Commercial Space Transportation

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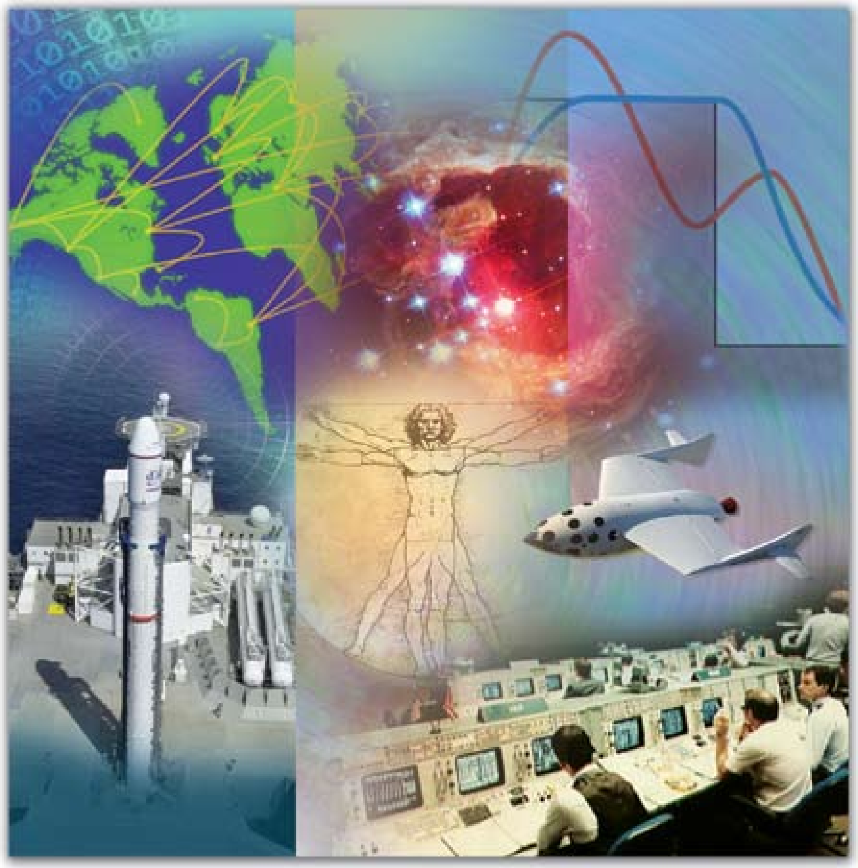

FY-2005 Research and Development Accomplishments

October 2005

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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 five Research and Development (R&D) projects undertaken by the Office of Commercial Space Transportation (AST) in the Federal Aviation Administration (FAA) during fiscal year 2005. Three new research projects were selected and assigned to an AST division. Work also continued on two projects, one initiated in FY 2003 and the other in FY 2004. 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 Working Group (RLVWG) and Launch Operations Support Working Group (LOSWG), 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 2005 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.

Debris Risk Analysis

As part of the commercial launch licensing process, AST uses computer-based models to develop casualty expectations associated with launch accidents affecting the uninvolved public. This research project evaluates the fidelity of the current computer models of buildings and how people within them would be affected by debris resulting from such accidents. Validity of AST's models is important because these calculated results are used to establish limits on launch parameters and insurance requirements, both of which may cause considerable burden to launch operators.

This project compares data from actual explosive-created damage to inhabited buildings, and the resulting debris-caused casualties, with the computed results from AST models. Data collected from the bombings at the Khobar Towers, London during WWII, Oklahoma City, and SCUD missile attacks on Israel provide the basis for this comparison.

Before this evaluation, the AST models had been judged too conservative, but this anecdotal view does not appear to be the case so far. To date, only the Khobar Towers data have been evaluated, and the analysis revealed a good correlation between the AST models and real-world data. This initial finding remains to be supported by the research on the other three locations.

This project is slated for completion in 2006.

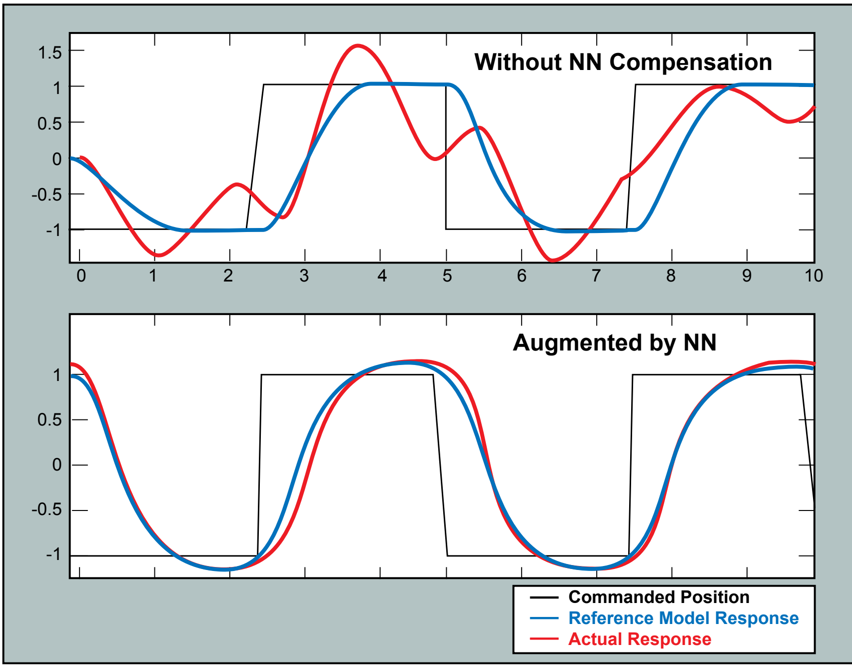
Supports FAA Strategic Goal: SAFETY

Reconfigurable Control Allocations for Reusable Launch Vehicles

AST initiated a study on reconfigurable control allocations for next generation reusable launch vehicles (RLVs) in FY 2005. This study evaluated advanced guidance and control methods that may have significant potential to increase the safety and reliability of future RLVs and to reduce the cost of performing trajectory guidance as well as navigation and control analysis. Management of emergency situations arising from control surface degradation or actuator failure, using other available operating mechanisms and a reconfigured adaptive control strategy, may improve safe mission return or abort scenarios. This generic problem widely affects the general class of RLVs and is of great importance from a safety perspective.

Having RLV control algorithms adapt to changing flight conditions, using available control surfaces and effectors, would be desirable. A key aspect is the ability of the guidance laws to distribute control responsibility among available actuators in a reconfigured mode with a new management strategy that adjusts the flight profile to reflect the modified goal, such as safe mission return.

To this end, AST built upon the NASA-derived concept of an executive reconfiguration control scheme that is independent of the physical hardware layer if a major component failure occurs. Such a hierarchical scheme means the overall reconfiguration control allocation arrangement is design and device independent. Therefore, the approach applies to all generic RLV physical equipment incorporating an autopilot.



An adaptive controller example, designed around a linearly approximated model of the actual system, was studied. Any nonlinearities or model errors, such as actuator failures, affect the performance of the control system and potentially lead to instability. To compensate for these modeling deficiencies, a neural network (NN) was used to augment linear controllers. Figure 1 shows the comparison between the system response, with and without NN compensation, in response to commanded plant (RLV) dynamics in the presence of unmodeled uncertainties and the resulting improvement in system response.

Supports FAA Strategic Goal: SAFETY

Radio Frequency Blackout During Reusable Launch Vehicle Reentry

A study was completed to assess the radio frequency blackout phenomenon caused by plasma generation around reusable launch vehicles (RLVs) during reentry. Methods for mitigating this condition that might apply to prospective commercial space vehicles for operation within the National Airspace System and Space and Air Traffic Management System were evaluated.

Toward this end, the ability to predict the ionized flow field and, thereby, identify the altitude of blackout onset has been demonstrated. This phenomenon is most likely to be encountered in the high-altitude regime. Four mitigation methods, under active and passive classes, were studied: aerodynamic shaping, injection of liquids, application of magnetic fields, and use of high frequencies.

Passive methods, such as aerodynamic shaping and use of high frequencies, appear the most promising. Results were derived for a body with sharp-tipped antenna, and the effectiveness compared to Shuttle and Kistler orbital vehicles. Findings indicate that through such methods it may be possible to significantly reduce the signal blackout and attenuation periods to maintain continuity of communications.

Such passive approaches, which alleviate the signal attenuation condition, might be more amenable for commercial segment reentry RLV bodies for cost effectiveness reasons. Secondly, initial efforts to identify frequency bands suitable for communications in the presence of plasma shielding has been made.

Supports FAA Strategic Goal: SAFETY

Non-Traditional Flight Safety Systems and Integrated Vehicle Health Monitoring

TAST completed a follow-on study to the report on non-traditional flight safety systems performed in fiscal year 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 fully autonomous systems and semi-autonomous systems that interface with pilots, ground controllers, or both. AST anticipates the application of autonomous and semi-autonomous methods to spacecraft safety and health-monitoring systems in the near future. Proper regulation of these systems is essential to maintaining a consistent level of safety at a variety of ranges and spaceports.

In the 2003 study, AST developed a verification framework for the regulatory approval of non-traditional systems. In an effort to gauge the effectiveness of this methodology, this framework was applied to an autonomous flight safety system being developed and tested by NASA at its Wallops Flight Facility. Because this program is still evolving, portions of the test evaluation relied on current plans as well as the results of completed tests. Results and lessons learned during this trial application provided AST with additional insight into the various approaches for granting regulatory approval for commercial applications of these types of systems.

1Fudge, Michael, Thomas Stagliano, and Sunny Tsiao. Non-Traditional Flight Safety Systems & Integrated Vehicle Health Management Systems Descriptions of Proposed & Existing Systems and Enabling Technologies & Verification Methods: Final Report. Contract DTFA01-01-D03013, Delivery Order 3. Prepared by ITT Industries, Advance Engineering & Sciences Division, for the FAA Office of the Associate Administrator for Commercial Space Transportation. August 26, 2003. (See http://ast.faa.gov/files/pdf/DO3_Report_final.pdf, accessed September 23, 2005.)

Evaluating Expendable Launch Vehicle Weather Delays

A study aimed at identifying the top weather-related reasons for delays and scrubs experienced by expendable launch vehicles (ELVs) was completed. Weather plays a direct role on all aspects of launch operations, starting with prelaunch operations, continuing through vehicle processing, and ending with mission success. Any delay or scrub directly influences launch costs, which can easily exceed hundreds of thousands of dollars.

This study provides useful information regarding typical launch delays and scrubs and expected environmental conditions on a given range throughout the year.
Such information will help commercial ELV launch operators make sound decisions regarding launch operations and planning. These results highlight new methodologies and help identify areas for future studies to aide commercial ELV operations.

Over 300 launches from the Eastern Range at Cape Canaveral, Florida, and the Western Range at Vandenberg Air Force Base, California, were examined to determine the most frequent types of weather-related delays and scrubs that occurred from 1988 through 2005. In addition, data from several recent launches at Kodiak Launch Complex in Kodiak, Alaska, were reviewed. Weather delays and scrubs were divided into the following categories:

Lightning Launch Commit Criteria	Range Safety	User Weather Constraints	Other
Natural Lightning	Blast	Lightning	Down range weather
Clouds	Ceiling	Precipitation	
Smoke plumes	Debris	Solar	
Electric fields	Toxics	Temperature	
Triboelectrification	Visibility	Winds	

At both the Eastern Range and the Western Range, 21 percent of the scrubs and 8 percent of the delays were weather-related. However, these events were caused by differing constraints during differing times of the year. For example, Eastern Range scrubs frequently occurred during the summer and were typically influenced by lightning launch commit criteria. Western Range delays and scrubs occurred primarily from December to May and were usually associated with user constraints, such as upper level winds. Note, however, down range weather was responsible for 13 percent of these occurrences. While insufficient data exists to develop statistically valid trends for Kodiak, its top weather-related delays and scrubs occurred during the summer and showed a linkage to such range safety constraints as visibility and to lightning launch commit criteria, such as clouds.

Supports FAA Strategic Goal: SAFETY