characterization and structural concepts ballistic impact testing; impact tests of several metal alloys, composite materials, and fabrics in various "hardwall" and "softwall" structural configurations; identification of critical deformation and failure mechanisms for metal alloys and fiber-reinforced polymer composites; preliminary development of improved mathematical models and computational tools for containment systems structural analysis and design.

Structural Dynamics
Point-of-Contact: George L. Stefko, Chief, Structural Mechanics and Dynamics

The Structural Mechanics & Dynamics Branch (formerly the Machine Dynamics Branch) has established a comprehensive program in magnetic suspension aimed toward a "More Electric Engine" for commercial service around 2015. That oil-free engine will have contact-free shaft suspension by magnetic bearings and an integral starter/generator. The Branch has designed, built and tested compact magnetic bearing prototypes for aero and space applications. Fundamental advances have been made in magnetic efficiency, power management, control architecture, multiplane vibration suppression and supercritical shaft speed stability control. New facilities test magnetic bearings to 1000F and 20,000 rpm (rig operating), evaluate redundancy methods for them (rig under construction) and will explore compressor blade-tip clearance control and possible stall control by magnetic shaft suspension and actuation (rig preliminary design completed).

LeRC Recent Technical Accomplishments

Acoustics
Point-of-Contact: Dennis L. Huff, Chief, Acoustics Branch

The Acoustics Branch work has concentrated on developing noise reduction concepts and prediction methods for turbomachinery components, with emphasis on fans and nozzles for air breathing propulsion systems. Lewis has led the engine noise work in the subsonic program to develop an integrated fan noise prediction code, model scale demonstration of fan noise reduction concepts that reduce turbofan noise by 3 EPNdB, and advanced suppression methods to reduce jet noise by 3 EPNdB. Lewis is also pioneering new ways to reduce fan noise using Active Noise Control methods. Computational Aeroacoustic methods are being developed for the next generation of noise prediction methods. The expertise of the Lewis researchers teaming with industry/ universities, and unique facilities like the 9'x15' Low-Speed WindTunnel and the Aeroacoustics propulsion Laboratory have led to these accomplishments. Future acoustic work at Lewis will directly impact NASA's strategic goals to reduce aircraft noise by 20 dB over the next 20 years.

Mechanical Systems
Point-of-Contact: John J. Coy, Chief, Mechanical Systems Branch

A patented seal developed for the National Aerospace Plane by the Mechanical Systems Branch (formerly the Mechanical Components Branch), has won NASA’s 1996 Government Invention of the Year Award. The advanced High Temperature, Flexible, Fiber Preform Seal is braided out of emerging high temperature ceramic fibers or superalloy wires into a flexible, flow-resistant seal. The patented seal technology was used successfully by General Electric in the joint NASA/DOD/GE Integrated High Performance Turbine Engine Technology Program. The invention has been successfully evaluated by Pratt & Whitney as a potential replacement for sealing interfaces between large nozzle turning vanes and flow-path fairing elements for the F119 engine for application for the F22 fighter. NASA Lewis is working with Praxair, a $4.4B producer of industrial gases, to license the seal technology for use in the company’s high temperature, proprietary industrial gas systems.

Advanced Metallics
Point-of-Contact: Michael V. Nathal, Chief, Advanced Metallics Branch

The Advanced Metallics Branch has developed new disk and blade superalloys to meet the performance goals for advanced engines. As part of the Enabling Propulsion Materials portion of the High Speed Research program, the team of GE Aircraft Engines, Pratt & Whitney, and NASA LeRC have been developing advanced nickel base superalloys with improved properties required by the unique HSCT mission. A powder metallurgy superalloy has been developed for the compressor and turbine disks, and represents a significant advancement in high temperature, long time durability over existing alloys, yet still maintains the necessary processability that allows the technology to be implemented. A new high pressure turbine airfoil system has also been developed, again representing an advancement in performance. This consists of a new single crystal blade alloy combined with an advanced thermal barrier coating. Both of these new alloys have attracted considerable interest beyond the HSR program, and have been identified as the prime material candidates for both advanced commercial subsonic and advanced military engine programs.

LeRC Recent Technical Accomplishments

Ceramics
Point-of-Contact: Stanley R. Levine, Chief, Ceramics Branch

The Ceramics Branch has developed ceramic matrix composites for space propulsion applications. The NASA LeRC Ceramics Branch initiated a long-term fiber reinforced ceramic matrix composites (FRCMC) turbopump development program in the late 1980's. The program incorporated Marshall Space Flight Center as technology customer and was completed (with financial and testing support from the Air Force) in 1996. The data bases, design and fabrication technologies, and highly successful component test results obtained by Rocketdyne advanced FRCMC technology for rocket engine turbines from a NASA Technology Readiness Level (TRL) of 2 (Technical Concept and/or Application Formulated) to TRL 6 (System/Subsystem Demonstrated in Relevant Environment). This (1) provided Rocketdyne with sufficient impetus and confidence to propose these materials as baseline in the turbopumps and aerospike nozzle of the Lockheed-Martin RLV (Reusable Launch Vehicle), and (2) has had a significant impact on DOD and other government/industry programs for a variety of space propulsion applications.

Surface Science and Tribology
Point-of-Contact: Mary V. Zeller, Chief, Tribology and Surface Science Branch

The Tribology and Surface Science Branch has developed an advanced high temperature solid lubricant which results in low friction and low wear coatings for numerous aerospace applications. Most recent formulations have provided one of the technological breakthroughs enabling the development of high temperature, high speed foil bearings. The composition of the plasma sprayed composite coatings (PS300 series) has been tailored to achieve strong adhesion and thermal coefficient of expansion matching with various substrates; low wear and low friction at start/stop and high speed; oxidation resistance up to 700 C; and a low cost manufacturing process. The PS304 coating has successfully lubricated foil journal bearings at high loads for over 100,000 start/stop cycles at 120,000 rpm from 25 to 700 C. This accomplishment is a major step in building an oil-free turbocharger which will be demonstrated early in 1999. The turbocharger is a low cost test bed for formulating an Oil-Free Turbomachinery (OFT) project. The ultimate goal of an OFT project is the design of an oil-free engine.

Polymers
Point-of-Contact: Michael A. Meador, Chief, Polymers Branch

The Polymers Branch research has resulted in significant advances in polymer matrix composites. PMR polyimides were developed at LeRC in the early 1970's in response to an aerospace industry need for processable, high temperature polymers for use in fiber reinforced composites. The principal PMR resin, PMR-15, has become the industry standard for use in applications operating at temperatures as high as 450 to 550 F (232 to 288 C). The current world-wide market for PMR-15 is about 40,000 to 50,000 pounds/year. Military and commercial aircraft engine applications for PMR-15 include the GE F-404 outer bypass duct and the GE/Snecma CF6-80A3 core cowl. Higher temperature PMR polyimides have been developed for 650 to 700 F applications (343 to 371 C). "Environmentally friendly" versions of PMR-15 have been developed that could save industry millions of dollars per year in costs associated with the handling and disposal of PMR-15 resin and prepreg. A LeRC/General Electric/Fiber Innovations Inc. team recently developed the Solvent Assisted Resin Transfer Molding (SARTM) process which reduces manufacturing costs for PMR based components by 30% or more over traditional hand lay-up based methods.

Environmental Durability

Point-of-Contact: Leslie Greenbaur-Seng, Chief, Environmental Durability Branch

The Environmental Durability Branch has recently completed studies of the oxidation, corrosion, and recession behavior of silicon-based ceramics. Understanding high temperature degradation mechanisms in advanced materials is fundamentally important to developing strategies to enhance and predict component time and temperature durability in gas turbine engines. NASA LeRC researchers have made significant contributions in our knowledge of silicon-based monolithic and composite ceramic materials durability. Important issues such as active/ passive oxidation, dopant-induced corrosion, silica scale substrate interactions, effects of water vapor and scale volatility have been carefully studied providing vital mechanistic and performance information. Continuing contribution in the development and evaluation of environmental barrier coatings are being pursued, with GE Aircraft Engines and Pratt & Whitney, for Si-based material combustor liners in the High Speed Research Program.

LeRC Capabilities: Research

Structures and Materials
Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
Sensory / adaptive structures		LeRC				LeRC			LeRC
Impact mechanics/containment concepts		LeRC							
Simulation / probabilistic design methods		LeRC				LeRC			LeRC
Brittle material/composites life models		LeRC				LeRC			LeRC
High Temp deformation/fatigue physics		LeRC				LeRC			LeRC
High Temp materials character/testing		LeRC				LeRC			LeRC
Propulsion system flutter		LeRC				LeRC			
Aero forced vibration		LeRC				LeRC			
Propulsion system rotor/comp dynamics		LeRC				LeRC			
Active/passive vibration control		LeRC				LeRC			
Turbomachinery noise reduction		LeRC				LeRC			
Jet and fan noise modeling		LeRC							
Materials / lubricants for mech power transfer		LeRC				LeRC			
Propulsion component NDE		LeRC				LeRC			
Mechanics / physics of rotating machinery		LeRC				LeRC			
Lunar/Martian simulation for mechanisms		LeRC				LeRC			
Adv. 700 F resin chemistry		LeRC				LeRC			
High temp Titanium and superalloy dev.		LeRC				LeRC			LeRC
High temp met. alloy and composites dev.		LeRC				LeRC			LeRC
Long life durable, Hi Temp coatings		LeRC				LeRC			LeRC
Low cost processing/process dev.		LeRC				LeRC			LeRC
Long time aging / durability of materials		LeRC				LeRC		LeRC	LeRC
Material degradation mechanisms, life prediction and protection schemes		LeRC				LeRC		LeRC	LeRC
Fiber/matrix interactions/coatings		LeRC				LeRC			LeRC
Advanced fibers and ceramic composites		LeRC				LeRC			LeRC
Tribological coatings		LeRC				LeRC			LeRC
Hi Temp computational Mat'l science		LeRC				LeRC			LeRC
Hi Conductivity copper alloys / comps.		LeRC				LeRC			LeRC
Toughened ceramics		LeRC				LeRC			LeRC

LeRC Capabilities: Technology Development

Structures and Materials
Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
Sensory / adaptive engine structures		LeRC				LeRC			
Containment structures		LeRC							
Structure design / optimization tools		LeRC				LeRC			LeRC
Brittle structure / component design tools		LeRC				LeRC			LeRC
Hi Temp complex coupon / component lifing		LeRC				LeRC			LeRC
System flutter & aero forced vibration		LeRC				LeRC			
System rotor & component dynamics		LeRC				LeRC			
System active / passive vibration control		LeRC				LeRC			
Turbomachine noise reduction		LeRC				LeRC			
Jet and fan noise reduction/active noise con		LeRC							
Multi-plane magnetic bearing systems		LeRC				LeRC			
Mechanical power transfer components		LeRC				LeRC			
Mechanical power transfer health monitoring		LeRC				LeRC			
Lubrication systems		LeRC				LeRC			
PMC Propulsion materials development		LeRC							
Metallic fan / compressor mat'ls devel.		LeRC				LeRC			
Radiator/hi heat transfer mat'ls devel.		LeRC				LeRC			LeRC
Combustor materials devel/eval.		LeRC				LeRC			LeRC
Turbine blade / disk alloys/composites		LeRC				LeRC			
Titanium / superalloys and composites for high temp. components		LeRC				LeRC			LeRC
Hi velocity, long term durability materials eval./life modeling		LeRC				LeRC			
Long life, durable protective coatings		LeRC				LeRC		LeRC	LeRC
Solid / liquid lubes		LeRC				LeRC			LeRC
Low cost mat'l processing scale-up concepts		LeRC				LeRC			LeRC
Atomic oxygen durability for LEO spacecraft								LeRC	LeRC
"Green" polymer mat'ls / processes		LeRC				LeRC			
Thin film tribological coating/process		LeRC				LeRC			LeRC
Ceramics/Cer Comp. for high temp appl		LeRC				LeRC			LeRC
Flight hardware, design, analysis, test, cert.		LeRC				LeRC		LeRC	LeRC

LeRC Facilities and Laboratories

- **Polymeric materials processing and testing laboratories**
  Fabrication and processing of lab-scale polymeric and composite samples, prepregging, autoclave processing, hot presssing and vacuum hot pressing, instrumented impact tester, elevated temperature tensile testing to 700 F, autoclave and long-term aging/durability rigs.
- **Metallic materials processing and testing laboratories**
  Complete metals, alloys and metallic composites processing facilities including melting/casting, powders, hot working, and welding and joining. Sixty-five (65) creep test machines, 10 universal testing machines, 6 thermomechanical fatigue rigs, elevated temperature capability to 5400 F with controlled atmospheres and vacuum.
- **Ceramic materials processing and testing laboratories**
  Processing facilities for green-article fabrication, tape casting, hot pressing and hot-isostatic pressing; single crystal fiber growth facility, inert and air tensile testing to 3000 F in fast fracture and creep modes.
- **Structural mechanics laboratories**
  Smart propulsion structures lab for vibration mitigation and aero-acoustic emission suppression, ballistic blade impact/containment structures lab, computational propulsion structures evaluation and optimization lab.
- **Environmental durability laboratories**
  Burner rigs and cyclic oxidation, ambient and low pressure plasma spray facilities, and high temperature mass spectrometer laboratory; high heat flux/thermal fatigue laser test lab, high heat flux rocket materials facility
- **Life prediction complex (fatigue and fracture laboratory)**
  48 fatigue test machines for low cycle fatigue, high cycle fatigue, and thermomechanical fatigue, mechanical load capability to 110 Kips, and subcomponent test rigs, fiber-matrix interface testing and evaluation
- **Space environmental durability evaluation laboratory**
  World's largest capacity atomic oxygen beam facility and the only one with in-vacuum spectral reflectance characterization; large area 5'x7' atomic oxygen exposure facility, high rate thermal cycling facilities, soft x-ray exposure facility, 13 atomic protective coatings evaluation facilities, and protective coatings deposition facilities.

LeRC Facilities and Laboratories, continued

- **Martian atmospheric chemistry simulation facility**
  Capable of simulating the pressure, gas composition, and temperatures of expected space systems operating on the surface of Mars.

- **Materials characterization and analysis laboratories**
  Chemistry labs, metallography labs, and nondestructive evaluation labs; nuclear magnetic resonance facility including imaging and high termperature (500 F) solids capabilities; surface topography lab

- **Propulsion structural dynamics laboratories**
  Bladed stage mechanics spin rig, rotor dynamics vibration suppression lab, rotor vibration control dampers, shaft dampers, blade damping facilities, turbine stage aeroelastic flutter and forced vibration facilities.

- **Magnetic suspensions laboratories**
  Multi-planar elastic mounted turbomachine high speed magnetic bearings lab for extreme temperature service, magnetic levitation lab, real-time controls and electromagnetic actuators lab.

- **Propulsion component NDE laboratories**
  Ultrasonic, computed tomagraphy, radiologic NDE lab for high temperature, ceramic, refractory alloy, high temperature composite propulsion materials and components.

- **Propulsion mechanical components laboratories**
  Structural panel and engine flow path seals, rolling element components, bearings, geared systems, lubrication systems, mechanical system noise generation and emission control, health monitoring, and environmental simulation rigs for thermal extremes, vacuum, Lunar and Martian soil simulation.

- **Tribology facilities**
  Foil bearing and brush seal rigs, high temperature and vacuum tribometer test facilities, and surface analysis laboratory

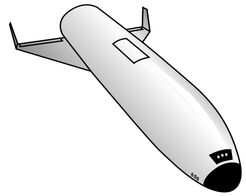
- **Vibration test laboratory**
  40K, 28K, and 6K-lbf shakers for qualification testing of flight hardware.

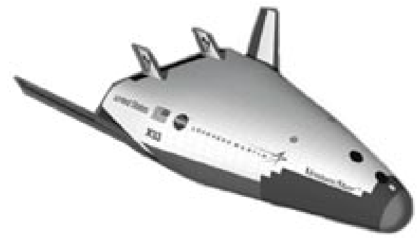
- **Structural static test laboratory**
  Multi-axial strength characterization of flight hardware, stiffness characterization and life tests of structures, proof tests of pressure vessels, and component testing of engineering materials.

Ames Research Center

Technology Applications

- Thermal protection systems (TPS)





Technical Capabilities

- Development of reusable and ablative TPS materials and systems including characterization, test, and instrumentation
- Development of integral TPS / Cryogenic Insulation Systems
- Arc Jet and Flight Testing of TPS
- Development of tools to model TPS interactions with shock layer gases and to define TPS designs to meet specific mission requirements

Facilities and Laboratories

- Aerodynamic heating facility
- Interactive heating facility
- Panel test facility
- 2x9 turbulent flow duct
- Giant planet facility
- Thermal blanket acoustic re-entry simulator
- Ames vertical gun range
- Ceramic TPS processing laboratory
- Organo-ceramic TPS processing laboratory
- Flexible TPS processing laboratory
- Laser accurate surface catalysis laboratory
- Thermal, mechanical, and analytical materials characterization laboratories

Directory of Technical Points of Contact at ARC

COE Leadership Team:

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Technical Points-of-Contact:

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Howard E. Goldstein	Chief Scientist, Space Technology Div.	650-604-6103
Daniel J. Rasky	Chief, Thermal Protection Materials and Sys. Br.	650-604-1098
Paul F. Wercinski	Chief, Reacting Flow Environments Branch	650-604-3157
G. Joseph Hartman	Chief, Thermo-Physics Facilities Branch	650-604-5269

ARC Programs and Workforce (FY 98)

Programs and Projects	Workforce CS FTE's
Aeronautics and Space Transportation Technology Enterprise	
242-33 Reusable Launch Vehicles (X-33 Program)	11
242-80 Engineering Capability Development	21
242-72 Advanced Reusable Transportation Technology	8
Structures & Materials Workforce: Ames Space Technology Div.(ST)	**40**

Notes: 1. Workforce includes civil service S&E's, program managers, and technicians assigned to the specific programs in the Space Technology Division **ONLY** for Ames Research Center.
2. Includes "indirect/overhead" civil servants working to support these programs..
3. Does not include on-site personnel such as contractors, students and professors, or NRC Post-Doctoral Fellows.

ARC Recent Technical Accomplishments

Planetary entry missions use Ames Lighweight Ablators and TPS sizing tools
Point-of-Contact: Daniel J. Rasky, Chief, Thermal Protection Materials and Systems Branch

A number of recent planetary entry missions are using Ames-patented lightweight ablators and TPS sizing tools. The Silicone Impregnated Reusable Ceramic Ablators (SIRCA) was flown on the Mars Pathfinder Vehicle. The vehicle used SIRCA for the aft heat shield. The Phenolic Impregnated Carbon Ablator (PICA) is being baselined for the Stardust Sample Return Capsule. TPS sizing tools developed by Ames were used to design the Mars Pathfinder, Stardust, and Mars 2001 Aerocapture and Lander vehicles.

TPS Development Tasks for the X-33 and X-34 Flight Projects
Point-of-Contact: Daniel J. Rasky, Chief, Thermal Protection Materials and Systems Branch

Ames is on schedule with all of its X-33 TPS development task agreements with Lockheed-Martin. These tasks include aerothermodynamics and TPS analysis and verification, TPS development, Arc Jet testing, flight software independent verification and validation, and Project Management. Lockheed Martin Skunk Works management is very pleased with Ames Leadership in TPS for the program. The X-34 TPS development tasks agreements with Orbital Sciences Corporation are also on schedule. The SIRCA nose cap and wing leading edges are scheduled for delivery in September, 1998. Orbital Sciences Corporation management is very pleased with Ames progress.

Ames successfully demonstrates United States leadership in ultra-high temperature TPS materials
Point-of-Contact: Daniel J. Rasky, Chief, Thermal Protection Materials and Systems Branch

Ames recently demonstrated its national leadership role in the development of ultra-high temperature TPS materials. In just 5 months from the go-ahead in early calendar year 1997, a 0.141 inch radius nose cap material was flown on a re-entry body launched by a Minute Man III missile. This demonstrated that the new materials can be flow at re-use temperatures of 4140 F and single use in excess of 5,000 F. Deputy Associate Adminstrater for OASTT, Gray Payton, highlighted this accomplishment in recent Congressional testimony.

Ames Arc jet complex heavily used in its role as a national facility.
Point-of-Contact: G. Joseph Hartman, Chief, Thermo-Physics Facilities Branch

The Ames Arc Jet complex continues to be heavily used as a national facility. Again this past year, the complex successfully completed around 600 tests. About 70 % of these were for the reusable launch vehicle program (X-33 and X-34) and 30 % were in the planetary exploration area.

ARC Capabilities: Research

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
Low cost internal multilayer insulation dev					ARC				
Organic composite TPS materials dev					ARC				
Ultra High Temp. Ceramic TPS Dev					ARC				
Erosion resistant TPS dev					ARC				
High temperature felt TPS dev					ARC			ARC	
Dual purpose TPS/cryoinsulation mat'ls dev				ARC	ARC				
Flexible blanket advancements					ARC				
Coatings development					ARC			ARC	
Attachment technologies dev					ARC				
Waterproofing development					ARC			ARC	
Material surface characterization					ARC			ARC	
TPS sensors and instrumentation					ARC		ARC	ARC	
TPS vehicle health management dev					ARC		ARC		
Smart TPS materials					ARC			ARC	
Low cost TPS concept dev					ARC			ARC	
TPS seal, gap, and joint development					ARC				
TPS/Cryo integration evaluation				ARC	ARC			ARC	
Arc Jet Flow Characterization					ARC				
Analytical Models of TPS performance					ARC				

ARC Capabilities: Technology Development

Structures and Materials
Center of Excellence

Applications / Capabilities	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
Refractory Diboride ceramicsTPS					ARC				
Advanced Ablators dev					ARC			ARC	
Toughened ceramic TPS dev					ARC				
Metallic covered flexible blanket dev					ARC				
High fidelity TPS sizing tool development					ARC			ARC	
Integrated Design Systems					ARC			ARC	
TPS Operability Analysis tool development					ARC			ARC	
Arc Jet & Aerothermal testing					ARC			ARC	
Low Cost TPS development					ARC				
Ceramic TPS manufacturing Methods					ARC			ARC	

ARC Facilities and Laboratories

- **Aerodynamic Heating Facility**
  Convective stagnation-point heat flux applied to nose cap or wedge-shaped test bodies in conical nozzle flow streams from 12 to 36 inches in diameter. The 8-foot test chamber is evacuated by 5-stage steam ejector pump and has optical access. Air, nitrogen, or argon is heated by a 20 MW electric arc heater with enthalpy ranging from 2000 to 15,000 Btu/lb operating up to 30 minutes.

- **Interaction Heating Facility**
  Two facility configurations: Convective heat flux is applied to 32 x 32 inch panels at variable angle of attack obtaining surface temperatures from 800 to 2700F with small pressure and temperature gradients; or convective stagnation-point heat flux applied to nose cap or wedge-shaped test bodies in conical nozzle flow streams from 6 to 41 inches in diameter. The 8-foot test chamber is evacuated by 5-stage steam ejector pump and has optical access. Air is heated by a 60 MW electric arc heater with enthalpy ranging from 2000 to 20,000 Btu/lb operating up to 30 minutes. Three dimensional test articles can be run in the panel test mode and run-time optical access is possible.

- **Panel Test Facility**
  Convective heat flux from transition/turbulent supersonic flow is applied to 16 x 16 inch panels at variable angle of attack obtaining surface temperatures from 800 to 2700 F with small pressure and temperature gradients. The 4-foot test chamber is evacuated by 5-stage steam ejector pump and has optical access. Air is heated by a 20 MW electric arc heater with enthalpy from 2000 to 15,000 Btu/lb operating up to 30 minutes. Three dimensional test articles can be run in the facility and run-time optical access is possible.

- **2x9 Turbulent Flow Duct**
  Convective heat flux from highly turbulent supersonic flow is applied to 8 x 20 inch panels within an enclosed duct obtaining surface temperatures from 1000 to 3000 F with small gradients in pressure and temperature. The 2 x 9 inch cross section duct is evacuated by 5-stage steam ejector pump and has optical access. Air or nitrogen is heated by a 15 MW electric arc heater at enthalpy levels from 2000 to 5,000 Btu/lb for up to 30 minutes.

ARC Facilities and Laboratories, continued

- **Giant Planet Facility**
  Combined convective and radiative stagnation-point heat flux applied to 1.5 inch diameter blunt test bodies in a supersonic hydrogen plasma in a conical nozzle of diameter 2.75 inches. The 8-foot test chamber can exhaust to atmosphere or the 5-stage steam ejector vacuum pump and has optical access. Hydrogen gas mixutures are heated by an 80 MW electric arc heater with enthalpy ranging from 150,000 to 300,000 Btu/lb operating up to several minutes. Facility is on standby (9/97.)

- **Thermal Blanket Acoustic Re-Entry Simulator**
  Acoustic testing of a 4 x 4 inch panel in a room-temperature supersonic flow duct in a 4-foot evacuated test chamber with optical access. Acoustic levels to 165 dB with dynamic pressure to 510 psf.

- **Ames Vertical Gun Range**
  Impact physics

- **Ceramic TPS processing laboratory**
  Facilities for fabricating fibrous ceramic materials and components. An example product from this facility is a new durable tile, TUFI (Toughened Uni-piece Fibrous Insulation), which is replacing damaged original tiles on all the Shuttles to reduce operational costs.

- **Organo-ceramic TPS processing laboratory**
  Facilities for fabricating organo-ceramic materials and components. Example products from this facility include SIRCA (Silicone Impregnated Reusable Ceramic Ablator) which was flown on the Mars Pathfinder vehicle and is being fabricated for the X-34, and new integral TPS/cryo-insulation materials incorporating advanced aerogels.

ARC Facilities and Laboratories, continued

- **Flexible TPS processing laboratory**
  Facilities for fabricating flexible TPS materials and components. An example product from this facility is DurAFRSI, a metallic foil-faced flexible blanket being developed for use on the X-33.

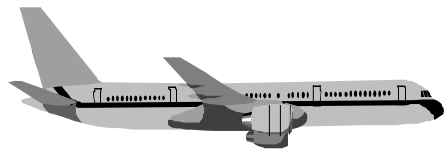
- **Laser accurate surface catalysis laboratory**
  Facilities and laser diagnostics for measuring chemical surface recombination characteristics of materials. This facility is being used to determine the catalytic and optical properties of the coated metallic TPS for the X-33.

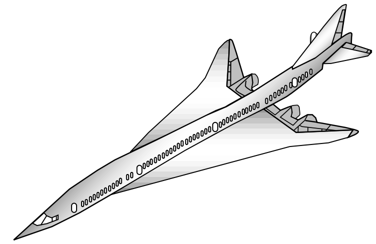
- **Thermal, mechanical, and analytical materials characterization laboratories**
  Facilities for measuring conductance, specific heat, mass and composition stability, and flow permeability characteristics of fibrous materials; optical properties of TPS materials and coatings; moduli, strengths and impact capabilities of fibrous materials; and facilities for performing sectioning and polishing, optical microscopy, electron microscopy, and elemental and crystalline structural analyses of materials

Dryden Flight Research Center

Technology Applications

- Atmospheric flight qualification, demonstration, and evaluation





Technical Capabilities

- Laboratory and flight measurement systems, aero/thermal loads testing, and structural concept validation
- Aeroelastic & modal test & analysis, multidisciplinary analysis, and applications of computational methods
- Health monitoring systems, and smart structures demonstrations

Facilities and Laboratories

- Flight Loads (and thermostructural) Laboratory
- Structural dynamics laboratory

Directory of Technical Points of Contact at DFRC

COE Leadership Team:

Michael V. DeAngelis	A. Director, Research Engineering Directorate	805-258-3921

Technical Points-of-Contact:

Michael W. Kehoe	Chief, Aerostructures Branch	805-258-3708
W. Lance Richards	Lead, Thermo-Structures Test & Analysis Group	805-258-3562
Lawrence C. Freudinger	Lead, Structural Dynamics Group	805-258-3542
David F. Voracek	Lead, Airframe Vehicle Health Monitoring Sys.	805-258-2463

DFRC Programs and Workforce (FY 98)

Programs and Projects	Workforce CS FTE's
Aeronautics and Space Transportation Technology Enterprise	
522 Airframe Systems Program	2
242 Reusable Launch Vehicles (X-33 Program)	1
529 Flight Research Program	23
Other Programs	
DDF	1
Structures and Materials Workforce, DFRC CS FTE Total	**27**

Notes: 1. Workforce includes civil service S&E's, program managers, and technicians assigned to the specific programs.
2. Does not include "indirect/overhead" civil servants or other Government Agency personnel co-located at the Center.
3. Does not include on-site personnel such as contractors, students and professors, or NRC Post-Doctoral Fellows.
4. Does not include non-Enterprise programs such as Code AE, Code Q, and Center Discretionary programs.

DFRC Recent Technical Accomplishments

Flutterometer being developed for flight flutter clearance testing
Point-of-Contact: Lawrence C. Freudinger, Structural Dynamics Group

The Structural Dynamics Group is in the process of developing a tool called the flutterometer for use with flight flutter testing which uses flight data measurements from stable flight conditions to predict the flight conditions associated with flutter instabilities. The basis for the flutterometer is a robust stability algorithm based on m (mu) analysis that computes flutter margins which are worst-case with respect to a set of uncertainty operators. The flutterometer uses flight data to generate operators which describe errors and unmodeled dynamics in a model so the resulting predictions account for the true properties of the aircraft which usually differ from those predicted by a computer model. The flutterometer will increase the efficiency of flight flutter testing by decreasing the associated time and cost while increasing safety to aircraft and crew. Nominal and robust flutter margins have been computed for the F-18 SRA airplane using m and the traditional p-k methods. The similarity of the predicted flutter margins demonstrates that the m method is a valid tool for computing flutter instabilities. A wing is being designed and fabricated to provide a functional test platform to validate the robust stability algorithm based on m analysis. The wing will be mounted to the F-15B flight test fixture and flown to the point of instability while the robust stability algorithm estimates the flutter margins in real-time.

NASP Side Shear Panel test
Point-of-Contact: Lance Richards, Thermo-Structures Test & Analysis Group

In support of the National Aero-Space Plane (NASP) program, many structural test articles were used to validate design concepts, fabrication methods, and design and analyses tools. Additionally, the test articles were used to demonstrate structural performance when subjected to the load and temperature conditions expected in flight. One of these test articles was a four-foot square, hat-stiffened panel, fabricated from a titanium matrix composite material. This panel was representative of an external fuselage skin section on the side of the flight vehicle in the location having the highest shear loading. A test fixture was designed and fabricated, and a test program conducted that provided for combined shear and tension, and combined shear and compression loads, at temperatures up to 915 °F. The Side Shear Panel was tested at room temperature and at 500 °F with applied mechanical loads up to design limit. The performance of both the Side Shear Panel and the combined loads test fixture was evaluated during the test program. Test results showed that a comparison of the Side Shear Panel experimental test data with analysis was exceptional as was the performance of the combined loads test fixture. A structurally stable system was maintained during compressive loading, and uniform temperature and stresses were maintained throughout the test panel. Since this was the last titanium matrix composite test panel built by the NASP program, it was decided not to test the panel at the 915 °F temperature without attempting to quantify potential creep.

DFRC Capabilities: Research

Structures and Materials
Center of Excellence

Applications / Capabilities	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
Laboratory simulation of aero/thermal loads	DFRC	DFRC	DFRC		DFRC				
Aeroelastic test & analysis methods	DFRC		DFRC						
Modal test & analysis methods	DFRC		DFRC						
Laboratory & flight measurement systems	DFRC		DFRC						
Multidisciplinary analysis methods	DFRC		DFRC						

DFRC Capabilities: Technology Development

Structures and Materials
Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
Structural concept validation	DFRC	DFRC	DFRC		DFRC				
Experimental methods & verification tests	DFRC		DFRC		DFRC				
Aeroelastic test & analysis demo.	DFRC								
Modal test & analysis demo.	DFRC								
Laboratory & flight measurement systems	DFRC		DFRC						
Computational methods demonstrations	DFRC		DFRC						
In-situ health monitoring systems demo.	DFRC								
Smart structures applications	DFRC								
Multidisciplinary analysis applications	DFRC								

DFRC Facilities and Laboratories

- **Flight Loads (and thermostructural) Laboratory**

  120 ft x 160 ft high bay test area, an instrumentation installation lab, a systems development lab, a test control room, and support offices; mechanical load capability includes four universal testing machines from 10 Kips to 220 Kips and hydraulic actuators to 350 Kips; heating capability includes several ovens with programmable control to 2000 F, one vacuum/ inert atmosphere oven (3 ft x 3 ft x 3 ft test chamber) programmable to 2000 F, an optical pyrometer and heat flux gage calibration system, quartz lamp heaters with capabilities to 100 Btu/ft^2-sec, 3000 F, 150 F/sec, and 20 MW power; nitrogen cooling to -320 F temperature is also available.

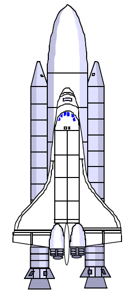
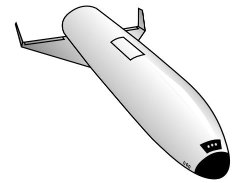
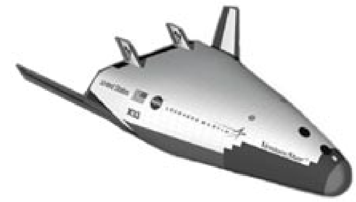
- **Structural Dynamics Laboratory**

  The Structural Dynamics Lab provides the capability to perform modal testing of aircraft and aircraft components, general vibration testing, in-flight structural excitation system testing, and flight data analysis methods development.

Marshall Space Flight Center

Technology Applications

- Space propulsion system structures & materials
- Structures, materials, TPS, and cryotanks for space transportation vehicles
- Structures and materials for space optics

Technical Capabilities

- Materials contamination and space environmental effects
- Nondestructive evaluation and tribology
- Polymers and composites, and ceramics and ablative materials
- Nonmetallic processes and automation
- Metallurgical and failure analysis, corrosion engineering, and mechanical metallurgy
- Metallurgy research and processes development
- Environmental and analytical chemistry, and environmental replacement technology
- Propellant compatibility, toxic offgassing, flammability
- Project engineering and materials selection and control
- Structural dynamics, loads and durability analysis for launch vehicles, payloads and propulsion system components
- Vibration, acoustics and shock design and test criteria
- Advanced dynamic data analysis for propulsion system structural components
- Pyrotechnics for structural separation and meteroid/debris shielding design
- Integrated structural/thermal analysis

Facilities and Laboratories

- Large component structural testing facilities
- Structural dynamics test facilities
- Materials combustion research facility
- Materials and processes technical information system
- Space environmental effects facility
- Tribology research laboratory
- Materials Research Facility
- Hydrogen test facility
- Metallurgical diagnostics facility
- Thermal spray facilities
- Joining techniques development
- Environmental and analytical chemistry laboratory
- Productivity enhancement complex
- Hot gas facility
- Combined loads and environments test facility
- Vibration test facility
- Acoustic test facility

Directory of Technical Points of Contact at MSFC

COE Leadership Team:

Ann F. Whitaker	Director, Materials & Processes Laboratory	(256) 544-2481
or, in alternating years,		
Randy Humphries	Director, Structures & Dynamics Laboratory	(256) 544-7228

Technical Points-of-Contact:

M. Ralph Carruth	Chief, Engineering Physics Division	(256) 544-7647
Paul M. Munafo	Chief, Metallic Materials & Processes Division	(256) 544-2566
Corky Clinton	A. Chief, Nonmetallic Materials & Processes Div	(256) 544-2673
Dennis E. Griffin	Chief, Project & Environmental Engr Division	(256) 544-2493
John L. Ransburgh	Chief, Fabrication Services	(256) 544-1080
Carmelo Bianca	Chief, Structural Analysis Division	(256) 544-1483
Pedro Rodriquez	Chief, Structural Design Division	(256) 544-7006
James Owen	Chief, Thermal and Life Support Division	(256) 544-7213
Clifton Kirby	Chief, Structural Test Division	(256) 544-1101

MSFC Programs and Workforce (FY 98)

Programs and Projects	Workforce CS FTE's
Aeronautics and Space Transportation Technology Enterprise	
Various Programs (242, 262)	106.3
Human Exploration and Development of Space Enterprise	
Various Programs (250, 260, 477, 546, 906, 947, 959, 963)	149.8
Earth Science Enterprise	
Various Programs (608, 962)	4.5
Space Science Enterprise	
Various Programs (188, 236, 454, 632)	30.4
Other Programs	
CDDF, Code AE/Q, Technology Transfer, Indirect	38
Structures and Materials Workforce, MSFC CS FTE Total	**329**

Notes: 1. Structures and materials workforce is used across various COE's, for example Propulsion and Micro-Gravity.

MSFC Recent Technical Accomplishments

Engineering Physics
Point-of-Contact: Ralph Carruth, Chief, Engineering Physics Division

The Engineering Physics Division has generated considerable space flight data on the effects of the space environment on materials in flight experiments including LDEF, EOIM, Shuttle experiments, the SPSR used via EVA on Mir, and OPM on Mir. Also, very stringent contamination requirements have been developed for optical flight experiments such as LIS, SXI, and the next great observatory, AXAF. Several optical techniques have been developed for quantifying surface contamination levels for hardware. These techniques are more quantifiable and easier to use than solvent based analysis. Advanced NDE techniques including computed tomography, shearography, thermography, ultrasonic, and acoustic emissions with neural networks signal processing have been developed and are being applied to flight hardware at MSFC and at contractor locations to support NASA programs. Tribology research has led to the development of silicon nitride bearings which are being flown in the Shuttle main engines and are continuing to be introduced. New environmentally friendly lubricants are also being developed and characterized.

Metallic Materials and Processes
Point-of-Contact: Paul Munafo, Chief, Metallic Materials and Processes Division

The Metallic Materials and Processes Division, Paul Munafo, Chief, recently completed the development of Design Allowables for use in structural analysis. Examples include aluminum lithium properties for the Superlightweight Tank, and hydrogen "debits" for use in SSME/ATD. Manufacturing Process Control Systems have been developed for use by contractors in producing flight hardware. Examples include the Marshall Automated Weld System (MAWS), currently in use at MAF, and some robotic welding systems that were used on the SSME program. Production of flight and development hardware include the aluminum oxygen tank for the Fastrac program, gold-plated lenses for X-ray telescopes, and hydrogen barrier coatings for SSME Fuel Turbopump components.

Nonmetallic Materials and Processes
Point-of-Contact: Corky Clinton, A. Chief, Nonmetallic Materials and Processes Division

The Nonmetallic Materials and Processes Division, Frank Ledbetter, A. Chief, completed the production of flight and development hardware include the X-34/Fastrac chamber/nozzle, RP composite tank, composite lines and ducts, ET composite nose cone, and SRB composite nose cap. Development of advanced materials and components include the CMC blisk and aerospike engine composite nozzle ramp. Composite materials properties, including mechanical and physical properties and design allowables, have been developed for the ET composite nose cone, X-34 Fastrac chamber/nozzle, RP composite tank, CMC blisk (labs in development), and SRB composite nose cap (just underway).

Project and Environmental Engineering
Point-of-Contact: Dennis Griffin, Chief, Project and Environmental Engineering Division

The Project and Environmental Engineering Division, Dennis Griffin, Chief, completed materials compatibility tests & analyses for Phase I and II of the X-33 Composite LOX Compability Program to determine requirements for the qualification and use of composite materials for liquid oxygen. Composites flight qualification tests have been completed for the Composite Nose Cone for the External Tank Program. GOX and LOX evaluation of materials testing has redefined the combustion pressure threshold limits in gaseous oxygen (based on statistically significant data) for propulsion system materials used in oxygen systems. The data was added to the MSFC's Materials and Processes Technical Information System (MAPTIS).

MSFC Recent Technical Accomplishments

Fabrication Services
Point-of-Contact: John Ransburgh, Chief, Fabrication Services Division

The Fabrication Services Division, John Ransburgh, Chief, recently completed fabrication activities include the design and analysis of special test equipment and tooling, and flight and development hardware in support of center projects.

Structural Analysis
Point-of-Contact: Carmelo Bianca, Chief, Structural Analysis Division

The Structural Analysis Division, Carmelo Bianca, Chief, produced load, stress, and fatigue reports for the X-34 propellant lines, bulkhead attachments, and line attachments. A number of mounts were redesigned to achieve positive margins of safety. Load, stress and fatigue reports were produced for the 60K Fastrac Engine. Thermal and load induced analyses of the high temperature ablative engine nozzle resulted in successful redesigned configuration. Load and stress reports were produced for the propellant test article. Analytical modeling, proof testing, and field engineering support were provided for the planned testing at Stennis.

Structural Design
Point-of-Contact: Dr. Pedro Rodriquez, Chief, Structural Design Division

The Structural Design Division, Dr. Pedro Rodriquez, Chief, completed the design and fabrication of a composite secondary support structure prototype for hypervelocity meteoroid/debris protection of the International Space Station. Data was provided to the Russians for use in their "fix" for recent inadvertent collision repair. Design optimization trade studies were completed for the selection of a configuration that meets mass and performance requirements in the development of an Advanced Shuttle Upper Stage. Three configurations were evaluated with one being selected for proposed future Shuttle Upper Stage. Assembly and integrated installation drawings were developed for the X-34 Main Propulsion System, including secondary support structure. All drawings were delivered on schedule to the developer, OSC. Pyrotechnics testing and analysis methods were developed that will be used to optimize the design of the frangible SRB Holddown Nut. Structural tests were recently conducted to reassess materials change impacts.

Thermal and Life Support
Point-of-Contact: James Owen, Chief, Thermal and Life Support Division

The Thermal and Life Support Division, James Owen, Chief, completed the integrated thermal and structural analysis of the NGST Optical Telescope Assembly (OTA) segmented mirrors utilizing software developed at MSFC to provide full correspondence of the transient temperature field to the finite element structural analysis model. Feasibility of maintaining very low temperature mirrors, with small gradients has been predicted. The integrated thermal and structural analysis of the composite structure and ablative liner of the 60K Fastrac Engine has been accomplished, including modeling of the chemical kinetics of the ablation process. The resulting temperature fields have been mapped onto structural analysis finite element models to enable prediction of liner material structural response. Thermal analysis results have been correlated to engine and component test results. Integrated thermal and structural analyses have been accomplished for turbine section components of the Space Shuttle Main Engine (SSME) Alternate Turbopump. These transient analyses have been fully integrated with structural analysis finite element models to enable prediction of structural response and component life. These models are three dimensional, include complex geometry, and transient boundary conditions. The finite element grids provide one to one correspondence of the predicted temperature field to the structural model.

Structural Test
Point-of-Contact: Clifton Kirby, Chief, Structural Test Division

The Structural Test Division, Clifton Kirby, Chief, has successfully completed the first in a series of large payload modal tests for the Resource Node of the International Space Station. The Resource Node instrumented with 1251 accelerometers was mounted in a constrained modal test for a five trunnion mounted payload test. As a result of recently completed vibration/cryogenic testing, Lockheed Martin showed that the vibration environments for the LH2 Liquid Level Sensors for the Super Light Weight Tank would be 95.5 Grms. A vibration fixture was built to support the baffle attachment point some 12 feet off the floor. The vertical test required an input of 30 Grms, and the test hardware was significantly damaged while obtaining enough data to perform further analysis. In analyzing this data, it was discovered that the qualification levels for the sensors currently flying in the light weight tank were not high enough, which invalidated their qualification and threatened flight schedules. A test procedure was developed to vibrate the sensors at -423 degrees Fahrenheit. The sensors survived the environments, resulting in no impact to Space Shuttle flight schedules. Finally, a full scale RLV thrust structure was subjected to a series of quasi-static load test conditions for Rockwell Aerospace. The test conditions included design limit load, life cycle loads, proof loads, and test article failure loads. The test article consisted of structure to illustrate the load path for transmitting engine forces through the vehicle structure. Failure load for the test article was 165% limit load.

MSFC Capabilities: Research

Structures and Materials
Center of Excellence

Applications / Capabilities	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
polymer synthesis and processing						MSFC		MSFC	MSFC
PMC preform and curing process dev			MSFC	MSFC		MSFC			
PMC structure-property char.				MSFC		MSFC			
light alloy synthesis & processing						MSFC			
nickel-based superalloy syn. & processing					MSFC	MSFC			
metal forming and joining process dev			MSFC	MSFC		MSFC			
metallic alloy structure-property char.			MSFC	MSFC		MSFC			
refractory composite dev. & processing						MSFC			
refractory composite struc-prop. char.						MSFC			
mechanics of nonlinear material behavior			MSFC	MSFC					
mech. & dyn. of nonlinear structural behavior			MSFC	MSFC					
durability, damage, & mech. of failure			MSFC	MSFC		MSFC	MSFC	MSFC	
sensor & measurement physics for instr.							MSFC	MSFC	
smart materials and structures							MSFC	MSFC	
orbital debris methodology			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
probabilistic structural analysis methods			MSFC	MSFC		MSFC			
combined thermostr testing of integrated tank				MSFC					
development and test of cryogenic seals				MSFC					
an. and num. methods for high-temp PMC						MSFC			
rapid prototyping			MSFC	MSFC		MSFC		MSFC	
structural alloy development			MSFC			MSFC		MSFC	
alternative processing refinement						MSFC		MSFC	
inspection method development			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
material combustion research				MSFC		MSFC			
refurbishment			MSFC	MSFC	MSFC	MSFC		MSFC	
foam material/systems			MSFC	MSFC	MSFC	MSFC		MSFC	
ablative insulation processing			MSFC	MSFC	MSFC	MSFC		MSFC	
environmental replacement technology		MSFC	MSFC	MSFC	MSFC	MSFC		MSFC	

MSFC Capabilities: Technology Development

Structures and Materials
Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
materials combustion test and evaluation			MSFC	MSFC	MSFC	MSFC			
joining techniques development			MSFC	MSFC	MSFC	MSFC	MSFC		
refurbishment			MSFC	MSFC	MSFC	MSFC		MSFC	
foam materials/systems			MSFC	MSFC	MSFC	MSFC		MSFC	
ablative insulation processing			MSFC	MSFC	MSFC	MSFC		MSFC	
environmental replacement technology		MSFC	MSFC	MSFC	MSFC	MSFC		MSFC	
non-ODC cleaning process			MSFC	MSFC	MSFC	MSFC		MSFC	
lubricant development & evaluation			MSFC			MSFC	MSFC	MSFC	MSFC
refractory composite frabrication scale-up						MSFC			
structural concepts			MSFC	MSFC		MSFC	MSFC	MSFC	
computational methods & design tools			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
test methods for design allowables			MSFC	MSFC		MSFC	MSFC	MSFC	
polymer matrix composite fabrication			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	
structural strength tests			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	
experimental stress tests			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	
dynamics load tests			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	
experimental dynamics tests			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	
structural response measurements			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	
alternative model test methods			MSFC				MSFC	MSFC	MSFC
damping properties for CMC's						MSFC	MSFC	MSFC	
structural dynamics and loads			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
hydroelastic fluid modeling				MSFC					
flight operations simulation tests				MSFC	MSFC				
environment testing of integrated tank sys				MSFC	MSFC				
structural modeling and assessment			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
structural criteria			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
probabilistic assessment			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
fatigue and fracture assessment			MSFC	MSFC		MSFC	MSFC	MSFC	MSFC
structural test mon., interpr., and an. cor.			MSFC	MSFC		MSFC	MSFC	MSFC	MSFC
Vibration, acoustics and shock criteria eval.			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
Thermal modeling and design assessment			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC

MSFC Capabilities: Technology Development

Structures and Materials Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
engine diagnostic data analysis						MSFC			
structural/thermal/optical integrated performance analysis							MSFC		
design optimization			MSFC	MSFC			MSFC		
survivability from orbital debris			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
failure analysis	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
NDE of raw material, joined element, subsysem., & component		MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
verif. of compositional, environmental, & cleanliness req.			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
evaluation of anomalous structural comp.			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
process dev., optimization, & verification of fab. methods			MSFC	MSFC	MSFC	MSFC	MSFC	MSFC	MSFC
fab of full scale art. for manufacturing demo & hot-fire			MSFC	MSFC	MSFC	MSFC		MSFC	MSFC
material characterization for design data			MSFC	MSFC	MSFC	MSFC		MSFC	MSFC
specialized structural, coating, and environmental applications			MSFC	MSFC	MSFC	MSFC			
rapid prototyping for concept evaluation, wind tunnel testing, & accel. fab. tech.			MSFC	MSFC	MSFC	MSFC		MSFC	MSFC
simulated evironment testing			MSFC	MSFC	MSFC	MSFC		MSFC	MSFC
bearing and seal testing						MSFC			

MSFC Facilities and Laboratories

- **Large component structural testing facilities**
  Universal test facility with three high bay test areas, large structure quasi-static load facility, component / system quasi-static load facility, hazardous structural test facility, cryogenic structural test facility

- **Structural dynamics test facilities**
  Vibration test facility, vibroacoustic test facility, pyrotechnic shock test facility, modal test facility, and control dynamics facility

- **Materials combustion research facility**
  Flammability, toxic offgassing and materials compatiblity testing in low and high pressure/temperature environments including air, LOX/GOX, enriched oxygen and reactive fluids, test methods (NHB 8060.1, NASA-STD-6001, ASTM) and system evaluation

- **Materials and processes technical information system**
  Mechanical and physical properties for metals and non-metals, materials test data, in oxygen environments, thermal vacuum stability, flammability, LOX/GOX and other data generated per NHB 8060.1, also stress corrosion, corrosion, and Hydrogen embrittlement data for metals

- **Space environmental effects facility**
  Facilities for long-term exposure and materials characterization in simulated space environment

- **Tribology research laboratory**
  Lubricant & bearing development

- **Materials Research Facility**
  Alloy synthesis, processing, and characterization facilities

- **Hydrogen test facility**
  Materials characterization in low pressure & high pressure liquid and gaseous hydrogen

- **Metallurgical diagnostics facility**
  Hardware failure analysis, failure analysis database, electron optics facility, full service metallographic facility, and evaluation of material properties

- **Thermal spray facility**
  Refractory composite development

MSFC Facilities and Laboratories, continued

- **Joining techniques development**

  Friction Stir welding

- **Environmental and analytical chemistry laboratory**

  Chemical analysis of liquid, gas and solid materials and contamination using a wide range of analytical methods and diagnostic techniques including: chromatography, thermal analyses, inductively coupled plasma, combustion analyses, wet chemistry, atomic absorption, mass and emission spectrometry; UV, IR, and X-ray analyses; as well as EPA methods

- **Productivity Enhancement Complex (PEC)**

  The PEC is a multiple cell area which accomodates thermal and cryogenic insulation materials development and processing; automated composite manufacturing; materials and processing for environmental replacement; rapid prototyping technologies; development of subscale solid & hybrid propulsion systems; automated refurbishment technology; mechanical, thermal, physical and chemical property characterization for polymers, polymer matrix composites, adhesives, and ceramix matrix composites; adhesive development and evaluation; and high temperature ablative materials testing and evaluation

- **Hot Gas Facility**

  The MSFC Hot Gas Facility (located in the east test area) is a nominal Mach 4 aerothermal wind tunnel that burns a lean mixture of air and gaseous hydrogen. HGF combustion chamber operating range is 1400 to 2200 °F at pressures of 130 to 220 psia. HGF heat flux range is 3 to 35 BTU/sf-s (convective cold wall) on test articles with a max panel size of 12x20 inches (test section cross section area is 16x16 inches) The HGF is capable of providing combined radiant and convective heating. Test specimen substrate cooling to cryogenic conditions can be provided. Infrared data is available upon request.

- **Combined Loads and Environments Test Facility**

  Combined acoustics, pressure, thermal and cryogenic induced loads that simulate launch and on-orbit vehicle conditions.

- **Vibration Test Facility**

  Dynamic loads including random, sine, sine-on-random, random-on-random, and transient vibration that simulate engine thrust, aerodynamic, and vehicle transient loads.

- **Acoustic Test Facility**

  Diffuse field and progressive wave dynamic loads with $\pm$2dB overall spectra control that simulates engine acoustic and aerodynamics loads.

Goddard Space Flight Center

Technology Application

- Development and flight of advanced spacecraft subsystems and instruments for earth and space science

Technical Capabilities

- Materials engineering, assurance, testing, NDE, and analysis
- Design, analysis, fabrication, and testing of science instruments and advanced spacecraft subsystems
- Development of advanced structures and mechanisms that are highly dimensional stable and/or thermally conductive, precision deployable, actively controlled, multifunctional, and/or inflatable/rigidizable
- Analysis and testing including steady-state acceleration, structural dynamics, force-limited vibration, shock, fracture and fatigue, acoustic, thermal/optical performance, jitter, kinematic, contamination, and thermal distorsion/heat transfer

Facilities and Laboratories

- Materials characterization and microscopy laboratories
- Instrument laboratory (life testing of components/assemblies)
- Mechanical testing laboratory
- Tribology Laboratory
- Nondestructive evaluation laboratory
- Advanced development laboratory
- Contamination measurement laboratory
- Thermal coatings properties laboratory
- Molecular kinetics (MOLKIT) laboratory
- Electromechanical laboratory
- High capacity centrifuge
- Structural test laboratory
- Electro-plating facility
- Composite materials (processing) laboratory
- Laser welding facility

Directory of Technical Points of Contact at GSFC, 1 of 2

COE Leadership Team	Title	Phone No.
Stephen J. Brodeur	Associate Chief, Mechanical Systems Center	301-286-6555

Name	Technical Capabilities	Phone No.
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Frederick C. Gross	Polymer Processing	301-286-8349
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John T. Van Sant	Thermal Material Property Measurements	301-286-6024
Sandra M. Irish	Mechanical Systems Modeling & Analysis	301-286-8944
Scott A. Gordon	Structural Loads & Strength Analysis	301-286-9940
Debra F. Wheeler	Shuttle Payloads Structural Analysis	301-286-7955
Robert J. Coladonato	Dynamic Environments Definition	301-286-8284
Frank J. On	Vibroacoustic Analysis	301-286-5398
Timothy M. Carnahan	Virtual Reality Animations and Data Visualization	301-286-7196
Alan J. Posey	Instrument and Spacecraft Structural Design	301-286-8325
William L. Niemeyer	Advanced Composites Design	301-286-9532

Directory of Technical Points of Contact at GSFC, 2 of 2

Rodger E. Farley	Analysis & Test Deployment Mechanisms Design	301-286-2252
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Sharon Cooper	Fracture Control and Analysis	301-286-9939
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Gary L. Brown, Jr.	Mechanism Control Electronic Design/Simulation and Testing	301-286-1304
Kenneth A. Blumenstock	Mechanism Electromagnetic Design and Simulation	301-286-4268
Robert E. Federline	Mechanism Mechanical Design/Analysis/Testing	301-286-8209
Gene G. Gochar	Instrument Mechanical Design/Analysis/Testing	301-286-2637
Armando Morell	Instrument Optomechanical Design	301-286-8907
Gilbert W. Ousley, Jr.	Thermal Control Design Concepts, Approaches, and Procedures	301-286-6600
Carol L. Mosier	Computer Design Codes & Analytical Tech. for Thermal Control Models	301-286-3186
Theodore D. Swanson	Advanced Thermal Control Technologies	301-286-8618
Philip T. Chen	Contamination Control Technologies	301-286-8651
Donald J. Hershfeld	Advanced Structural Dynamic Test Techniques	301-286-5081
Jamie L. Dunn	Thermal Vacuum Test Design	301-286-6058
Robert J. Vernier	Environmental Performance Verification	301-286-0409
Stanley M. Wojnar	Environmental Test Engineering	301-286-5145

GSFC Programs and Workforce (FY 98)

Programs and Projects		Workforce CS FTE's
Mission to Planet Earth Enterprise		
225	Earth Observing System AM-1 Mission	6.9
226	Earth Observing System PM-1 Mission	4.9
227	Earth Observing System Instruments Mission	13.0
228	Earth Observing System Chemistry and Special Flights Mission	6.9
257	SAC-C Mission	3.0
258	NMP Earth Observing-1 Mission	7.2
259	Vegetation Canopy Lidar Mission	2.8
419	Total Ozone Mapping Spectrometer Mission	3.1
437	Tropical Rainfall Measurement Mission	0.8
634	Landsat-7 Mission	4.0
Space Science Enterprise		
265	Far-Ultraviolet Spectrographic Explorer Mission	1.2
287	Microwave Anistropy Project	31.2
344	SIRTF Infrared Array Camera	2.2
353	Balloon Science Missions	3.9
440	ASTRO-E Instrument	5.4
458	Hubble Space Telescope Mission	56.0
632	Spacecraft & Remote Sensing RTOP's	13.2
689	Midex Missions	1.0
839	GLAST Gamma Ray Missions	9.9
854	Spartan Missions	9.4
864	Small Explorer Missions	12.9
879	Sounding Rocket Missions	16.0

Table Continued, next page

GSFC Programs and Workforce (FY 98), Cont.

Programs and Projects		Workforce CS FTE's
Other Programs		
243	Technology Inventory	1.0
264	Get-Away Special and Hitchhiker Missions	16.9
274	Center Director's Discretionary Fund	3.1
314	DoD Mission Support	1.0
323	Spacecraft Loads and Acoustic Measurements	1.4
389	Manufacturing Support for Science Instrument Development	1.9
615	Polar Orbiting Environmental Satellite Missions	2.3
616	Geostationary Orbiting Satellite Missions	4.3
926	Hitchhiker Missions	5.7
991	Independent R&D	6.4
998	New Science Mission Proposal Support	12.7
	Other activities	35.5
Structures & Materials Workforce: GSFC CS FTE Total		**307.0**

Notes:
1. Workforce includes civil service S&E's, program managers, and technicians assigned to the specific programs.
2. Does not include "indirect/overhead" civil service or other Government Agency personnel co-located at the Center.
3. Does not include on-site personnel such as contractors, students and professors, or NRC Post-Doctoral Fellows.
4. Includes Center Discretionary programs
5. Workforce data changes rapidly, good for 3-6 months.

GSFC Recent Technical Accomplishments

Development of Tabless Test Specimens
Point-of-Contact: Michael Viens, Group Leader, Materials Engineering Branch

Traditionally, separate specimens from specific panels were required for each property. They also had to have tabs. All of this increased prep time and expense. We demonstrated that a single tabless cross ply test specimen, from a single panel could be used to determine several mechanical properties including compressive, shear and tensile strength, Young's and in-plane shear modulus.

XRF of Bolts
Point-of-Contact: Mark McClendon, Materials Engineering Branch

Rapid and accurate compositional analysis of bolts has been achieved using a portable X-ray fluorescence system. The key to this accomplishment lies in the fact that we were able to demonstrate accurate results in spite of the fact that the bolts were smaller than the detector window area and of variable size. XRF permits non-destructive, rapid throughput resulting in excellent statistical analysis of lot properties and the resulting material certification.

Threaded Fastener Control
Point-of-Contact: Michael Barthelmy, Associate Head, Materials Engineering Branch

Several years ago, threaded fastener suppliers were found to be shipping counterfeit fasteners and fraudulent test reports. These findings and the subsequent investigations led to the introduction of a comprehensive set of requirements to assist fastener users in the procurement and inspection of flight fasteners. These guidelines are still the basis for quality control of flight fasteners and have been adopted by other NASA Centers. The document, GSFC Fastener Requirements, has eliminated concerns with threaded fastener fraud.

X2096 Al-Li Alloy Characterization
Point-of-Contact: Michael Viens, Group Leader, Materials Engineering Branch

Many materials properties were obtained including tensile, shear, fatigue, fracture toughness (KIc), and bearing strength. The main advantage of this alloy over aluminum is its 10% greater stiffness.

Stiffness of Composites by Acoustic Resonance
Point-of-Contact: Michael Viens, Group Leader, Materials Engineering Branch

An inexpensive and portable acoustic resonance apparatus has been used successfully to determine the stiffness of composites from a simple rectangular specimen. Data using this, method, has been provide to MAP, GLAS and FUSE.

Improved Dampers for Deployment Mechanisms
Point-of-Contact: Charles Powers, Materials Engineering Branch

Digital radiography of dampers that failed to perform properly revealed bubbles in the damping fluid that became more pronounced when exposed to vacuum. Collaboration with the damper vendor resulted in modifications to the fill procedure and sealing methods. Improved dampers have been supplied to NOAA, POES, MAP, TRACE, WIRE and others.

Life Testing of Lamps
Point-of-Contact: Charles Powers, Materials Engineering Branch

The MEB has performed life testing on lamps and LEDs, used in the VISSR and VAS instruments and flown on the GOES spacecraft, for a number of years. This testing has led to a thorough understanding of the dual degradation mechanisms associated with these lamps and has resulted in very accurate lifetime predictions for these lamps under a variety of operating conditions. Life testing capabilities have been expanded to cover mechanisms (slip rings, bearings) in support of other instruments including HEMT (MAP), AVHRR and MODIS.

NDE of CZT
Point-of-Contact: Bradford Parker, Group Leader, Materials Engineering Branch

A HQ funded technical program to use NDE to evaluate the quality of bulk cadmium zinc telluride (CZT) for use in gamma ray and hard x-ray detectors was initiated earlier this year. X-ray spectral maps have been correlated with IR transmission images to identify which types and populations of bulk defects are responsible for poor detector performance.

Radiographic Videos for Flaw Detection
Point-of-Contact: Timothy Van Sant, Materials Engineering Branch

Time lapse video of radiographic images combined with controlled changes in environmental parameters (temperature, pressure) have enhanced our ability to see defects and flaws in materials and mechanisms using a real-time digital x-ray system. The time-lapse images are collected on video tape and played back in a motion picture mode. This technique was very successful in finding and demonstrating that the GOES motor failures were due to low cycle thermal fatigue of the motor windings.

Solar Array Deployment Gravity Negation System
Point-of-Contact: Jon F. Lawrence, Mechanical Engineering Branch

A gravity negation system was developed to perform ground deployment testing of the Tropical Rainfall Measuring Mission (TRMM) solar arrays. The two solar array wings each comprise twin seven foot square solar panels at the end of a twelve foot articulated boom and are deployed to their operational configuration by a complex spring/damper deployment system. The design of the gravity negation system uses an air pad flotation system and is modular to allow its setup in several locations, including the launch site in Japan. Both plan form and height can be varied, to meet the requirements of the test configuration and the test facility. Since deployment failure would be catastrophic to the mission, a total of 17 deployment tests were completed to qualify the system for the worst case launch and orbital environments. This successful testing culminated in the flawless deployment of the solar arrays on orbit, 15 minutes after launch, on November 27 1997.

Force-Limited Vibration Testing
Point-of-Contact: Daniel B. Worth, Environmental Test Engineering and Integration Branch

In collaboration with JPL, state-of-the-art force-limited vibration testing capability was developed and implemented. By measuring interface forces between test article and shaker during the test, and then limiting those forces to predicted flight interface forces in real time, notches are produced in the input acceleration spectrum that are similar to those which occur in flight. This technique produces a more realistic test for flight hardware while minimizing overtests inherent in conventional acceleration-limited vibration testing methods. This technology has quickly come into great demand and has successfully been used on several recent space science instruments and, in the first application to a spacecraft, on the WIRE spacecraft.

Precision Investment Castings for Spaceflight Structures
Point-of-contact: Thomas E. Wallace, Carrier Systems Branch

Precision investment castings have recently been qualified for use on Shuttle payloads and have decreased development costs and times. Monolithic aluminum castings were developed for the precision satellite structure for PAMS, which flew successfully on STS-78, and for the mounting structure for the RMS grapple fixture that flew on the Spartan 207/Inflatable Antenna Experiment flight. Casting designs can be produced in less time and with less weight than competing designs based on composite materials, with comparable safety and reliability. Among the advantages of castings are lower costs for complex parts, significantly reduced parts count, reduced assembly costs, and the ability to produce a more compact packaging for spacecraft and instrument systems, including electronics box enclosures.

Low Thermal Conductivity Instrument Cryostat Supports
Point-of-Contact: Gordon V. Casto, Mechanical Engineering Branch

A very low thermal conductivity, high stiffness mounting interface was developed for the WIRE instrument, consisting of a telescope and infrared detector housed in a solid hydrogen cryostat. The interface was designed to incorporate tubular composite struts bonded to titanium fittings. The composite utilized for this application was "gamma(g) alumina/epoxy". The g-alumina is a fiber form of crystalline Al2O3, in which the fibers are spread and impregnated with epoxy to make a composite pre-preg tape. The tubes are 12" long with 1.5" I.D. and a wall thickness of .080", with a lay-up of [0∞3/+45/-45/0∞3]s. This resulted in a tube with the same axial stiffness as titanium with 1/10 the thermal conductance. The resulting benefit to the WIRE program was a 10% increase in mission life.

Contamination Control Devices
Point-of-Contact: Patricia A. Hansen, Thermal Engineering Branch

Several contamination control and measuring devices have been developed and flown on spaceflight missions. A molecular adsorber, a new technology, was incorporated into the HST Fine Guidance Sensor instrument design to prevent performance degradation of critical instrument optical surfaces. The molecular adsorber minimizes the contamination threat posed to critical surfaces by effectively controlling outgassing along the transport path. Surface Acoustic Wave (SAW) sensors, an SBIR-developed technology, have been qualified for spaceflight. These passive sensors are 200 times more sensitive than conventional contamination devices. They accreted deposits of a mere 8 angstroms thickness, enabling chemical analysis of trace contaminant species. The Contamination Environmental Package (CEP) was flown on HST Servicing Mission 2 (and will be flown on Mission 3), and the data collected from the CEP has been extremely valuable to the Shuttle payload community by allowing many contamination sensitive instruments to improve their contamination control design for the measured environment.

GSFC Capabilities: Technology Development

Structures and Materials Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
Composite materials testing and evaluation							GSFC	GSFC	
Contamination & spacecraft charging assmts							GSFC	GSFC	
Failure and stress analyses							GSFC	GSFC	
Glass and ceramics technology							GSFC	GSFC	
Nondestructive eval. (UT, RT, EC, IR, AE)							GSFC	GSFC	
Polymer processing technology							GSFC	GSFC	
Tribological testing and evaluation							GSFC	GSFC	
Welding and brazing technology							GSFC	GSFC	
Atomic oxygen testing							GSFC	GSFC	
Electrical testing							GSFC	GSFC	
Heat treatment--air and inert atmospheres							GSFC	GSFC	
Inorganic chemical an. (OES, XRD, Auger)							GSFC	GSFC	
Life testing: bearings, lamps							GSFC	GSFC	
Mechanical testing							GSFC	GSFC	
Metallographic evaluation							GSFC	GSFC	
Microscopy--electron, optical & atomic force							GSFC	GSFC	
Optical and laser testing laboratory							GSFC	GSFC	
Organic analyses (IR, GCMS)							GSFC	GSFC	
Outgassing testing ASTM E-595 + dyn tests							GSFC	GSFC	
Surface analysis (ESCA)							GSFC	GSFC	
Surface tension measurements							GSFC	GSFC	
Surface thermo-optical properties							GSFC	GSFC	
Thermal analyses (Tg, CTE, th. stability, etc.)							GSFC	GSFC	
Thermal conductivity and thermal exp. coef.							GSFC	GSFC	
Vacuum testing and thermal cycling							GSFC	GSFC	
Precision deployable structures							GSFC	GSFC	
Structures/control system interaction							GSFC	GSFC	
Smart adaptive structures							GSFC	GSFC	
Inflatable/rigidized structures							GSFC	GSFC	
Analysis tools for inflatable structures							GSFC	GSFC	

GSFC Capabilities: Technology Development

Structures and Materials
Center of Excellence

Applications / Capabilities	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Technology Development:TRL 4-6									
Deployment control for inflatable structures							GSFC	GSFC	
Multi-functional structures							GSFC	GSFC	
High-thermal conductivity structures							GSFC	GSFC	
High-thermal cond. electronic enclosures							GSFC	GSFC	
G-negation test methods							GSFC	GSFC	
Structural dynamic testing							GSFC	GSFC	
Advanced structural dynamic test methods							GSFC	GSFC	
Low-cost manufacturing techniques							GSFC	GSFC	
Lightw't dimensionally stable optical bench							GSFC	GSFC	
Structural dynamic/stress analysis							GSFC	GSFC	
Structural/Thermal/Optical Perf. (STOP) an.							GSFC	GSFC	
Acoustic/vibroacoustic analysis							GSFC	GSFC	
Launch vehicle/payload trans't response an.							GSFC	GSFC	
On-orbit jitter vibration analysis							GSFC	GSFC	
Computer-aided design/man. (CAD/CAM)							GSFC	GSFC	
3-D Kinematic simulations							GSFC	GSFC	
Precision mechanisms							GSFC	GSFC	
Vibration suppression (active & passive)							GSFC	GSFC	
Large deployable appendages							GSFC	GSFC	

GSFC Facilities and Laboratories

- **Materials characterization and microscopy laboratories**
  Gas chromatography mass spectroscopy for chemical analysis of cold finger residues & organic materials; Auger electron microscope to identify trace elements in surface films; electron spectroscopy for chemical analysis, depth profiling & secondary electron imaging; x-ray diffraction for identifying crystalline phases, stress analysis, degree of crystallinity and grain size; optics and physics labs with scanning probe microscope, laser dilatometer, plasma etching/atomic oxygen generator; characterization using FTIR microscopy; SEM analysis and instruments for preparing conductive coatings (EDAX capabilities); and optical emission spectroscopy to identify trace elements (PPM) & perform material certs

- **Instrument laboratory (life testing of components/assemblies)**
  Provides life testing of flight components and assemblies (testing of lamps and rotating mechanism assemblies)

- **Mechanical testing laboratory**
  Provides equipment used to characterize physical properties of materials (tensile, impact, & fatigue testing, etc.)

- **Tribology Laboratory**
  Provides friction & wear testing, lubrication studies and refurbishing of flight bearings

- **Nondestructive evaluation laboratory**
  Provides wet film and real-time digital radiography, ultrasonic, thermographic and eddy current testing of components, photographic darkroom for film processing

- **Advanced development laboratory**
  Used to develop advanced applications for spacecraft technology (includes 1,000 pound crane with 17 ft hook height, air table for deployable structures)

- **Contamination measurement laboratory**
  Analysis & measurement of particulate & molecular contamination on various coatings/ surfaces for spacecraft and instruments (measures BRDF, particle size & distribution & vacuum UV effects on coatings)

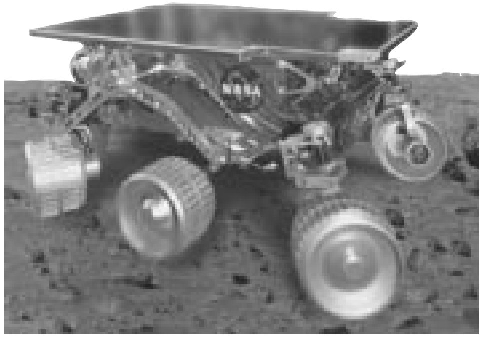
GSFC Facilities and Laboratories, continued

- **Thermal coatings properties laboratory**
  Used for measuring normal emittance/solar absorptance of various paints, tapes, and other thermal control surfaces for virtually all GSFC programs
- **Molecular Kinetics (MOLKIT) Laboratory**
  Used to study and measure molecular kinetics of materials as they outgas in vacuum, measures emission, re-emission rates and mass species of various materials
- **Electromechanical laboratory**
  Used for integration and functional testing of electromechanical systems, jitter vibration testing and mechanism control system sensitivity testing
- **High capacity centrifuge**
  Provides acceleration testing of large spacecraft and instruments; largest facility of its kind in western hemisphere
- **Structural test laboratory**
  Used for structural qualification, screening and characterization of engineering model and flight hardware (vibration, structural & acoustic testing, modal & mass properties characterization, data analysis, and associated computer and control room); includes 6 degree-of-freedom virbation shaker.
- **Electro-plating facility**
  Provides high-quality electro-plating for spacecraft, instrument, detector, and GSE components
- **Composite materials (processing) laboratory**
  Used for layup and cure of composite material components in ultra-low humidity environment
- **Laser welding facility**
  Used for precision laser welding and cutting of spacecraft, instrument, and detector components

Jet Propulsion Laboratory

Technology Application

- Spacecraft and science instrument development and application



Technical Capabilities

- Advanced thermal and structural technology, low temperature science and engineering, mechanical and robotics technologies, and advanced materials and fluid processes technologies
- Structure and configuration, mechanisms, spacecraft and instruments structures and dynamics, flight materials and processes
- Flight hardware materials and analysis, materials testing and comtamination control, and thermal and fluids systems engineering
- Nondestructive examinations of flight hardware by qualified Level III personnel

Facilities and Laboratories

- Spacecraft and instrument fabrication and assembly facilities
- Thermal vacuum chambers for outgassing
- Planetary protection (microbiology) facilities
- Materials development and testing laboratory
- 27-ft Space simulator facility
- 13-ft Space simulator facility
- Thermal-vacuum test chambers
- Acoustic test facility
- Vibration test facilities
- Structural assembly static load test facility
- Cryovac Chamber with controlled mechanical loading
- Advanced actuation materials development and testing facility

Directory of Technical Points of Contact at JPL

COE Leadership Team:

Michael C. Lou, Member Technical Staff, 818-354-3034

Technical Points-of-Contact:

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* Thermal Engineering

JPL Programs and Workforce (FY 98)

Programs and Projects	Workforce CS FTE's
Earth Science Enterprise	
Earth Science Program Projects	78
Technology and Applications Programs	23
Telecommunication & Mission Operation	6
Space Science Enterprise	
Space Science Program Projects	77
Technology and Applications Programs	23
Mars Exploration	25
Telecommunication & Mission Operation	5
Other Programs	
Engineering and mission assurance	3
Structures and Materials Workforce, JPL FTE Total	**240**

3-DIMENSIONAL NEAR ISOTROPIC MACHINABLE COMPOSITE

Point-of-Contact: Greg Hickey, Materials Laboratory Group

A novel 3 D machinable composite material has been developed that has comparable specific strength and 50% better flexural strength compared to 6061 T-6 Aluminum. The material is made from 3 dimensional graphite fiber preform, which has 35% of the fibers in the X direction, 35% of the fiber in the Y direction and 30% of the fibers in the Z direction. This is an improvement over previous stitched fiber preforms, which have a maximum of 15% of fibers in the Z direction. The fiber preform is vacuum impregnated with epoxy, to produce a graphite-epoxy composite material with a density of 1.3 gm/cc. Because the fiber volume percent are nearly uniform in each of the X, Y and Z planes, the resulting composite material has near isotropic properties. The material can be made from fiber preforms up to 4 inches thick. The 3-D material is machinable to complex geometry with conventional machining processes. A minimum gauge thickness of 0.050 inches is achievable without affecting mechanical properties. The material can be threaded to hold fasteners as small as 0-80, or drilled to hold standard steel inserts. The material has been qualified for some flight applications, and has found particular applications for composite joints and end fittings to other conventional 2-dimensional composite tubes and structures. With the appropriate resin system, the material is nonmagnetic, and has found applications on magnetometers.

LIGHTWEIGHT INTEGRATED STRUCTURE AND THERMAL INSULATION

Point-of-Contact: Greg Hickey, Materials Laboratory Group

A improved lightweight integrated structure and thermal insulation has been developed for the Rover Warm Electronics Box (WEB) that has 50 % less mass than a previous opacified silica powder designs and 30 % lower thermal conductivity. The integrated insulation system was developed as part of the Mars Rover Flight Experiment program to provide structure and thermal insulation for the Rover's electronics at a reduced mass than a previous state of the art design. The novelty of this design is to combine a low thermal conductivity fiber reinforced composite structure with an ultra-lightweight hydrophobic solid silica aerogel, which acts as thermal insulation. This innovation produces a structural component with extremely low thermal conductivity. It provides excellent thermal insulation both at low gas pressures and in vacuum; and meets the structural requirements for spacecraft launch loads and for a 30-g impact landing at Mars without damage to the insulation or structure. The new structural insulation system is composed of an E-glass/epoxy sheet and spar structural design, with the column volume filled with low density solid silica aerogel. The solid silica aerogel performs as the thermal insulation, with the thermal design tailored to minimize heat loss through the vertical spars. Between the sheets of the aerogel is gold coated Kapton, which acts as a radiation barrier. The solid aerogel insulation has an extremely low density, 20 mg/cc (1.25 lb/ft3), is hydrophobic, and has good mechanical shock resistance. The thermal conductivity of the structure is not expected to vary at lower vacuum pressures. The system has low outgassing, and is comprised of space flight qualified materials. The structural performance can be tailored to meet a range of design requirements, without compromising the structure's low thermal conductivity. The present design has an application range from -150 °C to 150 °C, and can be modified to extend the environmental range. The design can be expanded in size and geometry.

NEW FABRICATION METHOD FOR LIGHT WEIGHT DS-2 SPIDER
Point-of-Contact: Don Bickler, Advanced Mechanical Systems Group

A method of fabricating curved beam structural elements was invented for the Mars Pathfinder Rover suspension arms. This design results in a thin lightweight curved structural member with closed section to handle both torsion and bending. In fabricating, the center portion of a solid beam is machined out using a relieved cutter to undercut surfaces which have access holes. More specifically, 1) lightening holes are drilled into (or through) the beam, near the centerlines, following whatever curvature exists, 2) a milling cutter reduced in diameter at its shank to allow undercutting after insertion into the holes, is fabricated, and 3) this cutter is used to machine away the center of the beam, leaving a thin wall. Advantages of this technology include metallurgy of the material is unchanged (no welding, no bending), access and curve beam shaping can be from one side only, beam stiffness in the Ixx can be independent from stiffness in the Iyy, and readily fabricated by numerical control machining. This method of fabrication can also make tapered beams curved in different planes having the cross section tailored at each point along the beam. This method is being used to fabricate the spider which mounts the DS2 vehicle.

INFLATABLE SPACE SYNTHETIC APERTURE RADAR (SAR) ANTENNA
Point-of-Contact: Michael Lou, Science and Technology Development Section

An untra-lightweight roll-up SAR array antenna was developed by using space inflatable structures technology. The feasibility of this inflatable SAR concept was successfully proven by testing two 1/3 scale models designed, fabricated and assembled by ILC-Dover and L'Garde, respectively. It was shown that highly controlled deployment of this class of inflatable structures can be achieved by several methods, including embedded constant-force coil springs, Velcro strips and spaces rigidizable aluminum laminates. The flatness and between-layer separation requirements for the RF membranes were met by employing a catenary tensioning system. At this time, RF tests at JPL radar ranges have been completed on the ILC-Dover model with excellent results obtained. The L'Garde model will be RF tested in the near future.

ADVANCED ACTUATORS DRIVEN BY ELECTROACTIVE MATERIALS
Point-of-Contact: Yoseph Bar-Cohen, Mechanical & Robotics Technologies Group

A novel ultrasonic motor has been developed that can operate for an extended period in extremely low temperature and vacuum. (This effort is conducted jointly with QMI and is being commercialized under contract with Teleflex). Further, unique electroactive polymers and mechanisms were developed for miniature robotics and for wiping dust from surfaces. (This is a joint effort with UNM and LaRC).

ADVANCED NDE TECHNOLOGIES
Point-of-Contact: Yoseph Bar-Cohen, Mechanical & Robotics Technologies Group

The JPL NDEAA has been responsible for the development of several key NDE technologies. A Mult-Function Crawler System for in-service rapid, robotic inspection and maintenance has been developed. The system is currently under licensing considerations by Boeing; and the DOD is seeking to use the technology to efffectively address the issue of corrosion on aging aircraft. The LLW method, pioneered by Dr. Yoseph Bar-Cohen and developed jointly with UCLA, enables the determination of composite materials adhesive stiffness constants nondestructively. A methodology for noninvasive probing of ground layers has been developed for planetary applications and currently is used to study coal in mines. Finally, an ultrasonic technology for medical diagnostics and treatment of blood clots is being developed jointly with CSMC and QMI which has the potential for cancer sono-treatment.

MICRODYNAMICS FLIGHT EXPERIMENTS
Point-of-Contact: Marie Levine-West, Advanced Thermal & Structrural Technology Group

The Microdynamics Program, funded by JPL's Interferometry Technology Program, is tasked to assess high-bandwidth sub-micron motions in large precision space optical platforms that could adversely affect the performance of the instruments. Because of possible gravitational effects, low-background noise requirements, and non-existent flight data in the range of interest, two JPL microdynamics flight experiments have been recently flown. The first experiment, IPEX-I, measured the broadband (0-350Hz) micro-g thermal-mechanical stability of the DLR/DASA free-flying platform ASTRO-SPAS. This mission was flown during STS-80 (November 1996). IPEX-I demonstrated that this platform met the stability requirements for a possible space interferometry mission. The second microdynamics flight experiment, IPEX-II, flown during STS-85 (August 1997) measured the thermo-mechanical stability of a 2.3m, 9-bay AEC-ABLEADAM mast boom, cantilevered off the side of the ASTRO-SPAS. This boom is a representative element of several NASA Origins flight programs, and is similar to the SRTM mast (a 1999 flight mission). The instrumentation included 24 micro-g accelerometers, and collocated temperature sensors, with a sampling rate of 1000 Hz. It was demonstrated that, contrary to popular belief, pre-loaded joint-dominated structures do exhibit large transient snapping events. Futhermore, broadband multi-shaker modal tests performed on the boom on-orbit have already indicated a significant increase in damping on-orbit. Post-flight ground modal tests and model correlations will be performed to assess the differences in structural properties. Although the large transient snap disturbances may affect the instrument performance locally, the measured broadband boom stability meets the broadband RMS stability requirements for space interferometry.

FORCE-LIMITED VIBRATION TESTING
Point-of-Contact: Terry Scharton, Dynamics Environments Group

During the past six years, personnel at JPL have developed, demonstrated, and documented the technology for implementing force limiting in vibration tests. Force limiting results in more realistic vibration tests of aerospace hardware and reduces the cost, schedule and performance penalties of overtesting and overdesign. As a result of this effort, force limiting is now used in almost every major vibration test at JPL and in many of the vibration tests at GSFC and aerospace contractors. For example, force limiting was used for the vibration tests of the Cassini and DS1 spacecraft at JPL, the WIRE spacecraft at GSFC, and for many of the instruments on these and other spacecraft. A monograph (NASA RP-1403) which discusses the detailed history, theory, and applications of the method has been completed and widely distributed. In addition, a more concise description of the approach is presented in a complementary handbook (NASA-HDBK-P011), a draft of which is in its second cycle of NASA reviews.

SHUTTLE VIBRATION FORCES
Point-of-Contact: Terry Scharton, Dynamics Environments Group

The Shuttle Vibration Forces Experiment (SVF), which is flying on STS-90 in April 1998 and STS-96 in December 1998, will provide the first known inflight measurements of the vibration forces acting on an aerospace payload at launch. (Only accelerations are typically measured.) The force data are urgently needed to evaluate the analytical and semi-empirical methods currently being used to derive the force limit loads for vibration testing. JPL is providing the principal investigator and force gage instrumentation, GSFC is providing the payload (a shuttle sidewall-mounted Hitchhiker canister), and JSC is providing the stand-alone recorders for this experiment.

COMBINED DYNAMIC TESTING

Point-of-Contact: Terry Scharton, Dynamics Environments Group

The objective of this program is to develop and demonstrate technology for combining dynamic tests (vibration environment, quasi-static design verification, and modal model updating) to reduce cost and schedule without sacrificing the tests' effectiveness. Mounting the vibration test item on force gages enables one to obtain modal data, while conducting an environmental test. In addition, the force measurements also provide a true measure of the cg acceleration for validating the quasi-static design. The combined dynamic testing approach has already been utilized for the DS1 spacecraft and the SVF flight experiment and several other flight projects involving GSFC and LeRC are in the planning stages.

TECHNOLOGY DEMONSTRATION OF A VENUS AEROBOT GONDOLA CONCEPT:

Point-of-Contact: Moktar Salama and Jeffrey L Hall, Instrument Structures and Dynamics Group

The gondola concept under development will demonstrate the feasibility of a temperature and pressure protected instrument-enclosure for use in the exploration of the lower atmosphere and surface of Venus. The gondola will be balloon-born during a Venus AEROnautical roBOT (AEROBOT) mission involving repeated descents to the surface of the planet. The result of this technology demonstration is the design, assembly and testing of a prototype two concentric, thermally-insulated spherical enclosure, that contains most of the key features of an actual device. Performance of the gondola concept is evaluated under a simulated Venus environment of 92 bar pressure, 460∞ C surface temperature, and 250 g deceleration during atmospheric entry. Heating rates and possible heat leak into the gondola will be assessed for two candidate insulation technologies; fiberglass and multi-layer insulation.

DEPLOYMENT DYNAMICS OF INFLATABLE STRUCTURES:

Point-of-Contact: Moktar Salama, Instrument Structures and Dynamics Group, and Michael Lou

The goal of this research is to develop in-depth understanding, analytical modeling, simulation tools, and verification experiments which help ensure predictable deployment of future inflatable space structures. Most inflatable space applications require such a capability. The deployment process is simulated from the packaged (folded) state to full inflation in order to assess the stability of deployment. Flow of the inflating gas and its interaction with the extremely flexible folded membrane material of the inflatable enclosure are represented by a control volume model and the gamma law gas equation of state. Various packaging schemes are being studied. To verify assumptions made in the simulation model, a number of basic laboratory experiments are performed using high speed photography to monitor relevant deployment parameters.

MULTIFUNCTIONAL STRUCTURES AND FLEX INTERCONNECT TECHNOLOGY

Point-of-Contact: Tosh Fujita, Thermal & Fluids Systems Engineering Group

Multifunctional Structures (MFS) and associated Flex interconnect Technology were selected by the New Millennium Program (NMP) as a breakthrough technology. The technology provider is Lockheed Martin Astronautics (LMA) with sponsorship from the Air Force Research Laboratory (AFRL), Phillips Site. An experiment to validate several key elements of MFS technology is incorporated in the NMP Deep Space 1 (DS-1) flight. The Flex Interconnect Technology, a key technology within MFS, is being validated as an enabling component of the NMP Deep Space 2 (DS-2) Micropenetrator to be deployed on the Mars 98 mission. The MFS approach focuses on minimizing weight and dimensions, simplifies integration of Multichip Modules (MCMs) by providing sockets, uses bonded flexible interconnect jumpers between standardized circuit patches having thermal control provisions in the substrate. The copper polyimide circuit patches and inter-patch jumpers mounted on a composite spacecraft panel essentially eliminates electronic chassis and cabling. This maximizes the ratio of electronic parts at the lowest level to the packaging volume and results in significant weight and volume savings (up to 90% based on paper redesigns of existing spacecraft). In addition, this design method supports volume production and assembly accuracy thereby increasing yield and lowering manufacturing costs. Use of the bonded flexible jumpers developed for MFS as the basis for flex circuitry was proposed for the NMP DS2 Mars Micropenetrator. Key benefits were the provision of miniaturization and the ease of accommodating MCMs. In ensuing discussions, an additional application as a tether interconnect between the forebody and aftbody was also identified. Both of these uses for flex interconnect material have become flight enabling due to mass, volume and assembly limitations. The forebody size prevents the use of traditional wiring regardless of conductor size. The tether system is approximately 2 m long by 7 mm wide and is “fanfolded” into a small rectangular box on the aft end of the forebody. When the penetrator strikes the surface, the flex is pulled out of the forebody as it travels downwards. The system has performed flawlessly in multiple airgun tests into varying densities of soil. The anisotropic bonding system for interconnecting the flex has been tested to -100 degree C to demonstrate compatibility with the surface and subsurface temperatures to be encountered.

JPL Capabilities: Technology Development

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
Technology Development:TRL 4-6									
Precision deployable structures								JPL	
Inflatable structures								JPL	
Active smart structures							JPL	JPL	
Precision, stable optical benches							JPL	JPL	
Lightweight precision reflectors							JPL	JPL	
Lightweight collapsible suspension for planetary mobility systems								JPL	
Lightweight dexterous manipulator arms for planetary sampling							JPL	JPL	
Pyrotechnic experimentation DBR laser velocity testbed								JPL	
Deformable space reflectors							JPL		
Dynamic test methods, modal testing, force-limited testing, system ID							JPL	JPL	
Vibroacoustic loads prediction							JPL	JPL	
Vibration suppression/isolation							JPL	JPL	
Microdynamics Analysis/testing							JPL	JPL	
Multi-functional structures							JPL	JPL	
Planetary aerobot mat'ls & thermal coatings							JPL	JPL	
NDE of microelectronics / microsystems							JPL	JPL	
Microelectric packaging materials							JPL		
Piezoelectric/electrorestrictive actuators							JPL		
Loads analysis methodologies								JPL	
Development of of complex, 3-D composite							JPL	JPL	
Lightweight propellant tanks								JPL	
Silicon carbine structures							JPL	JPL	
High-speed impact physics								JPL	
Thermally insulated structures							JPL	JPL	
Cryogenic structures and sensors							JPL	JPL	

JPL Facilities and Laboratories

- **Spacecraft and instrument fabrication and assembly facilities**
  Machine shop for fabrication of specialty structural components such as optical bench hardware, complete fabrication (sheet metal, welding, etc) facility for specialty spacecraft and instrument needs, large clean room for final assembly and functional checkout of complete systems.

- **Thermal vacuum chambers for outgassing**
  Thermal vacuum chambers for outgassing bakeout of structural and mechanical components and subassemblies to meet contamination requirements. Temperatures of up to 150 C are possible for outgassing bakeouts.

- **Planetary protection (microbiology) facilities**
  Planetary protection facilities and equipment to preclude microbiological and other forms of contamination on hardware to be sent to other solar system bodies

- **Materials development and testing laboratories**
  Mechanical property characterization at temperatures from 4 K to 2200 K, STM microscopy, X-ray diffraction, SEM/EDS, ESR and ENDOR spectroscopy, molecular contamination investigation facility for evaluating material outgassing properties, chemical analysis laboratory, and composites prototype laboratory.

- **27-ft Space simulator facility**
  Space simulator facility, 27 ft diameter, 85 ft high, 1 x 10-6 torr, cryogenically cooled walls, -185 C to +105 C, 2.7 Solar Constants. The maximum solar beam size is 19-ft in diameter, providing a test volume of 19-ft by 25-ft high. A thermal data acquisition system is available with a capability of 1000+ channels.

- **13-ft Space simulator facility**
  Space simulator facility, 10 ft diameter, 35 ft high, 1x10-6 torr, cryogenically cooled walls, -185 C to +150 C

JPL Facilities and Laboratories, continued

- **Thermal-vacuum test chambers**

  Wide variety of thermal-vacuum test chambers including ultra-clean chambers for optical components. Chambers range in size from 3-ft by 3-ft horizontal to 10-ft by 10-ft horizontal. All chambers have cryogenically cooled walls, -185 C to + 105 C and are capable of 1x10-6 Torr. All chambers can be fitted with quartz windows for solar or optical testing.

- **Acoustic test facility**

  18 ft x 21 ft x 26 ft chamber, 157 dB OA, 20 - 1000 Hz, Class 10,000 cleanliness. Eight channel microphone control is possible and 100 channels of signal conditioning and data recording is available.

- **Vibration test facilities**

  Variety of shakers up to 28,000 lb; sine, random, transient, shock spectrum and force-limited testing, and modal testing. Vibration control is provided by a state of the art M+P vibration control system utilizing up to 32 channel external control. 100 channels of signal conditioning and data acquisition is available.

- **Structural assembly static load test facility**

  System and subsystem structural test facility with test cell size of 15 ft x 15 ft x 30 ft 16-channel automated load control, with a wide variety of load cells and force actuators up to 50,000 lb.

- **Cryovac chamber with controlled mechanical loading**

  Torque/force loading system Model 20UD made by SATEC integrated with other test hardware allowing to measure the electrical, mechanical (torque, force, strain and displacement) and thermal performance of actuation materials and devices under controlled conditions. A vacuum chamber (10-2 torr) with a cryo-cooling system (down to 120K). Also, a custom modified Janis ST-400 system for high vacuum (10-6 torr) and a broad temperature range from77K to 450K capable of operating from 5K.

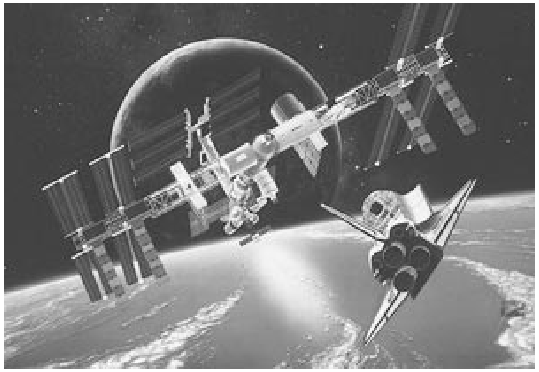
- **Advanced actuation materials development and testing facility**

  A facility for fabricating and testing piezoelectric and electrostictive actuation materials is part of the nondestructive examination lab. A large number of electrical parameters can be analyzed in the 10 Hz to 32 MHz frequency range using a Schlumberger Impedance Analyzer Model 1260. Displacement is measured with a Kaman Model KDM-7200 unit, which provides a resolution of 0.1 micron and can be operated down to cryogenic temperatures.

Johnson Space Center

Technology Applications

- Space shuttle
- Space station
- Advanced spacecraft development and application



Technical Capabilities

- Materials and failure analysis
- Manufacturing and process development
- Non-metallics manufacturing
- Structural design, analysis, and certification; vibration and acoustic flight environmental testing and analysis, static and fatigue testing
- Thermal analysis, design and development, and combined temperature/pressure testing to simulate reentry environmental conditions
- Mechanical design, analysis, and testing to support the develop of spacecraft flight hardware
- Hypervelocity impact resistant materials, design, and testing

Facilities and Laboratory at JSC:

- Radiant heating test facility
- Atmospheric reentry materials and structures evaluation facility
- Vibration and acoustics test facility
- Materials technology laboratory
- Structures test laboratory

at White Sands Test Facility

- Hazardous hypervelocity impact facility
- High flow test facility
- Ignition susceptibility and flammability test facility
- Hazardous fluids test facility
- Instrumented mechanical impact test facility
- Long-term pressurized testing facility
- Burst testing facility
- Materials compatibility laboratory
- Offgassing and outgassing test laboratory
- Chemistry and metallurgy laboratory
- High energy blast facility
- Vapor and gas phase detonation facility

Directory of Technical Points of Contact at JSC

COE Leadership Team:

Edward T. Chimenti	Chief, Structures and Mechanics Division	281-483-8883

Technical Points-of-Contact:

Glenn J. Miller	Dep Chief, Structures and Mechanics Division	281-483-8831
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Gail Horiuchi	Chief, Materials and Processes Technology Br	281-483-8927
Harry Johnson	White Sands Test Facility	505-524-5722

JSC Programs and Workforce (FY 98)

Programs and Projects	Workforce CS FTE's
Aeronautics and Space Transportation Technology Enterprise	
Reusable Launch Vehicles (X-33 Program)	2
Human Exploration and Development of Space Enterprise	
Shuttle (fracture, labs, and flight hardware)	10
Station (fracture, labs, flight hardware, X-38 and Transhab)	46
Other Programs	
White Sands Test Facility	11
Structures and Materials Workforce, JSC CS FTE Total	**69**

Notes: 1. Workforce includes civil service S&E's, program managers, and technicians assigned to the specific programs.
2. Does not include "indirect/overhead" civil servants or other Government Agency personnel co-located at the Center.
3. Does not include on-site personnel such as contractors, students and professors, or NRC Post-Doctoral Fellows.

TransHab Development Testing
Point-of-Contact: Glenn J. Miller, Dep. Chief, Structures and Mechanics Division

TransHab is an inflatable structure proposed to the International Space Station Program as an enhanced living quarters for on-orbit crew members. The development unit of the TransHab underwent successful hydrostatic testing in the JSC Neutral Buoyancy Lab on May 30th. The twenty five foot diameter development unit, consisting of a bladder, restraint layer, and central core, was pressurized with water to verify the behavior and structural integrity of the component materials. The system performed as predicted passing a proof pressure of 22.1 psi without leakage and failing at approximately 33 psi in a longeron seam away from the shell to core interface. Additional tests in mid-July will seek to demonstrate the enhanced performance of a woven seam configuration over the sewn pattern previously used in the May testing. The first full scale test of the prototype TransHab structure will be in a thermal vacuum chamber and will demonstrate packaging and inflation techniques. This October test will include a redundant bladder, full length restraint layer and a MMOD layer consisting of foam and Nextel. Design of this test article is currently underway.

X-38, Vehicle 201 Assembly
Point-of-Contact: Glenn J. Miller, Dep. Chief, Structures and Mechanics Division

The 201 vehicle will be the spacecraft used by the X-38 program to demonstrate the application of technology necessary for an operational Crew Return Vehicle. The 201 vehicle will be carried aloft in the Orbiter payload bay and released on-orbit for an atmospheric reentry flight. The assembly of the cabin primary structure is progressing on schedule. The riveting of the forward two bays of the cabin has been completed with the aft two bays in work. The exterior composite panels that attach to the cabin frames are being matched drilled as each bay is finished out. After the match drilling, the panels are removed and the bonding of the Thermal Protection System tiles begins. The assembly of the aft fuselage which attaches to the cabin is scheduled for mid-July. Components of the aft fuselage are being designed and fabricated in Europe. Other structural systems such as the fins, body flaps and rudders will be integrated into the assembly this fall, working towards a completed airframe by mid-December of 1998. Static testing of this proto-flight structure is scheduled for the spring of 1999.

JSC Capabilities: Technology Development

Structures and Materials
Center of Excellence

Capabilities \ Applications	Aircraft		Space Transportation				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
Technology Development:TRL 4-6									
Durability, environmental effects, mis. sim.			JSC					JSC	
Structural concepts			JSC					JSC	
Computational methods & design tools			JSC		JSC			JSC	
Subcomponent design & manufacturing			JSC		JSC			JSC	
Experimental methods & verification tests			JSC		JSC			JSC	
Manufacturing of composites for adv. sys.			JSC					JSC	
Automated design through mfg.			JSC		JSC			JSC	
Product database dev. and management			JSC		JSC			JSC	
Fracture mechanics analysis and control			JSC					JSC	
Miniature manufacturing			JSC					JSC	
Damage detection: modal techniques			JSC					JSC	
Arc jet & large radiant heat entry sim. test					JSC				
Vibration and acoustic testing			JSC					JSC	
Thermal vacuum testing			JSC					JSC	
Rapid prototyping			JSC						
Nanotube production and applications							JSC	JSC	

JSC Facilities and Laboratories

- **Radiant heating test facility**

  Facility provides a multizone high temperature radiant heating capability for testing large spacecraft TPS and structures in a controlled pressure environment to simulate reentry thermal profiles, thermal gradients and pressure conditions. The facility supports performance of advanced system tests requiring accurate simulations of temperatures to 2800 F in a controlled pressure environment with pressures as low as 0.5 Torr. Test articles up to 6 ft x 8 ft can be tested utilizing 22 independent heater zones to produce necessary thermal gradients. The facility has both 8 ft diameter, 10 ft diameter, and 10 ft x 20 ft stainless steel vacuum chamber.

- **Atmospheric reentry materials and structures evaluation facility**

  The facility provides the capability to test TPS and components subjected to heating profiles, pressure profiles, and gradients experienced by space vehicles during atmospheric entry. The facility consists of two test chambers each having an arc-heater, test nozzles, diffusers, heat exchangers, four-stage ejector vacuum system, and a 10 megawatt power system. The 10 ft and 12 ft diameter test chambers are available for long duration convective / radiative reentry environment simulation and materials testing. Both test chambers can be configured with supersonic or hypersonic conical nozzles having exit diameters from 5 to 40 inches and supersonic rectangular channel nozzles. The rectangular channel nozzle can accommodate test panel sizes of 8 x 10, 12 x 12, and 24 x 24 inches.

- **Vibration and acoustics test facility**

  The laboratories contained in this facility provide the capability to perform a wide range of testing including all aspects of acoustic, vibration, structural dynamics and shock. The facility consists of five separate laboratories capable of accommodating a wide range of test subject sizes. These five laboratories include the general vibration laboratory, modal test laboratory, sonic fatigue laboratory, spacecraft acoustic laboratory, and spacecraft vibration laboratory.

JSC Facilities and Laboratories, continued

- **Materials technology laboratory**
  The facilities consists of separate laboratories specializing in chemical analysis, optical analysis, thermal properties analysis, electron microscopy, flammability testing, atomic oxygen analysis, elastomeric materials testing, nondestructive testing, metallurgy, and mechanical properties testing.

- **Structures test laboratory**
  The facility consists of several servohydraulic test systems, several electromechanical test systems, a hydrostatic proof station, and data acquisition systems for measuring material properties of metallic and non-metallic materials. The load capability in the facility is 640 Kips in tension or compression.

JSC: at White Sands Test Facility

- **Hazardous hypervelocity impact facility**

  The Hazardous Hypervelocity Impact Facility is a remote, access-controlled test area capable of simulating micrometeoroid and orbital-debris impacts on spacecraft materials and components. The facility was designed to safely handle and test hazardous targets, making it unique within NASA. Five two-stage light gas launchers, 1.8 mm (0.07 cal), 4.3 mm (0.17 cal), 7.6 mm (0.30 cal), 12.7 mm (.50 cal), and 26 mm (1 in.) diameter, are used to launch particles at velocities up to 8 km/s (26,000 ft/s). A site-wide hazardous fluid handling and disposal network allows toxic, reactive, and explosive targets, such as pressurized containers and aerospace fluids, to be safely evaluated. Release energies up to 2.3 kg (5 lb) TNT equivalent can be accommodated within the facility's sealed target chambers. An external concrete pad was designed to accommodate a shaped charge launcher and is approved for free-air energy releases up to 11.3 kg (25 lb) TNT equivalent.

- **High flow test facility**

  The High Flow Test Facility is designed to conduct flow testing of materials and components in oxygen, nitrogen, or hydrogen gases at pressures up to 6000 psig and temperatures of up to 1000 °F in oxygen and nitrogen. Typical flow rates for oxygen/nitrogen test system are from 1.0 to 5.0 lb/s at pressures between 3000 and 4000 psig with outlet temperatures between 400 and 750 °F. A typical flow time for oxygen at 1.0 lb/s from 6000 to 3000 psig is 292 min. Maximum flow rate is approximately 8.0 lb/s at approximately 2500 psig. Typical flow rates for the hydrogen test system are from 0.25 to 1.1 lb/s at pressures from 3000 to 4000 psig and ambient temperature. A typical flow time for hydrogen at 0.25 lb/s from 6000 to 3000 psig is 24 min. Maximum flow rate is approximately 2.0 lb/s at approximately 3000 psig.

- **Ignition susceptibility and flammability test facility**

  Tests for evaluations of ignition sensitivity and flammability of materials used in habitable areas of spacecraft and liquid and gaseous oxygen systems are conducted following NASA and ASTM test methods. The NASA tests are conducted per NHB 8060.1C and include the following: upward flame propagation, heat and visible smoke release rates by cone calorimetry, flash point of liquids, wire insulation flammability, impact sensitivity in liquid or gaseous oxygen, sensitivity to pneumatic impact, promoted combustion of metals in oxygen, and arc tracking. ASTM tests methods capabilities include: autogeneous ignition temperature of liquids and solids in a high-pressure oxygen enriched environment, oxygen index, heat of combustion. Other ignition and flammability evaluation capabilities include configurational testing, large-scale fire testing, and special testing, such as frictional ignition and particle impact ignition of metals and metal alloys.

WSTF Facilities and Laboratories, continued

- **Hazardous fluids test facility**

  The Hazardous Fluids Test Facility supports testing of materials and components with hazardous fluids including high-pressure gaseous oxygen and liquid oxygen, high-pressure hydrogen, liquid hydrogen, hydrazine, monomethylhydrazine, and nitrogen tetroxide. Testing with exotic propellants and other hazardous fluid such as unsymmetrical-dimethylhydrazine, fluorine, red fuming nitric acid, inhibited red fuming nitric acid, ammonia, and hydrogen fluoride can also be accommodated. Component test capabilities include testing and analysis of components for functionality and fluid compatibility. Tests vary from engineering development testing of prototypes to qualification and life-cycle testing, including off-limit and destructive testing. Analysis capabilities include hazards analyses of component system interactions and component failure analyses, including nondestructive evaluation of component failures and failure modes. Material testing can include testing to explosive failure. Individual test cells can withstand an explosive event of 1.9 lb of TNT equivalent.

- **Instrumented mechanical impact test facility**

  The Instrumented Mechanical Impact Test Facility contains a drop weight impact test machine and associated data acquisition system and video display monitor. Test can be run on a variety of materials and test articles over a wide range of impact velocities, impactor geometries, and test media including ambient or cryogenic conditions. The facility is set up for remote operation, and pressurized testing is conducted inside a specially designed blast enclosure to contain blast wave and test article fragmentation in the event of a burst-upon-impact event.

- **Long-term pressurized testing facility**

  The Long-Term Pressurized Testing Facility provides the long-term pressurized storage of pressure vessel type test articles in either the undamaged or known damaged condition. Each test article is housed in a separate and independent test enclosure designed to decelerate and contain vessel fragments and test fluid with no effect on nearby vessels and personnel. Each enclosure is equipped with an independent pressure piping system. The facility is environmentally controlled. Test articles are typically tested utilizing a noncorrosive test media such as high-purity mineral oil.

- **Burst testing facility**

  The Burst Testing Facility has a fully integrated burst testing capability for the testing of pressure vessels and pressure components. The testing of test articles at precisely defined pressurization rates can be performed inside specially designed blast enclosures that provide both safety and controlled-burst events. Analysis capabilities include both traditional failure nalysis capability and nondestructive evaluation of test article failure mode coupled with scanning electron microscope fracture analysis.

WSTF Facilities and Laboratories, continued

- **Materials compatibility laboratory**

  Material compatibility studies are performed with aerospace propellants using immersion testing, isothermal microcalorimetry, accelerating rate calorimetry, and electrochemical methods to determine the reactivity of a material with a propellant. Immersion testing can be performed at specified use temperatures or the standard temperatures of 25 and 71 oC followed by post-test analysis of the fluid and material. Isothermal microcalorimetry is used to measure as little as 10 microwatts of heat and is especially useful in determining the reactivity of materials with fluids at near ambient temperatures of 25 to 55 oC. Accelerating rate calorimetry measures the temperature increase in an adiabatic system as a result of an exothermic reaction in the range of 100 to 350 oC. The combination of a direct current (dc) electrochemical technique and alternating current (ac) impedance spectroscopy provides data on the corrosion resistance of alloys, performance of corrosion inhibitors, dissimilar metal effects, and susceptibility of materials to pitting and crevice corrosion.

- **Offgassing and outgassing test laboratory**

  The Offgassing and Outgassing Test Laboratory performs offgas testing of materials, assembled items, and payloads in accordance with NASA Handbook NHB 8060.1 and the U.S. Navy submarine materials control protocol. Special test capability includes airtight gloveboxes used for simulated-use testing. Outgas testing, the release of gaseous compounds from a material or article under vacuum conditions, is performed in accordance with ASTM E595 and NASA SP-R-0022A. Configurational thermal vacuum stability testing can be performed on large payloads using thermally controlled quartz crystal microbalances. Bonded storage area for Flight Items, and a Class 1 electrostatic discharge protective workstation are available.

- **Chemistry and metallurgy laboratory**

  Chemical analysis, materials testing and non-destructive evaluation can be performed in both non-hazardous and highly reactive and toxic fluids such as hydrazine, monomethylhydrazine, nitrogen tetroxide. Analytical capabilities include Auger-ESCA, SEM-EDS, ICP-Mass Spectrometry, HPLC, Capillary electrophoresis, GC-Mass Spectrometry, Thermal Analysis (TMA, TGA, DSC), gas chromatography, spectroscopic methodologies (FTIR, UV-Visible, Atomic Absorption, Optical Emission), microcalorimetry, and Accelerating Rate Calorimetry. Mechanical properties tests of metallic and polymeric materials include tensile, compression, impact, hardness, and low-cycle fatigue. Vacuum melting of developmental alloys and thermal treatment by vacuum and inert atmosphere furnaces are also conducted. Non-destructive evaluation (NDE) capabilities include liquid penetrant, magnetic particle, ultrasonic imaging (contact and immersion flaw detection), experimental stress analysis, acoustic emission, electronic speckle pattern interferometry, infrared thermography, x-ray radiography, x-ray-computed tomography, neutron radiography, real-time x-ray radiography, and flash radiography.

WSTF Facilities and Laboratories, continued

- **High energy blast facility**

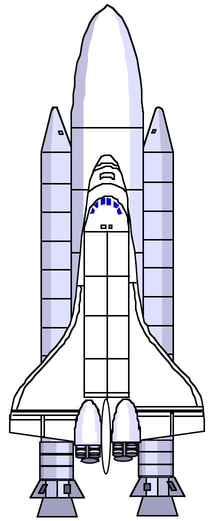
  The High Energy Blast Facility is a remote test facility, which has been designed to withstand explosive blasts equivalent to 500 lb of TNT. Testing with solid, cryogenic, and hypergolic propellants and with high explosives can be performed. The facility is equipped to handle the toxicity and environmental issues associated with these propellants. The data acquisition system is currently configured to obtain 100 data channels at 1 mega samples per second. Eight of these channels have extended memory modules (256 K samples per channel). Overpressure measurements from 4 to 500 ft can be obtained. Three 10,000 frame per second cameras, three 500 fps cameras, and standard video are available. All overpressure data and film and video frames are time correlated using IRIG timing.

- **Vapor and gas phase detonation facility**

  The detonation tubes and fluid supply systems have been designed for use with hypergolic propellants and are constructed from 300 series stainless steel and Teflon. The facility is equipped to handle the toxicity and environmental hazards associated with these propellants. Various gases can be supplied, and liquid media can be infected into the tubes. Initial test temperatures range from ambient to 400 K. Initial test pressures range from 10 to 150 kPa. Use of various initiators and initiation energies is possible. High speed data acquisitions systems are used to record velocity and pressure data. Experimental data are compared to Gordon-McBride code predictions of Chapman-Jouget velocity and pressure. Smoked foils are used to record detonation cell sizes.

Kennedy Space Center

Technology Applications



- Space launch operations

Technical Capabilities

- Materials characterization and analysis, material properties, nondestructive examination, and failure analysis
- Malfunction analyses and development testing of electrical and electronic subsystems, modules, and components
- Corrosion prevention and control
- Design, development, and troubleshooting of space launch facilities and ground support equipment

Facilities and Laboratory

- Chemical Analysis
- Materials Testing and Analysis
- Metrology
- Electrostatic Discharge Evaluation
- Beach Corrosion Exposure Facility
- Nondestructive Examination
- Electrical/Electronic Analysis
- Launch Equipment Test Facilities (LETF)

Directory of Technical Points of Contact at KSC

COE Leadership Team:

Timothy R. Bollo	Chief, Materials Science Division	407-867-7051

Technical Points-of-Contact:

Scott H. Murray	Lead Engineer, Mechanical Systems	407-867-3400
Coleman J. Bryan	Chief, Testing Branch	407-867-7051
Gary Lin	Chief, Analysis Branch	407-867-7051
Roger D. Hall	Chief, Elec. & Mech. Ground Support Sys. Of.	407-867-7589
John F. Poppert	Chief, Development Testing Laboratory	407-867-9509

KSC Programs and Workforce (FY 98)

Programs and Projects	Workforce CS FTE's
Aeronautics and Space Transportation Technology	
Support of Launch Operations	17
Human Exploration and Development of Space Enterprise	
Support of Launch Operations	52
Structures and Materials Workforce, KSC CS FTE Total	**69**

Notes: 1. Workforce includes civil service S&E's, program managers, and technicians assigned to the specific programs.
2. Does not include "indirect/overhead" civil servants or other Government Agency personnel co-located at the Center.
3. Does not include on-site personnel such as contractors, students and professors, or NRC Post-Doctoral Fellows.

Aqueous cleaning and analysis process developed to replace the traditional CFC methods
Point-of-Contact: Timothy W. Bollo, Chief, Materials Sciences Division

As a result of the mandated reduction and projected eventual ban of the use of chlorofluorocarbons (CFC) by the Montreal Protocol, the Materials Science Laboratory (MSL) developed an aqueous cleaning and analysis process to replace the traditional CFC methods. As a starting point in 1990, the MSL focused on using ultrasonication with hot, deionized water for cleaning small components and hot water/steam impingement for large components. After investigating several analytical procedures, it was found that total organic carbon (TOC) analysis of the final rinse water was a suitable analytical method. Additional studies verified that the aqueous ultrasonic/TOC method compared favorably with traditional CFC methods for cleaning and nonvolatile residue validation of precision cleaned hardware.

Failure analyses and accident investigations
Point-of-Contact: Timothy W. Bollo, Chief, Materials Sciences Division

The Materials Science Laboratory has conducted failure analyses and accident investigations for such disparate organizations as NASA, the Air Force, Navy, Marines, Coast Guard, Office of Naval Intelligence, Bureau of Alcohol, Tobacco, and Firearms (ATF), Occupational Health and Safety Administration (OSHA), and the National Transportation Safety Board (NTSB). The most intensive accident investigation performed by the laboratory in the past year was the investigation of the post-launch explosion of Air Force Delta Mission 241. All disciplines within the laboratory were utilized to ascertain the cause of the loss of the $150,000,000.00 mission. Other accident investigations have included crashes of Air Force reconnaissance aircraft, rescue vehicles, and ballistic missile D-5 railcars. Mishap investigations involving multiple fatalities have been conducted on general aviation aircraft and industrial equipment. The laboratory assisted the NTSB in the investigation of TWA Flight 800. Recently, an analysis was conducted on components from the Advanced X-ray Astrophysics Facility (AXAF) space-based telescope slated for future launch aboard the Shuttle. The laboratory performed failure analyses on components

KSC Capabilities: Mission Support

Structures and Materials
Center of Excellence

Applications / Capabilities	Aircraft		Space Transportation*				Spacecraft		
	Airframe	Engine	Pri. Str.	Cryotank	TPS	Engine	Instru't	Structure	Power
Research: TRL 1-3									
Technology Development:TRL 4-9									
Materials analysis and characterization			KSC	KSC	KSC	KSC			
Failure analysis			KSC	KSC	KSC	KSC			
Nondestructive examination			KSC	KSC	KSC	KSC			
Electrical / electronic analysis			KSC	KSC	KSC	KSC			
Corrosion prevention and control			KSC	KSC	KSC	KSC			
Acoustic and overpressure env & loads an.			KSC	KSC	KSC	KSC			
Structural and thermal stress analysis			KSC	KSC	KSC	KSC			
Fracture mechanics, crack growth, life pred.			KSC	KSC	KSC	KSC			
Structural stability and wind load analysis			KSC	KSC	KSC	KSC			
Structural dynamics, modal, & transient res.			KSC	KSC	KSC	KSC			
Space and weight structural optimization			KSC	KSC	KSC	KSC			
Vibroacoustic design and analysis			KSC	KSC	KSC	KSC			

***Capabilities provide mission support to ground launch facilities and equipment in addition to the launch vehicle.**

KSC Facilities and Laboratories

- **Chemical Analysis**

  Scanning electron microscopy (SEM) with energy dispersive and wavelength dispersive spectroscopy (EDS and WDS), emission spectroscopy (inductively coupled plasma spectrometer), infrared spectroscopy, mass spectroscopy, polarized light microscopy, wet chemistry, x-ray fluorescence spectroscopy, x-ray diffraction, and x-ray photoelectron spectroscopy (XPS).

- **Materials Testing and Analysis**

  Ability to perform failure analyses and physical/mechanical testing of metallic and nonmetallic materials. Includes: SEM with EDS, metallographic specimen preparation equipment, metallographic microscopes, stereomicroscopes, image analysis system; Rockwell, Brinell, micorhardness, and portable hardness testers, shore durometers, electrical conductivity tester for aluminum; thermal analysis equipment including thermogravimetric analyzer, thermomechanical analyzer, differential scanning calorimeter, dynamic mechanical analyzer; tension and compression testing machines with capacities from 2 g - 120,000 lb, thermal/vacuum chamber sizes at large chamber (1.22m x 1.22m x 1.52m) - 1 torr; -72 to 177 ^{o}C and small chamber (0.61m x 0.61m x 0.91m) - 10^{-7} torr; up to 205 ^{o}C; walk-In environmental chamber: -34 to 85 ^{o}C; 5-95% relative humidity, convection ovens up to 700 ^{o}C, salt fog chamber, weatherometer for UV exposure, vibration testing with 11,000 lb-force shaker and 3 ft x 3 ft slip table mechanical, fluid, and electromechanical components testing including pneumatic panels provide up to 3,000 psig GHe or GN2, and a 10,000 psig GN2 chamber is available for low-volume static component testing, hydraulic test bench, up to 5,000 psig; photodocumentation equipment includes Polaroid, 35mm, video and digital cameras, video printers, scanners, images can be placed on internet site (secured, if necessary) for remote viewing.

- **Metrology**

  Optical Comparator for 2-D measurements (accuracy to 0.0002 in.), coordinate measuring machine for 3-D measurements (accuracy to 0.0002 in.), non-contact video measuring machine for 3-D measurements, various gages (thread, hole, height, depth), micrometers.

KSC Facilities and Laboratories, continued

- **Electrostatic Discharge Evaluation**

  Evaluation of triboelectric (voltage generation and dissipation) activity of materials. Applications include developing and evaluating protective clothing for hazardous environments, assisting manufacturers in developing antistatic materials, including coatings and fabric, and devising practical solutions to potentially hazardous static conditions in electronics, explosives, aerospace, petrochemical and transportation industries.

- **Beach Corrosion Exposure Facility**

  The test site is located within 100 ft of the Atlantic Ocean. The Atmospheric Corrosion Site is an outdoor exposure facility with 600 ft of front row exposure for atmospheric corrosion specimens. 110 volt power and data acquisition connections are available within the site to power test articles and record onboard data instrumentation outputs. The Seawater Immersion Facility is composed of two immersion tanks with a continuous once-through, filtered supply of seawater pumped directly from the ocean. The water in the tanks is continuously monitored for salinity, temperature, dissolved oxygen, and pH. Power and data acquisition connections are available. A Weather Station is located within the test site, providing continuous information on air temperature, humidity, wind direction and speed, rainfall, total incident solar radiation, and incident ultraviolet B radiation levels. The Corrosion Laboratory is an indoor facility for on-site specimen preparation and evaluation. Electrochemical experiments, such as DC polarization resistance and AC impedance testing, can be performed here.

- **Nondestructive Examination**

  Nondestructive examination capabilities include: computed tomography, conventional radiography (x-ray and isotope), microfocus/real-time radiography, ultrasonic testing (thickness, flaw, liquid level, bolt torque), magnetic particle testing, liquid penetrant testing, eddy current testing, leak testing (helium mass spec., bubble, ultrasonic), infrared, and boroscopic

KSC Facilities and Laboratories, continued

- **Electrical/Electronic Analysis**

  Ability to perform malfunction analyses and development testing of electrical and electronic subsystems, modules, and components, including integrated circuits, transducers, instrumentation, cables, connectors, switches, controls, batteries, power supplies, motors, and other electrically powered devices. This capability includes alternating current and direct current power systems with the ability to test DC devices with up to 1,000 amperes at 28 volts and to test AC devices from 40 to 4,000 hertz with up to 6 kilovoltamperes at up to 280 volts. Voltage and current measuring equipment is capable of measuring up to 1,000 volts and up to 400 amperes. When necessary, the MSL uses an explosion chamber for destructive tests that may result in a violent reaction or produce smoke. Electronic modules and components are analyzed using a spectrum analysis system that can automatically perform a complete analysis over the range of 100 kilohertz to 12 gigahertz. KSC engineers can provide high frequency analyses on RF and Microwave. In addition, signal-generating equipment provides up to 100-megahertz signals, and digitizing oscilloscopes can acquire and analyze signals up to 400 megahertz. Component analysis equipment is capable of measuring complex component characteristics with capacitance from 0.00001 picofarads to 100 millifarads, 0.00001 ohms to 100 megaohms, and 0.00001 millihenrys to 100 kilohenrys. Digital electronic circuit diagnosis is performed using a Hewlett-Packard 16500A logic analysis system provides 12 channels of 50-megabit-per-second pattern generation and 80 channels of 25-megahertz state and 100-megahertz timing analysis, for diagnosis at both the module and component level. Microelectronic component analysis is performed using a semiconductor microcircuit capability which includes the ability to electronically probe and troubleshoot integrated circuits and perform microfocus x-ray imaging. When required, lab engineers identify failure mechanisms by preparing optical micrographs, scanning electron micrographs, and infrared micrographs of semiconductor junctions and other circuit components.

- **Launch Equipment Test Facilities (LETF)**

  The Launch Equipment Test Facilities provides simulation of the ground system's support structure and the vehicle during both static (non-firing) and lift-off conditions. The facilities provide the capability to develop, test, and check out ground support equipment including structures, servicing systems, launch accessories, and pyrotechnics. The facilities include a machine shop, fabrication shop, and model shop; a high bay and low bay; and a control room. The M7-505 Hi Bay includes a 10 ton bridge crane in a 60'x100'x70' assemby area with environmental control. The M7-505 Low Bay includes controlled shipping and receiving area, an assembly area, hydraulic charging unit, and a random motion simulator (RMS) hydraulic system. The control room includes extensive instrumentation capability for test control and data acquisition. The facility also includes the following vehicle systems test beds: liftoff simulator, random motion simulator, 600 ton test fixture, holddown post test fixture, and various specialized test fixtures for space shuttle umbilicals.

Stennis Space Center Facility

Technical Point-of-Contact: Bill Parsons, 601-688-1982

- **E-2 Test Facility (High Heat Flux Facility)**

  The combined environment actively cooled the test article with a Heat Flux capacity of 2500 BTU/FT2-sec and thermal storage (1700 degrees R) of gaseous hydrogen. Facility duration totals 60 seconds at maximum conditions and is limited by the Pebble Bed Heater. (The E-2 Test Facility, formerly known as the High Heat Flux Facility, was constructed to support materials development for the National Aerospace Plane (NASP) by subjecting special test articles to extreme temperature conditions. This facility has grown into a versatile test complex and has been modified after the cancellation of the NASP program. This facility would require some investment and time to be ready to be used as a High Heat Flux Facility but the basic infrastructure is in place.)

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13. ABSTRACT (Maximum 200 words)
This report presents the implementation plans of the Center of Excellence (COE) for Structures and Materials. The plan documented herein is the result of an Agencywide planning activity led by the Office of the Center of Excellence for Structures and Materials at Langley Research Center (LaRC). The COE Leadership Team, with a representative from each NASA Field Center, was established to assist LaRC in fulfilling the responsibilities of the COE. The Leadership Team developed the plan presented in this report.

A comprehensive inventory of Agencywide technical capabilities in structures and materials is contained in the Appendix.

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