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DC-X RESULTS AND THE NEXT STEP

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Introduction

Results from static and flight tests accomplished to date with the Delta Clipper-Experimental (DC-X) coupled with the ground operations and maintenance experience are proving out both the operational potentials for a reusable launch vehicle and the low speed flight characteristics of a vertical takeoff and vertical landing, single stage to orbit (SSTO) system. These tests are part of the Single Stage Rocket Technology (SSRT) Program being carried out under the direction and sponsorship of the Ballistic Missile Defense Organization (BMDO). Five flight tests totaling approximately eight minutes of flight time have been completed. These flight tests together with fourteen static tests have provided an extensive verification of the autonomous vehicle management system and software, including the ability to recognize and to successfully recover from emergency conditions. Although major goals of the DC-X program have been accomplished, additional tests are still required to validate the aerodynamics, control stability and propellant requirements for the low speed rotation maneuver required for vertical landing and to obtain additional base drag and control flap effectiveness characteristics to substantiate and calibrate the computational fluid dynamic models and wind tunnel tests.

A program is also underway with NASA to retrofit the DC-X with major subsystems and components representative of the advanced structures and materials and components required to achieve the lightweight, rugged vehicle capable of achieving single stage to orbit and being used over and over again like an airplane. The resulting system is designated the DC-XA and will be a flying test bed to evaluate the advanced launch technologies in the combined environments achieved during flight and ground operations.

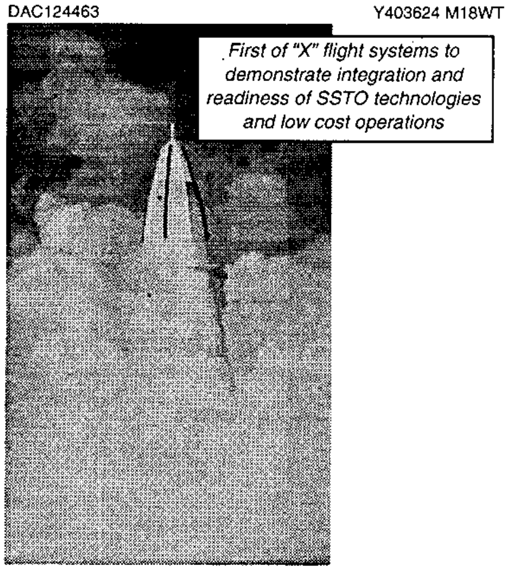
Based on the results from and plans for the DC-X and DC-XA, the U.S. will be in a position to proceed rapidly with the next step Advanced Technology Demonstrator to resolve engineering, manufacturing and operational uncertainties associated with building and operating a full scale operational SSTO system. Positive results from these developments and demonstrations would enable a full scale system to be operational shortly after the turn of the century.

Background

Few engineers now doubt the feasibility of using today's technology to develop and build a single stage rocket system capable of delivering useful payload to orbit and returning to be reused again. Lightweight, rugged materials exist which when coupled with the performance and thrust-to-weight of existing rocket engines enable the structural efficiencies to be achieved which satisfy the "physics" of getting to and from orbit with a single stage. Modern flight control approaches and software architecture coupled with processing power of today's computers enable the efficiencies of totally autonomous flight control to be achieved. Operations and maintenance approaches developed through years of experience with military and commercial aircraft can be directly applied to achieve similarly low operational cost approaches for reusable rocket ships.

What has been lacking is hard evidence and experimental data that would add engineering, manufacturing and operations confirmation to feasibility studies and concept designs. Concept designs based on highly sophisticated computer designs using realistic material properties and design margins and real performance data and component properties add credibility to the achievability of the "physics" of SSTO flight. Final validity must await the actual manufacturing, assembly and flight testing of the integrated system. Even less certain has been the achievability of the low costs of operation that are promised by being able to repeatedly use the same flight and ground systems. And low operational costs will only be achieved if the number of people, processes and replacement parts involved in operating the system and in preparing the same vehicle for flight are kept to a very small number and the time involved between flights can also be kept very small.

The objective of the SSRT project and the DC-X flight test program has been to provide the first step in demonstrating the achievability of the promised design and operational characteristics of the SSTO system. (Figure 1) Thus, the narrow focus of the DC-X has been to demonstrate the achievability of the low cost operations and maintenance of a rocket powered SSTO and to demonstrate the autonomous flight control capabilities, minimum number of flight



- ❑ Vertical takeoff and landing
  - Design for supportability
  - Autonomous control
  - All-weather operation
- ❑ Aircraft-like operation
  - Three-person flight crew
  - Small support crew
- ❑ Rapid system turnaround
  - Seven days
  - Three-day demonstration goal
- ❑ Rapid prototyping of hardware and software
  - Short schedule
  - Limited budget

Figure 1. Delta Clipper-Experimental (DC-X) Demonstration Goals

operations people and the low speed flight characteristics of a vertical takeoff and landing SSTO system. The objectives of the DC-X testing have been largely accomplished through the initial five flight tests and twelve static tests completed to date. During two of the flight tests, tests 2 and 5, system anomalies and subsystem failures caused by external events occurred. The overall capabilities of the vehicle management system and the ruggedness of the vehicle design enabled the DC-X to successfully recover from these emergencies and safely land the vehicle to be repaired and used for subsequent flight testing. The ability to design for safe, intact abort following an emergency is a key operational feature to be able to achieve a low cost, safe operational system - this has been demonstrated by the DC-X.

Test plans and supporting analysis are in place to complete the low speed rotation maneuver necessary to demonstrate the control authority and stability for reorienting the operational vehicle from its return from orbit nose forward position to its base downward landing position. These tests are necessary to complete the evaluation of and provide the design data for the vertical landing system.

The utility of the DC-X system will be extended under a project sponsored by NASA to use it as a test bed for evaluating advanced technology components, materials and structures in the integrated environment of a flight system. The development activities for this are currently underway to produce the long-lead advanced subsystems which will replace those currently in the DC-X. The resulting vehicle will be the DC-XA - Advanced Launch Technology Test Bed. Some of the major subsystems include a graphite-epoxy liquid hydrogen main fuel tank, an aluminum-lithium liquid oxygen main oxidizer tank (this will also evaluate the 1460 Al-Li alloy), graphite-epoxy intertank structures, and a liquid-gas converter for hydrogen.

With the completion of the DC-X and the DC-XA projects, key design and operational data will be available to support a decision to move on the next level of technology development and demonstration. As shown in Figure 2, the next major decision point in the development of a next generation reusable SSTO system will be made by or before December 1996. This will be a decision to move ahead with the large scale Advanced Technology Demonstration (ATD) of the engineering, manufacturing and operational readiness for an operational SSTO development and operation by 1999. Positive results from the ATD will support a decision to proceed with the development and certification of the full scale operational system which could be available for initial use by the 2002 to 2004 time frame.

Demonstrating the Delta Clipper Concept

The operational Delta Clipper vehicle, DC-3, together with its ground systems would be maintained, loaded, flown and serviced between flights like today's modern military and commercial aircraft. (Figure 3) It would use liquid oxygen and liquid hydrogen for its main engines and gaseous hydrogen and oxygen for its reaction control and power systems. Multiple engines would enable it to safely return to its spaceport in the event of equipment failure, including engines, any time during flight. On-board health monitoring systems would perform all system self checks prior to as well as during flight to both increase safety and mission reliability and to decrease the maintenance and turnaround times between flights. Its autonomous flight control system would enable rapid "reprogramming" for new missions, contributing to lower operations costs and increased responsiveness, as well as provide the robustness to recognize and respond to off-nominal conditions to assure mission success and flight safety. For example, the DC-3 would be able to both takeoff and land in winds and gusts, increasing its operational flexibility and utility.

The turnaround process for the DC-3 would start as it lands and starts it automated shutdown operations and the ground crew tows it back to its flight stand for unloading passengers and/or cargo, servicing and refueling and preparing for the next flight. This approach would be similar to that

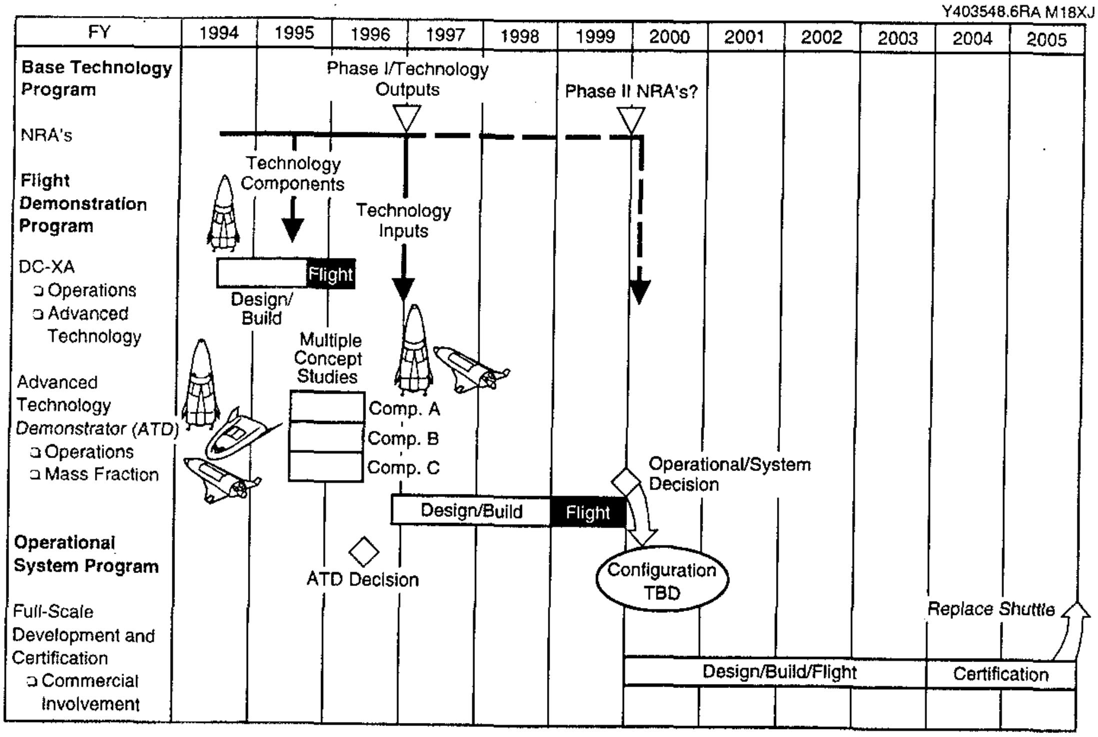


Figure 2. NASA Roadmap for RLV Next Generation System Development

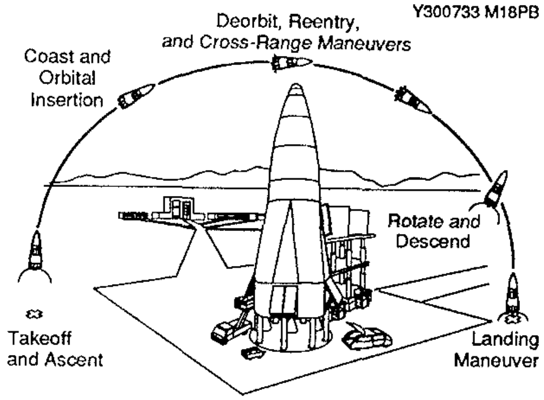


Figure 3. Delta Clipper Operational System

used today for commercial and military aircraft. All of these performance and operability features would enable the DC-3 to dramatically reduce the cost of transportation to and from low Earth orbit while achieving operational safety and reliability approaching that of today's aircraft.

Because the success of the operational DC-3 is as dependent on being able to achieve its low cost operations as it is on achieving its SSTO performance goals, demonstration of aircraft-like operability and supportability was considered to be an equally important demonstration goal for the DC-X along with demonstration of key low speed flight quality and control characteristics of an autonomously controlled vehicle. These dual goals were incorporated into the DC-X demonstration system, consisting of the vehicle, ground support and flight operations. (Figure 4)

Flight Test Results

The static and flight test data developed to date with the DC-X, coupled with the ground operations and maintenance experience gained, are proving out the operational potentials for a reusable launch vehicle and the low speed flight characteristics of a vertical takeoff and vertical landing, SSTO system. Five flight tests totaling approximately eight minutes of flight time have been completed. These flight tests together with fourteen static tests have provided an extensive verification of the autonomous vehicle management system and software, including the ability to recognize and to successfully recover from anomalies and emergency conditions. (Figure 5) The following sections provide a summary of the results and information obtained to date from these tests.

Operations and Supportability

From the very beginning the design of the DC-X system was driven to achieve both vehicle performance capability and system supportability objectives. The key metrics for the

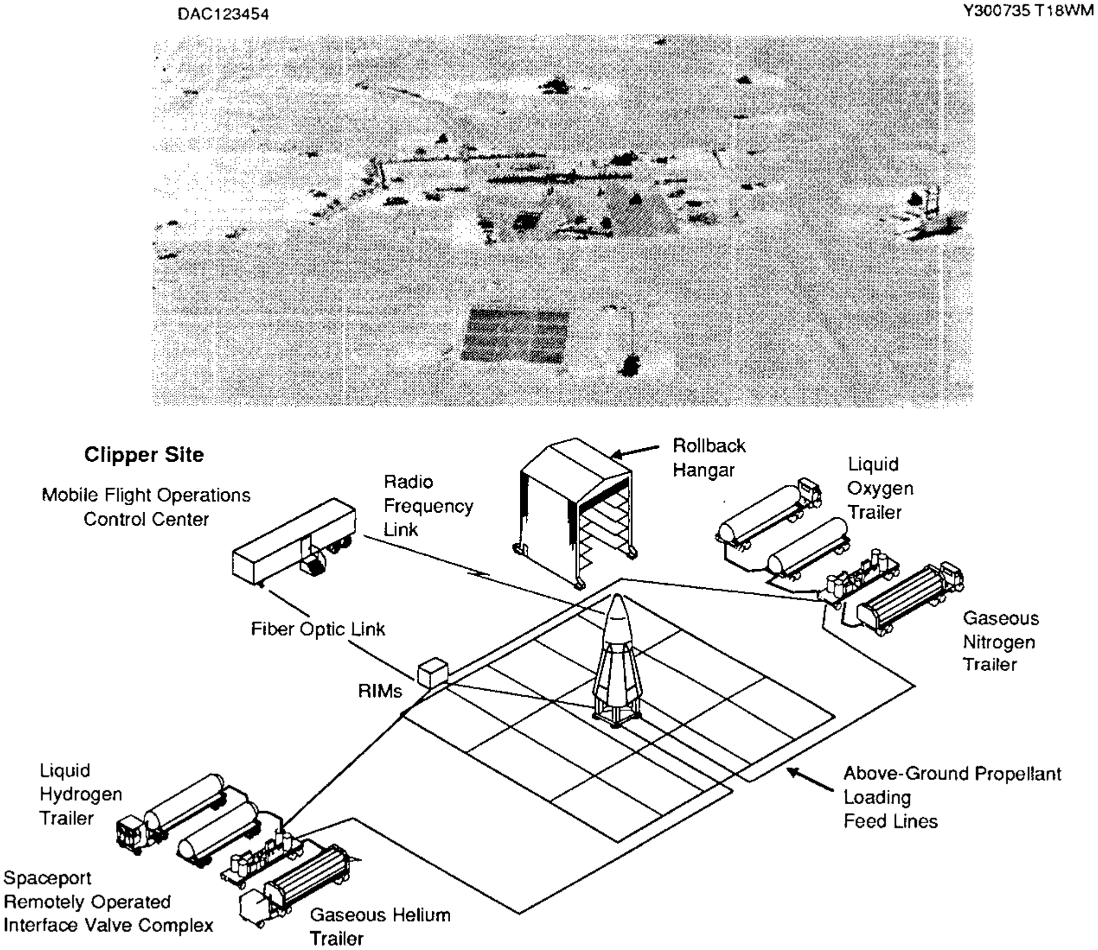


Figure 4. Flight Testing Demonstrates Total System Concept

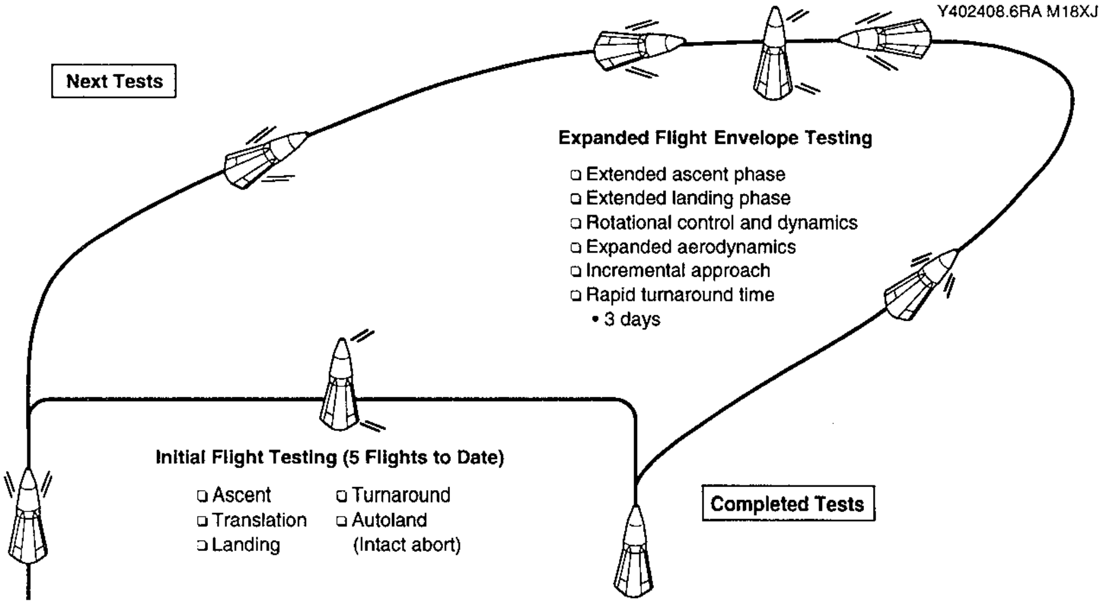


Figure 5. DC-X System Provides Combined Environment Resolution of SSTO Flight and Operations Issues

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