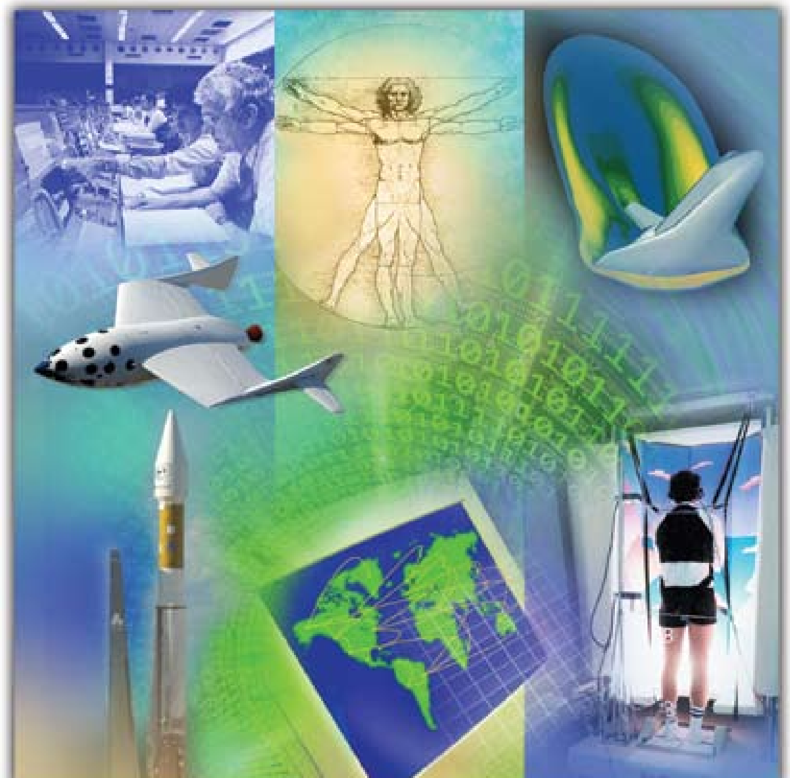
AST

Associate Administrator for
Commercial Space Transportation

Destination FAA

Associate Administrator for Commercial Space Transportation Research and Development Accomplishments FY 2004



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Mission

AST's mission is to ensure protection of the public, property, and the national security and foreign policy interests of the United States during a commercial launch or reentry activity and to encourage, facilitate, and promote U.S. commercial space transportation.

Introduction

This document describes seven Research and Development (R&D) projects undertaken by the Associate Administrator for Commercial Space Transportation (AST) in the Federal Aviation Administration (FAA) during fiscal year 2004. Four new research projects were selected and assigned to an AST division. Work also continued on three projects initiated in FY 2003. In addition to a description of each project, a summary of accomplishments to date is provided.

The AST safety research supports the development of the policy, standards, and guidance material needed to meet FAA goals and objectives. Such research is also essential in developing the knowledge necessary to maintain and improve FAA/AST materials used to verify that the products and procedures of launch vehicle and site operator licensees and applicants adequately comply with applicable safety standards.

To that end, AST formulated and instituted an R&D activity to support its mission and the FAA's strategic goal of safety. The AST Research and Development Plan provides a process for effectively applying resources for research based on clearly identified safety priorities each fiscal year. This Plan was used to solicit candidate research projects from internal sources, such as AST aerospace engineers and projects. External sources, such as the Commercial Space Transportation Advisory Committee (COMSTAC) Reusable Launch Vehicle (RLV) Working Group, were also solicited.

First, the AST R&D Advisory Board evaluated candidate research projects for relevance to AST's mission, relative importance, and cost. Second, the AST R&D Advisory Board ranked the candidate research projects to arrive at a prioritized list to present to the AST R&D Senior Steering Committee for review. Third, the AST R&D Senior Steering Committee selected the R&D projects to undertake in FY 2004 that had the greatest potential to fulfill AST's mission and to meet its budgeted requirements. Lastly, the R&D Advisory Board and Senior Steering Committee held periodic R&D project status reviews throughout the year.

Non-Traditional Flight Safety Systems and Integrated Vehicle Health Monitoring

AST initiated a follow-on study to a report on non-traditional flight safety systems that was completed in FY 2003. Flight safety systems minimize the threat to public safety and property posed by a malfunctioning launch vehicle. Non-traditional versions of these systems include autonomous and semi-autonomous systems that interface with pilots, ground controllers, or both. This follow-on study will apply a verification methodology developed in the FY 2003 report to an autonomous flight safety system currently being developed and tested by NASA.

To date, AST has conducted initial meetings and developed a study plan with its contractor, ITT Industries, headquartered in Reston, Virginia. ITT will conduct this research and complete the research report. Results and lessons learned during this trial application will provide AST with insight into the most appropriate methods for granting regulatory approval for license applications proposing use of these types of systems.

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Human Space Flight Safety

Under a cooperative research effort with the FAA's Civil Aerospace Medical Institute (CAMI) concerning commercial human space flight, aeromedical guidelines for commercial launch vehicles were completed. The CAMI is the medical certification, research, and education wing of the United States Department of Transportation, Federal Aviation Administration's Office of Aerospace Medicine located at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma. Through CAMI's National Research Council (NRC) program, a senior researcher worked on this AST R&D project to develop minimum guidelines for environmental control and life support systems and medical guidelines for assuring human survival during commercial launch vehicle operations.

This research effort began in August 2003 and culminates in a final report that the CAMI senior researcher delivers to AST. Results of this research effort will provide guidance to reusable launch vehicle operators who propose to carry crew and passengers and assist AST in evaluating such proposals.

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Structural Inspection Through Bonded Thermal Protection Systems

AST continued an FY 2003 R&D project to research existing and new techniques for inspecting components covered by Thermal Protection Systems (TPS). Assuring the health and flightworthiness of reusable launch vehicle (RLV) structures is a fundamental concern for the success and safety of future commercial space launch ventures. The myriad material- and component-level inspection processes performed throughout the manufacturing, testing, and service life of these flight hardware systems are critical to achieving this assurance. Nondestructive evaluation (NDE) methods used for assessing the quality of flight structures are among the most vital inspection processes. Such methods enable inspection without damaging, sampling, or otherwise sacrificing the inspected parts. Several NDE techniques are suitable for subassembly inspections; however, options narrow as material systems and subassemblies are integrated, and accessibility for inspection becomes limited.

Accessibility is particularly relevant to RLV flight structures covered with thermal protection systems. These systems provide necessary thermal barriers against harsh environments imposed during reentry or by other operational heat loads. As the external skin of the vehicle, TPS play a crucial role in protecting critical structural elements. The design and capabilities of TPS vary with location and vulnerability of the underlying structure. Examples of material systems used for TPS include ablative or durable insulation coatings, bonded or sprayed multilayers, flexible blankets, and ridged refractory tiles. These TPS can constrain access to the underlying structures for inspection. In some cases, removal and reapplication of the TPS may be required to inspect these structures. Where direct access to critical flight structures is unavailable or impractical without damaging the underlying structure, inspection processes that can penetrate the TPS are needed. An understanding of present NDE capabilities also serves to aid identification and guide development of advanced NDE techniques offering improved potential for inspection of future RLV structures.

This R&D project was completed in July 2004 when AST contractor, Aerospace Corporation (El Segundo, California) delivered its final report. This report presents a brief, descriptive summary of various NDE methods relevant to inspecting launch vehicle structures covered by TPS. Basic issues affecting inspection of such structures are identified. Inherent strengths and limitations of the various NDE techniques as they relate to the projected needs of future RLV systems are described.

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Develop and Calibrate a Reentry Vehicle Hazard Model

The FAA maintains public safety associated with commercial launch vehicle activities by developing safety standards and acceptable methods of verification. The FAA/AST intends to improve public safety regarding commercial space launch vehicles by investigating improvements to methods of analyzing debris survivability. In FY 2003, AST initiated an R&D project to develop a tabular handbook that would allow launch and reentry vehicle developers to perform a first-hand estimation of casualty expectation (E_c) for the reentry phase of missions. In developing this handbook, AST focused on the aerothermal demise of the reentry debris analysis process.

In addition to the development of the Aerothermal Analysis Handbook, AST tasked Aerospace Corporation (El Segundo California) to prepare a report addressing the enhancement of existing hazard models using the nonmetallic debris fragments recovered from the Space Shuttle *Columbia*'s reentry breakup. The primary focus will be on using the *Columbia* debris to calibrate existing vehicle breakup scenarios, trajectories, and predicted heating loads.

Results of this research project will help identify public safety issues associated with AST-licensed launch and reentry activities and mitigate risk to people on the ground caused by falling debris. In FY 2004, Aerospace produced a draft handbook that will enable an applicant to perform a first estimate of the E_c for a given mission. This interim report contains survivability tables for multiple materials (aluminum, titanium, and steel) and shapes (sphere, flat plate, square, and cylinder) as well as instructions on how to use the tables. The final report is scheduled for completion in February 2005. Because this R&D project has reached a sufficient level of maturation, it is considered essentially complete and was transitioned to an internal AST program.

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Radio Frequency Blackout During Reusable Launch Vehicle Reentry

A study was initiated to increase understanding of the high-temperature plasmas associated with space vehicle reentry that greatly affect radio frequency (RF) signal reception between the vehicle and ground controllers. Both voice communication and data telemetry between the reentry vehicle and ground control can suffer severe degradation or total loss during the most critical phase of the flight. This disruption occurs during an extended period encompassing before and after the maximum dynamic pressure phase. The resulting radio blackout can block controller communications and adversely affect safe operations.

Three main classes of representative vehicles were chosen for study: unpowered lifting glide vehicles, ballistic reentry vehicles, and powered air-breathing hypersonic vehicles. Within each of these groups, a number of specific subgroups were postulated that represent either existing or designed vehicles that may experience blackout conditions. Unpowered lifting glide vehicles include the Space Shuttle Orbiter and several designs for hypersonic boost-glide vehicles, such as the crew return vehicle. Ballistic reentry vehicles include sharp tip (ballistic missiles) and blunted cone designs (Gemini and Apollo reentry capsules). At this time, one private enterprise's reentry vehicle design, the Kistler Aerospace Corporation (Kirkland, Washington) K-1, falls within the ballistic reentry category, with a blunted cylinder flared at its end. Powered air-breathing hypersonic vehicles are still in the concept development and design stages.

The study considered two boundary layer, electron density, and collision frequency profiles for the sharp-tipped conical body, one at low altitude (15 kft) and one at high altitude

(154 kft). For the low altitude case, the plasma layer is thin and has an extremely high collision frequency (~150 GHz). At high altitudes, the plasma layer is thicker, and the collision frequency is several orders of magnitude less. The electron density and collision frequency were reduced to a data list which can be input to the planar code. These two profiles were used to determine the reflection from and transmission through the plasma over a transmission frequency range from 0.5 to 50 GHz.

The interim draft report, produced by AST contractor, Aerospace Corporation (El Segundo, California), addressed

- understanding of methods to mitigate communication outages during reentry and enable controller communications for operation within the National Airspace System and near space for civilian commercial space reusable launch vehicles operating within the Space and Air Traffic Management System,
- recommendations on techniques for reduced RF reception errors on reentry craft for Global Positioning System and other RF navigation signals,
- recommendations on methods for uninterrupted communications through plasma sheaths, and
- recommendations on requisite frequency bands to facilitate an AST decision on whether or not to request that the Federal Communications Commission reserve selected bands.

The final report is scheduled for completion in December 2004.

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Assessment of Alternate Methodologies for Establishing Equivalent Satisfaction of the Expected Casualty Criterion for Launch Licensing

AST completed a report summarizing the review of an alternate analytical methodology to meet the Expected Casualty (E_c) criteria for reusable launch vehicles (RLV), as proposed by the Commercial Space Transportation Advisory Committee (COMSTAC) RLV Working Group. This FY 2004 R&D project was performed to determine whether this approach demonstrated a level of safety equivalent to existing E_c analysis methods. The proposed alternate methodology derives an allowable catastrophic failure rate for RLVs, allocates that failure rate to subsystems, and proposes the use of a Failure Modes, Effects, and Criticality Analysis (FMECA) to demonstrate that the allocated allowable failure rates have been met. AST examined the proposed methodology by investigating the traditional FMECA process, including its advantages and disadvantages. Current use of FMECA within the FAA for aircraft certification, expendable launch vehicle licensing, and RLV licensing was documented. Then, the proposed process was reviewed and compared to existing AST processes for determining E_c.

This alternative ties the system safety process directly to specified reliability goals and is similar to methods used for commercial aircraft; however, the proposed methodology suffers drawbacks. Specifically, reliability goals and reallocations stated in this methodology were derived from aircraft experience and may not apply to RLVs. Additionally, this methodology does not include casualty area or population density.

Failure Modes, Effects, and Criticality Analysis is an excellent hazard analysis and risk assessment tool, but it suffers from other limitations. This alternative does not consider combined failures or typically include software and human interaction considerations. It also usually provides an optimistic estimate of reliability. Therefore, FMECA should be used in conjunction with other analytical tools when developing reliability estimates.

Results of this research will help AST in the development of future reliability and risk assessment guidelines in support of the RLV license evaluation process. While the proposed alternate methodology does not convincingly demonstrate a level of safety equivalent to existing E_c analysis methods, based on this AST study, it presents some concepts for further consideration. These concepts include setting vehicle reliability levels in support of system safety and using analytical methods, such as reliability allocation, to demonstrate those reliability levels. The resulting final report recommends that AST investigate setting vehicle reliability levels as safety criteria and investigate methods that combine rigorous analytical techniques with limited tests and flight experience to demonstrate an equivalent level of safety to that of the existing E_c analysis method.

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