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NASA's Spaceliner Investment Area Technology Activities

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Abstract

NASA's has established long term goals for access-to-space. The third generation launch systems are to be fully reusable and operational around 2025. The goals for the third generation launch system are to significantly reduce cost and improve safety over current conditions. The Advanced Space Transportation Program Office (ASTP) at the NASA's Marshall Space Flight Center in Huntsville, AL has the agency lead to develop space transportation technologies. Within ASTP, under the Spaceliner Investment Area, third generation technologies are being pursued in the areas of propulsion, airframes, integrated vehicle health management (IVHM), avionics, power, operations, and range. The ASTP program will mature these technologies through both ground and flight system testing.

The Spaceliner Investment Area plans to mature vehicle technologies to reduce the implementation risks for future commercially developed reusable launch vehicles (RLV). The plan is to substantially increase the design and operating margins of the third generation RLV (the Space Shuttle is the first generation) by incorporating advanced technologies in propulsion, materials, structures, thermal protection systems, avionics, and power. Advancements in design tools and better characterization of the operational environment will allow improvements in design margins. Improvements in operational efficiencies will be provided through use of advanced integrated health management, operations, and range technologies. The increase in margins will allow components to operate well below their design points resulting in improved component operating life, reliability, and safety which in turn reduces both maintenance and refurbishment costs. These technologies have the potential of enabling horizontal takeoff by reducing the takeoff weight and achieving the goal of airline-like operation. These factors in conjunction with increased flight rates from an expanding market will result in significant improvements in safety and reductions in operational costs of future vehicles.

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The paper describes current status, future plans and technologies that are being matured by the Spaceliner Investment Area under the Advanced Space Transportation Program Office.

Introduction

NASA's Office of Aerospace Technology (OAT) is trying to answer the following fundamental questions:

(1) How can we enable revolutionary technological advances to provide air and space travel for anyone, anytime, anywhere, more safely, more affordably, and with less impact on the environment, and improve business opportunities and global security?

(2) What cutting edge technologies, processes, techniques, and engineering capabilities must we develop to enable our research agenda in the most productive, safe, economical, and timely manner? How can we most effectively transfer knowledge from our research and discoveries to benefit both commercial ventures and the quality of human life?

To address these questions, OAT has set the following four goals:

(1) Revolutionize Aviation: Enable a safe, environmentally friendly expansion of aviation.

(2) Advanced Space Transportation: Create a safe, affordable highway through the air and into space.

(3) Pioneer Technology Innovation: Enable a revolution in aerospace systems.

(4) Commercialize Technology: Extend the commercial application of NASA technology for economic benefit and improved quality of life. [1]

The Advanced Space Transportation Program (ASTP) Office at the NASA's Marshall Space Flight Center (MSFC) in Huntsville, Ala. focuses on future space transportation technologies in support of OAT Enterprise's mid- and long-term goals. ASTP's primary objectives are to significantly improve safety and reduce payload transportation cost to low earth orbit (LEO) and in-space transfer. The Spaceliner Investment Area (SLIA), one of four investment areas in ASTP, focuses on the third generation reusable launch vehicles (RLV), see Figure 1, with goals to significant improve safety and reduce operational costs of future space access vehicles.

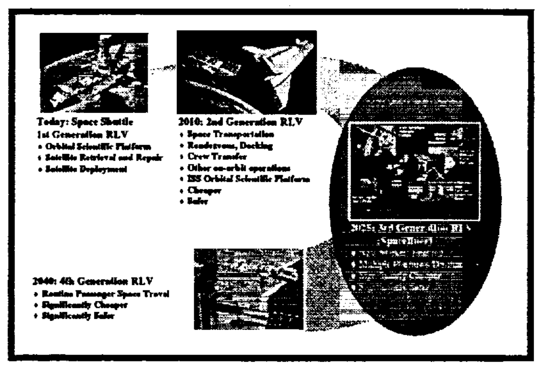

Figure 1. RLV Evolutionary Path

The plan is to substantially increase the design and operating margins to improve component robustness by allowing components to operate well below their design point. This approach will increase life, reduces maintenance and refurbishment requirements, and improve reliability. Improvements in operational efficiencies will be provided through use of advanced integrated health management, operations, and range technologies. These technologies have the potential of enabling horizontal takeoff by reducing the takeoff weight and achieving the goal of airline-like operation. These factors in conjunction with increased flight rates from an expanding market resulting from decreases in the cost of accessing space will result in significant improvements in both safety and costs of future vehicles.

Spaceliner Investment Area (SLIA) consists of the following seven main areas of focus:

- Propulsion
- Airframe
- Integrated Vehicle Health Management (IVHM)
- Avionics
- Power
- Operations & Range
- Demonstrators (flight)

Figure 2 indicate how the resources are to be invested in each of the areas over the next six years. The majority of the investment is applied to propulsion technologies.

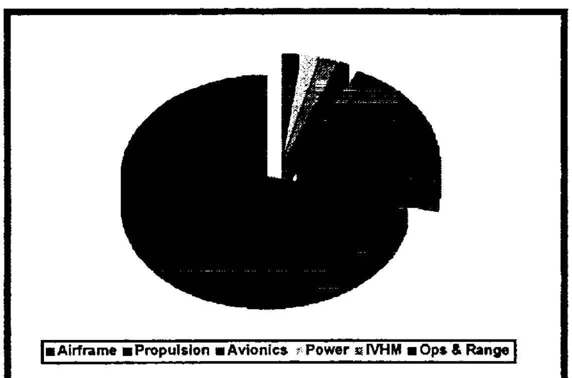

Figure 2. Spaceliner Investment

The next major investment is in airframe technologies and the remaining projects are approximately equally divided. The funding for the flight demonstrator area is currently not included.

The following sections provide a description of the activities in each technology area under the SLIA for the Advanced Space Transportation Program Office. Because of current budget limitations, the SLIA was recently restructured. The propulsion and airframe technologies are the only areas receiving funding in fiscal year (FY) 01. The other technology areas will be funded at the required level to support the demonstrator activities in FY 02. Funding for other needed technologies for the operational vehicle are planned to begin in FY 03.

Propulsion Technologies [2]

The SLIA Propulsion Projects have set the following technical challenges:

- Mission average specific impulse > 500seconds
- Increased propulsion system thrust-to-weight
- Increased life cycle capability to 500 missions
- Decrease development and operational costs
- Improve flight safety
- Improve analytical tools

Due to limited resources available the last several years, the major emphasis has been on the development of the rocket-based combined cycle (RBCC) flowpaths. Recently the projects were refocused to provide a more balanced approach for developing all the propulsion technologies required for a third generation RLV.

An extensive set of foundational technologies was proposed. These technologies deal primarily with material development and characterization and tools development. A lot of the material development focuses on high temperature/high strength applications to improving the thrust to weight ratio and allowable operating margins of propulsion systems. The tool development applies to fluid, structural, and system analyses. The main areas of focus for the foundational technologies are shown in Figure 3.

- ♦ Light Weight/ Long-Life Materials
  - Ceramic/CMC for Turbomachinery
  - Ceramic for Combustion Devices
  - Polymer Matrix Composite for Components
  - Cooled Composites for Nozzles & Structures
- ♦ Tools
  - Structures
  - Flow
  - System Analysis
- ♦ Advanced Propellants
  - Densified Propellants
  - High Energy Hydrocarbons
  - Advanced Monopropellants for Reaction Control Systems

Figure 3. Foundational Technologies

The crosscutting component technologies' primary focus is to develop components applicable to multiple propulsion concepts. The foundational technologies that have been developed will be incorporated into component designs. These components will support the planned subsytem and system demonstrators. The main technologies being pursued in this area are shown in Figure 4.

The focused concepts area evaluates specific advanced propulsion designs and performs detailed experimental evaluation, conceptual engine designs, and integrated flowpath performance assessment. This area focused primarily

- ♦ Turbomachinery
  - CMC Blisk
  - Bearings
  - MMC Housings
  - Ceramic/CMC Materials
- ♦ Combustion Devices
  - Ignition Devices
  - Lightweight Injectors/Thruster
  - CMC Chambers
- ♦ Nozzles & Cooled Structure
- ♦ Valves
- ♦ Instrumentation
- ♦ Seals

Figure 4. Crosscutting Component Technologies

on the RBCC flowpath development in the last several years. Three flowpaths have been tested in both direct and freejet tests facilities, see Figure 5. Summaries of the test results were presented at AIAA conferences in 1999 [3,4].

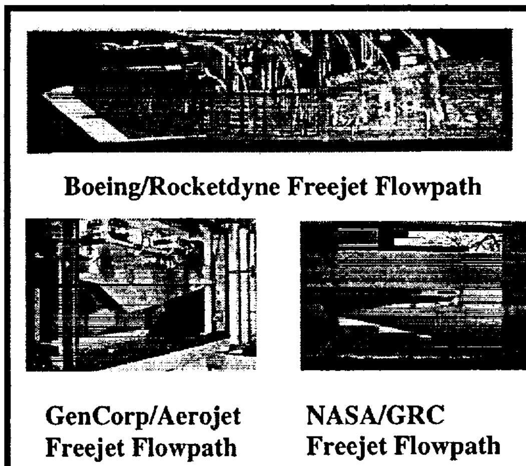

Figure 5. RBCC Test Articles

Future activities will include additional RBCC flowpath testing, turbine-based combined cycle (TBCC) testing and advanced rocket engine testing.

Two propulsion system testbeds, one for subsonic testing of airbreathing combined cycles and one for testing advanced rocket technologies, will be become the primary ground test facilities for propulsion systems and for verifying new technology performance in a system environment. Both of these testbeds will be located at NASA's Stennis Space Center. The advanced hydrogen rocket system testbed will be available for testing third generation advanced rocket technologies in 2003. This testbed is currently used for testing second generation RLV technology. The first engine system test article in the subsonic airbreathing testbed will be a flight-type RBCC engine, referred to as ISTAR. ISTAR will be a complete engine system that will include all the ancillary hardware, e.g., turbopumps, valves, manifolds, ignition systems, controller, etc. The design and scale of ISTAR will be the same as the engine for the first combined cycle flight demonstration. Sea level static testing of ISTAR is currently scheduled for 2005. Supersonic testing will take place in existing national facilities.

Airframe Technology

The airframe technologies being pursued are integrated airframe designs, integrated structures and materials, thermal protection system, structures and materials, and aero/aerothermal enhancements. Materials, design tools, and integrated airframe systems are the main focus of this area. Flight testing of sharp leading edges and ground testing of subscale hot/warm wing structures and conformal airframe/tank/TPS are planned. Also, propulsion/airframe integration capability incorporating all aero/aerothermal tasks (tools development, transition, morphing, and plasma, as well as CFD and wind tunnel experiments) will be developed. An integrated conformal tank/wing stub large-scale ground test article with the required IVHM is planned for FY 08.

IVHM Technologies

The IVHM technology area is responsible for the system engineering and integration of the health management system for all the subsystems. IVHM will develop the health monitoring technologies for the propulsion, structures, TPS, avionics, power, and ground operations subsystems. Some of the primary focus areas are smart sensors, self-healing systems, and informed maintenance systems. The activities main products will support the planned airframe and propulsion test articles and flight demonstrators.

Avionics Technologies

The avionics technologies include advancement of technologies in the area of information transport and processing, autonomous control and operations, self-adaptation intelligent flight systems and advanced software generation and verification. Some of technologies being considered are low power, embedded avionics that require no active thermal control and are fundamental components of other subsystems, fully autonomous intelligent controls that are adaptable and evolvable, and autonomous software code generation and verification. Also, advanced guidance, navigation and control systems, low cost avionics, fault tolerant intelligent networks, and robust avionics architectures are being considered. The activities main products will support the planned airframe and propulsion test articles and flight demonstrators.

Power Technologies

The power technologies are group in three major catagories, power management, storage and generation, and electrical actuation, see Figure 6. Power management and distribution technologies include high power switching, high power/high temperature electronics, and intelligent internal thermal control. Storage and generation includes energy storage devices (e.g., super capacitors), hybrid power sources (e.g., lithium polymer batteries, and advanced fuel cells and turbo-alternator technologies.

Power Management & Distribution
- High voltage/High current
- High Temperature
- High Power Density
- Thermal Control

Storage & Generation
- Batteries
- Super Capacitors
- Flywheels
- Fuel Cells
- Turbo-Alternator

Electric Actuation (EA)
- EA Technology Development
- Peak Power Storage Devices
- Supporting Components

Figure 6. Power Technologies

Electric actuation devices will be use for vehicle control surfaces and engines. The activities main products will support the planned airframe and propulsion test articles and flight demonstrators.

Operations and Range Technologies

The operations and range technologies being considered are Spaceport range and operations, ground operations, and launch-assisted takeoff. The goal is to minimize hands-on operations and maximize automated processing. Launch-assisted takeoff using magnetic levitation has been demonstrated at MSFC on a 50 feet track. Future plans include constructing 2,000 feet long track at Kennedy Space Center for demonstrating speed up to 600 mph. The current activity will focus primarily on the support required for the planned airframe and propulsion test articles and flight demonstrators.

Flight Demonstrators

The flight demonstrator area includes all demonstration vehicles required to mature those technologies that cannot be adequately tested on the ground. One of the major drivers for flight demonstrators will be propulsion technology. The dependence of airbreathing propulsion engine performance on vehicle design and the limitations of current wind tunnel facilities make flight demonstration mandantory. The first flight demonstrators will be the Hyper-X (X-43) vehicles that will test Scramjet technology at Mach 7 and 10. This will be the first flight demonstration of an integrated hydrogen fueled scramjet engine and hypersonic vehicle. The expendable vehicle is 12 feet in length and will be air dropped from a B-52 and then accelerated to either Mach 7 or 10 by a Pegasus solid booster. The vehicle will then separate from the booster and ignite to demonstrate powered scramjet flight. The current status of the Hyper-X program was presented at an AIAA conference earlier this year [5]. A series of three flights are planned, two at Mach 7 and one at Mach 10, see Figure 7.

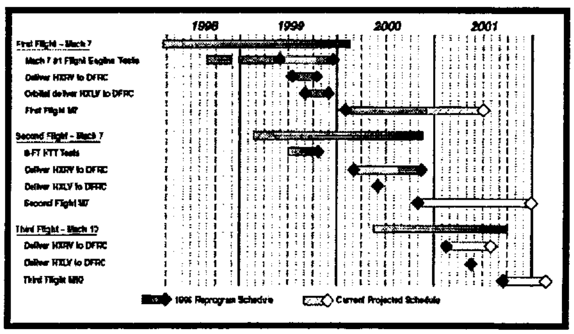

Figure 7. Hyper-X Program Schedule [5]

Additional demonstrators are being planned. Currently, the exact number and sequence of these demonstrators are being evaluated. However, additional subscale ramjet/scramjet testing as well as combined cycle testing (both RBCC and TBCC) is being planned. Hydrogen as well as hydrocarbon fueled engines is being considered. The first flight demonstration of a combined cycle engine will be the RBCC propulsion system (ISTAR). It is envisioned to fly around 2008.

System Analyses

In conjunction with the test program, system analyses are also being performed to assess technology benefits and impacts on future operational vehicles. The vehicle system analysis is an integral activity to establish the critical technologies required for meeting the third generation RLV goals and assess the contribution of the individual technologies toward those goals. Several vehicle configurations, Figure 8, are being studied to establish which architecture would best meet the cost and safety goals. Single stage to orbit (SSTO) and two-stage to orbit (TSTO) vehicles that would utilize either vertical takeoff (VTO) or horizontal takeoffs (HTO) are being studied. All configurations land horizontally. Hydrocarbon, hydrogen, and dual fuel are part of the trade space.

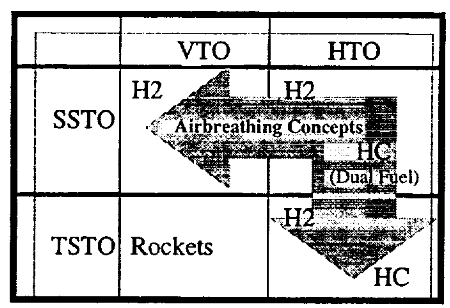

Figure 8. Vehicle Concepts

Summary

NASA's ASTP Spaceliner Investment Area has developed a plan to mature all vehicle technologies required to meet the third generation RLV goals of significantly lowering the transportation costs and improving safety over current conditions. The potential vehicle concepts considered include both TSTO and SSTO. The initial operational capability for a third generation RLV is around 2025. Therefore, the technologies will have to be demonstrated in a system environment by approximately 2015. For some of the technologies, especially the propulsion technologies, flight demonstrations will be required. The first flight demonstration will be the Hyper-X (X-43) vehicle that will test Scramjet technology at Mach 7 this year. Additional demonstrators are being planned. The actual number of demonstrators that will be developed and flown will be based on future analytical studies and test results of the technologies. Currently, the exact number and sequence of these demonstrators are being evaluated. The current plan is to build and ground testing an RBCC flight-type propulsion system (ISTAR) by 2005. Flight testing of an RBCC engine is projected around 2008. Testing of the advanced rocket technology in the hydrogen testbed facility located at SSC will begin around 2003.

Airframe technology activities are also being conducted in parallel with the propulsion technology activities. An integrated conformal tank/wing stub large-scale ground test article with the required IVHM is planned for FY 08.

The near term technology activities in the avionics power, IVHM, and operations disciplines will focus primarily on the support required for the planned airframe and propulsion test articles and flight demonstrators.

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