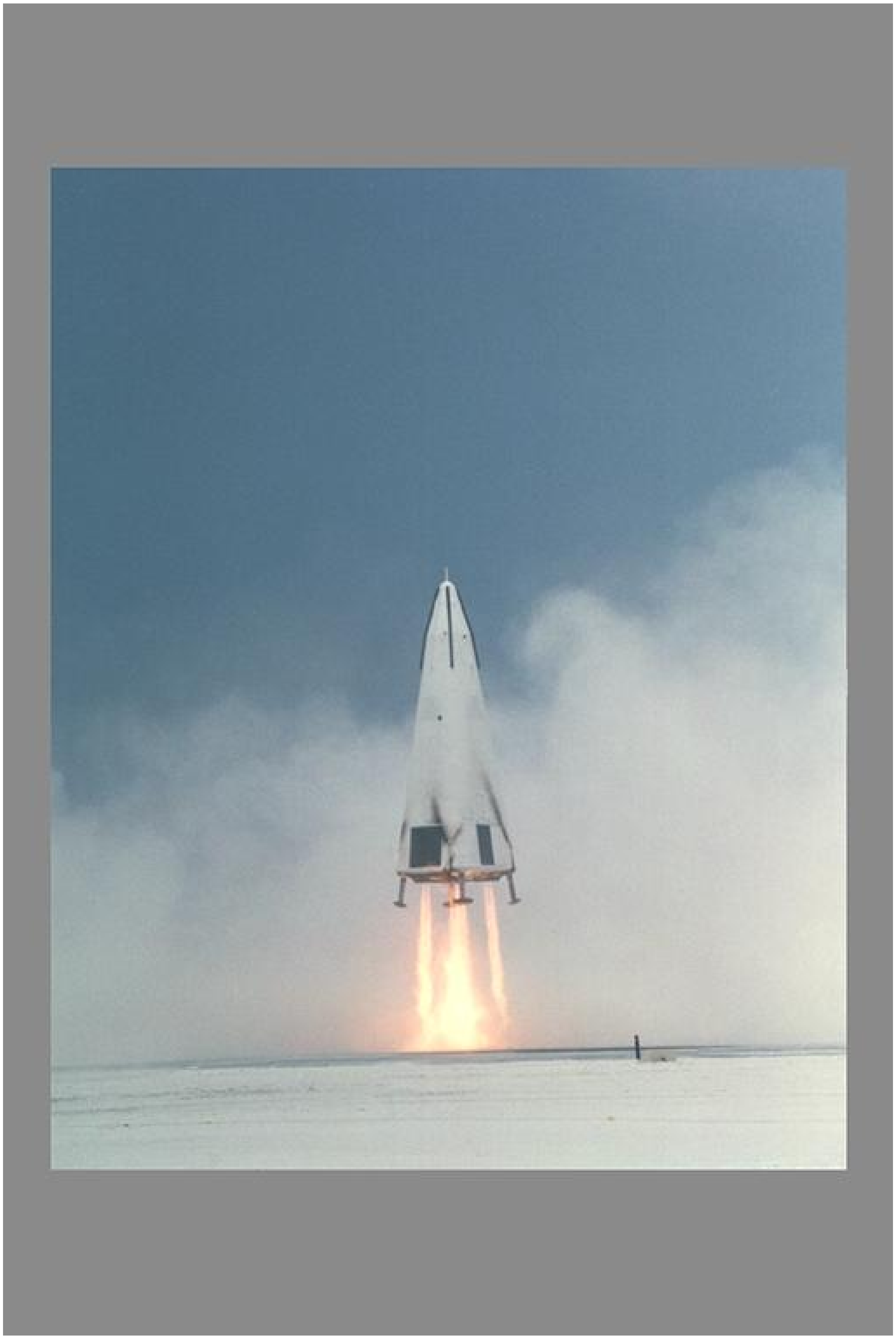
Delta Clipper

A Path to the Future



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Executive Summary

Although the Space Shuttle has well served its purpose for years, in order to revitalize and advance the American space program, a new space launch vehicle is needed. A prime candidate for the new manned launch vehicle is the DC-X. The DC-X isn't a state-of-the-art rocket that would require millions of dollars of new development. The DC-X is a space launch vehicle that has already been tested and proven. Very little remains to be done in order to complete the process of establishing the DC-X as an operational vehicle. All that's left is the building and final testing of a full-size DC-X, followed by manufacture and distribution.

The Space Shuttle, as well as expendable rockets, is very expensive to build, maintain and launch. Costing approximately half a billion dollars for each flight, NASA can only afford to do a limited number of Space Shuttle missions. Also, the Shuttle is maintenance intensive, requiring hundreds of man-hours of maintenance after each flight. The DC-X, however, is very cheap to build, easy to maintain, and much cheaper to operate. If the DC-X was used as NASA's vehicle of choice, NASA could afford to put more payloads into orbit, and manned space missions wouldn't be the relative rarity they are now.

Since not much remains in order to complete the DC-X, a new private organization dedicated solely to the DC-X would be the ideal choice for the company that would build it. Many of the larger existing companies are plagued by bureaucracy that would only hinder the development of the DC-X. NASA suffers from the same problem, and it also depends on outside support for continued funding. Therefore, a new company, started exclusively for the purpose of building the DC-X, would be the ideal choice.

Table of Contents

<u>List of figures</u>

Introduction

In the middle of the twentieth century, the Soviet Union launched the space vehicle Sputnik. That event helped start an international space race that culminated with the triumphant landing of Apollo 11 on the moon. After that, the United States, as well as other countries, continued to perform space missions, but there have been few great new undertakings in manned space missions since then. The International Space Station (ISS) is the one effort geared towards extending human presence in space. Currently, the United States uses two types of vehicles to get payloads into orbit and to get humans into space.

The main vehicle used by NASA to launch manned missions is the Space Shuttle. The Space Shuttle is a partially reusable, multi-stage launch platform. However, the Space Shuttle is very expensive to use. It costs approximately $500 million per launch, for a number of reasons. One reason is that the orbiter is decertified for flight after each mission, and so must undergo large amounts of maintenance. The engines are taken apart and rebuilt, the solid rocket boosters must be recovered, and a new external tank must be built. Also, recently, due to the Columbia incident, the Space Shuttle is no longer an operational vehicle; it is now classified as an experimental vehicle. The Space Shuttle has well served the need for a manned space vehicle for years, but with its large recurring costs, as well as its recent demotion to experimental status, a new vehicle would best serve a country actively reaching out into space.

Another type of vehicle used to launch payloads into orbit is the expendable rocket. Vehicles such as the Titan, Delta, and Atlas rockets are used to put satellites into orbit and to launch deep space probes. However, these rockets are fully expended during launch, and a new one must be built to be used for another launch. Also, these rockets cost a lot to build, and take a long time to construct and prep for flight.

In order to stimulate space exploration that has slowed down in the last 30 years, a new and cheaper space exploration vehicle must be found: a versatile vehicle that could perform both manned and unmanned launches, and could go to orbit with a single stage. A single-stage-to-orbit (SSTO) vehicle would eliminate any recurring rebuild or recovery costs, and help the vehicles achieve complete reusability as a reusable launch vehicle (RLV). Aerospace engineers have been working on the development of an SSTO rocket that is also an RLV. 10 years ago, a team in White Sands, New Mexico, built an experimental vehicle that proved that such a rocket is closer than it may have seemed [1].

Discussion

A Few Noble Attempts

Early on in the development stage for the Space Shuttle, NASA had investigated the possibility of building a fully reusable vehicle [4]. Their idea was to simply build a larger vehicle with all gas tanks and boosters inside the vehicle. As shown in Figure 1 below, the original concept was for a vehicle that was 202 feet long, and was fully reusable, with only a single stage. Later on, the designers decided to scale the vehicle down to 123 feet long, with the liquid hydrogen gas tanks externally attached. Finally, due to compromises with Congress and the then-current technology limitation, the Shuttle designers settled on a plan for a 110-foot long Shuttle, with both liquid hydrogen and liquid oxygen fuel tanks carried externally.

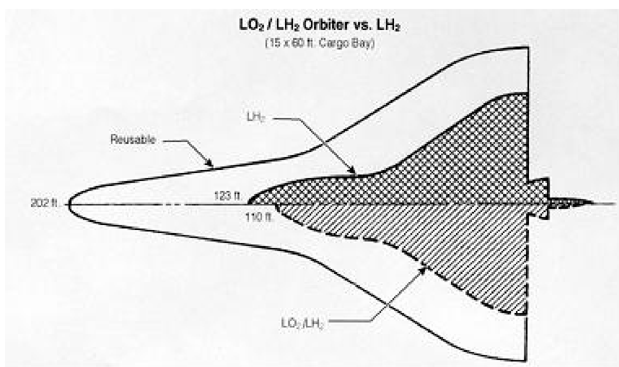

Figure 1: Original concepts for the Space Shuttle. Picture courtesy of NASA.

After the Shuttle was designed and built, NASA began investigating a possibility for an RLV called the X-33. The X-33 was a subscale technology demonstrator, meaning it was scaled-down version a full size vehicle, and was built to prove that the full-size vehicle could be built. The full-scale version was dubbed the VentureStar. The X-33 was designed with a vertical takeoff, horizontal landing configuration, similar to the Space Shuttle. NASA ended up budgeting $941 million for the project, and although the scientists and engineers did conduct drop tests of the model, no powered prototype ever flew.

Another noteworthy attempt at producing an RLV is the outcome of the current NASA project: the Space Launch Initiative (SLI), whose purpose is to eventually turn out a replacement for the Space Shuttle. One of the spacecraft being researched for the SLI is the X-37. The X-37 is a technology demonstrator, designed to validate concepts and designs that could be used in the future for an Orbital Space Plane (OSP). However, NASA doesn't intend for the OSP to be fully reusable. The X-37 is only intended to be a stopgap measure while more time and money is spent studying a true RLV. This is shown by the fact that, so far, NASA has only conducted drop tests and structural tests on the X-37.

Faster, Better, Cheaper

An eligible replacement for the Space Shuttle is the Delta Clipper. It was originally developed and built in 1991-1993, and was completed as the DC-X. The DC-X was a joint venture between the United States Air Force, and was intended to be a one third scale prototype of an RLV proposed by the Strategic Defense Initiative Organization (SDIO).

A primary goal of the Delta Clipper project was to show that an RLV was possible, and that the RLV could be operated in a manner similar to a commercial airliner. That meant that the Delta Clipper team was attempting to develop a spacecraft that could be flown very often, with little maintenance required between flights. The team succeeded in running the Delta Clipper from a much smaller building than the Space

Shuttle uses. Figure 2 below shows the Vehicle Assembly Building (VAB) that supports the Space Shuttle. The VAB is also where much of the between flight maintenance is performed. The VAB is a very specialized building, but it is also very massive; the American flag on the building is approximately the size of a football field. On the other hand, Figure 3 shows the support garage that the Delta Clipper team used to service and maintain the DC-X. The difference between the two buildings couldn't be bigger.

Figure 2: The Space Shuttle's Vehicle Assembly Building (VAB). Picure courtesy of NASA.

Figure 3: The support garage used to maintanence the Delta Clipper. Picture courtesy of NASA

Another way in which the DC-X could be operated in a manner similar to a commercial airliner was its long-term storage capabilities. At one point during the testing, the Delta Clipper project was temporarily halted due to budget cuts, and the engineers of the project turned the delay in funding into an experiment. The engineers built a makeshift shelter around the DC-X on its launch pad, and left it that way for some months. When the engineers returned from their prolonged break, the shelter was taken down, and the DC-X tested for flight readiness. The engineers determined that the spacecraft could be prepared and ready for a flight within a week.

The Delta Clipper's flight profile was also much simpler than the Space Shuttle's is. Figures 4 and 5 below show the mission profiles for the Space Shuttle and the Delta

Clipper, respectively. The Space Shuttle's mission profile is as follows. First, the Shuttle takes off, and then the solid rocket boosters are disengaged, and dropped into the ocean, from where they must be recovered later. Next, the fuel tank is detached and dropped. Then the Shuttle enters orbit, where it performs its mission. Finally, the Shuttle reenters the earth's atmosphere, and lands at one of the few places where the runway is long enough to accommodate it. The Delta Clipper, on the other hand, has a much simpler profile. The Delta Clipper takes off, enters orbit without dropping any fuel tanks or boosters, where it carries out its mission. Then, the Delta Clipper de-orbits and reenters the atmosphere, where it could land anyplace that has a decently size concrete pad.

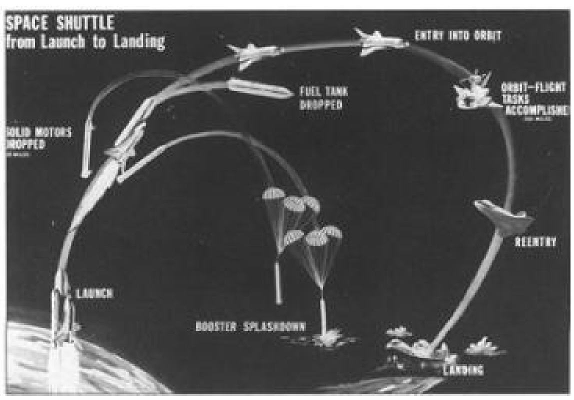

Figure 4: The Space Shuttle's mission profile.
Picture courtesy of NASA.

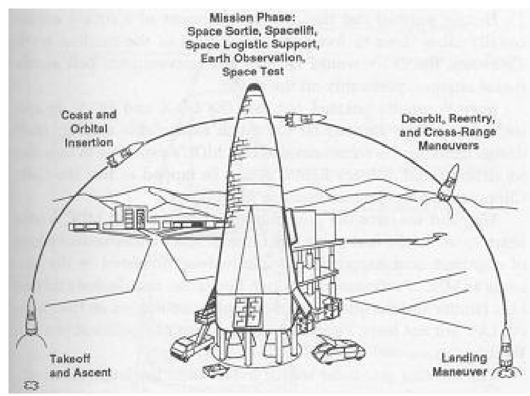

Figure 5: The Delta Clipper's mission profile.
Picture courtesy of McDonnell Douglas.

The simplicity of the Delta Clipper's flight plan isn't its only selling feature; it also takes a very short time to build, and is cheap enough to build several Delta Clippers for each of the Space Shuttle's launches. Even though the DC-X was just a subscale prototype, a full-sized Delta Clipper would still cost less to build than it costs to launch the Space Shuttle once. The original DC-X was completed in 21 months by a team of 100 people, and cost a grand total of $60 million, built completely of off-the-shelf parts [3]. After the build phase, the US Air Force completed 8 flight tests. During the fifth flight test, the vehicle demonstrated its automatic landing capabilities; after a small leak in the fuel lines caused an explosion, the vehicle initiated an automatic landing sequence and settled itself to the ground safely. The DC-X was also designed to have an engine-out capability comparable to the characteristic of the same name of commercial airliners.

Later on, NASA acquired the Delta Clipper program and changed the name to DC-XA. NASA installed experimental fuel tanks and better reaction control systems, reducing an already light vehicle's weight by 620 kilograms. NASA then conducted 4 flight tests and 2 static engine tests.

The effort required to resurrect the Delta Clipper program wouldn't be very great. Many tests showing the proof that the concept works have already been conducted, and the vehicle's capabilities have already been proven. Therefore, the Delta Clipper is simply a space vehicle nearly ready for use. All that remains is some final testing, building a full-size vehicle, and then putting the spacecraft to work.

A Path to the Future…

A full-scale Delta Clipper would be fully reusable and able to put payloads in orbit with one stage at one-tenth the current costs for orbital payloads [1]. This is an important feature for many reasons. Current vehicles require large unpopulated areas near the launch facility. The reason for this stems from the multi-staged nature of the rockets, where used stages fall off the rocket during flight and need safe areas to impact. Current rockets also require very specialized space ports. These facilities must be very large, again for safety reasons. Their specialized nature makes them expensive to build and the size requirements reduce the potential locations for space ports to places far from population centers.

Aside from simply reducing the cost per kilogram to launch payloads into orbit, another primary goal for the full size DC-X is to enable airline-like operations. Commercial airlines operate from many locations near cities, require little maintenance between flights, can be flown many times before major overhauls are needed, and require only a small ground crew at each airport. These are important qualities needed to make access to space both routine and cheap. An orbit capable DC-X would provide for each of these key points.

Whose Mission Should this Be?

Many aerospace engineers would immediately think this task is something that NASA should be in charge of. It was, after all, NASA that built the Saturn V rocket that put humans on the moon; and it was NASA who built the Space Shuttle, which despite having huge operational costs actually came in very close to budget when it was being designed [4]. NASA, however, should not build the Delta Clipper.

NASA is a consumer of launch services, not a supplier. In the early days of rocketry, the technology to put satellites and people into orbit was new and untried. Thus it only made sense that the agency tasked with performing research and development for all things that fly be the same group to put this new technology to use. However, this technology is now old and proven. To see this separation between using and developing new launch vehicles, it is helpful to examine NASA’s mission statement.

> NASA’s Mission Statement…
>
> … To understand and protect our home planet
>
> … To explore the Universe and search for life

… To inspire the next generation of explorers

… as only NASA can.

According to Sean O'Keefe, NASA Administrator, NASA's mission is to improve life here on earth, extend life past Earth, and to find life elsewhere in the Universe [5]. They are tasked with doing the things that cannot be done elsewhere. To this end they are a consumer of launch services. NASA's predecessor, the National Advisory Committee for Aeronautics (NACA) performed research on wing sections (the shape of a wing at various points along a plane's wing) [7]. This research was used, and is still being used, to build aircraft ranging from small general aviation aircraft to military aircraft. This is an example of how NASA does the research on new technologies and commercial entities build products using that research.

NASA, being a government agency, also suffers from bureaucracy. Projects are analyzed by Congress and budgets are set by people outside of NASA, people who do not share NASA's mission. The Space Shuttle is a study in compromises between NASA, the Department of Defense (DoD), and Congress. The Space Shuttle was meant to be more than it could achieve [4]. An example of relatively unhindered success is the DC-X program itself. The team responsible for the rocket was affected by politics only in obtaining the funding needed. For $60 million they built a rocket that performed feats no other rocket has ever achieved.

If NASA should not build this new rocket, it might be argued that one of the large Aerospace companies should build it. It was, in fact, one of these companies that built the original DC-X to begin with. These companies tend to suffer from similar levels of bureaucracy. What is needed is a fresh approach to the issue of a new vehicle.

What will the Delta Clipper be used for?

There are quite a few uses for a single stage reusable launch platform. These uses range from launching tiny new satellites to ferrying cargo to the moon.

The ability to put smaller satellites into orbit, while doing it much more often than is possible now, will enable applications that can only be dreamed of now. Motorola's Iridium satellite phone constellation would have been one such use for the Delta Clipper. The Iridium constellation consists of 66 satellites in Low Earth Orbit [6]. Had Motorola had the lower cost services of the Delta Clipper the launch savings would have been tremendous. Also beneficial would be the ability for many more universities to place tiny research satellites into orbit. The University of Texas at Austin Department of Aerospace Engineering's Icesat project would be one such nano-satellite.

The International Space Station (ISS) is another application of cheap and quick access to space. With the Delta Clipper, NASA could ferry many more scientific experiments to the station. It would also allow fast recovery of crews in the event of an equipment failure as well as faster construction of the station.

Space Tourism is also an application of the Delta Clipper. Before non-astronauts are allowed to venture into space in large numbers launch vehicles must be made as safe as the average commercial airline. The cost of launching a tourist must also be lower than it is today in order to make it both viable for consumers as well as profitable for the company operating the tourist service. The Delta Clipper would fit this task well.

Global same-day package delivery will be a driving force behind the early adoption of the Delta Clipper. G. Harry Stein has shown in his book 'Halfway to Anywhere' the financial viability of such a service.

Finally, the Delta Clipper in a modified form could serve as a vehicle for both the exploration of the moon as well as the ferry of parts for the construction of a permanent moon base. The Delta Clipper's ability to land vertically makes it ideal for use on planetary bodies without an atmosphere.

Why hasn't the project been completed?

An important question to ask is that of why the DC-X project wasn't taken beyond the technology validation demonstrator that it was. There are a couple of answers to this question.

Support, in the form of funding, from Congress is a large part of the reason we don't see an operational Delta Clipper now. Initially there were many opponents to the idea of a single stage rocket. These people believed that the concept was fundamentally flawed and impossible to build. The opposition went so far as to distribute a pamphlet full of erroneous information in an attempt to kill the funding for the DC-X [3]. The success of the DC-X was enough to change the views at NASA and obtain funding for the DC-XA follow-on project, but not enough to take the project beyond that.

NASA is also limited by its' budget. With the Space Shuttle, International Space Station, and all the explorative missions being performed the agency has little left to entertain more than one new shuttle replacement concept at a time. Sadly, due to many factors, not all of which are known to the authors, NASA has over the years overlooked the DC-X project as a possible new launch platform. Instead it has concentrated on the now cancelled X-33 project and the new Space Launch Initiative (SLI). It should be noted that the SLI consists mostly of technology studies designed to produce new technologies believed to be crucial to a replacement for the aging Shuttle fleet. A full-scale DC-X would require little new technology to be developed.

Why not just build the VentureStar or the Orbital Space Plane?

After the end of the DC-XA program NASA held a competition to choose the concept that was to replace the Shuttle fleet as the primary launch vehicle used by the agency. Lockheed Martin won the contract for the X-33 with their VentureStar concept. The X-33 was to use many new technologies, including a linear aerospike rocket engine and a new composite cryogenic fuel tank. The aerospike engine was test fired on the ground but was never flown. The new tank failed structural tests.

NASA's next move was to initiate the SLI program. The flight hardware that is supposed to be a result of the studies is called the Orbital Space Plane (OSP). The OSP is essentially a reusable astronaut ferry that is launched by placing it atop an existing expendable launch vehicle like the Boeing Delta series rockets [8]. The OSP has little cargo capacity. Expendable rockets are to provide cargo ferry services in this vision of the future.

The X-33 was supposed to have operated much like an airline. The OSP abandons the idea of such operations. In order to usher in a new era of space exploration the concept of rockets being operated similarly to the commercial airline business must be developed. This is why the Delta Clipper is an idea choice for further development. It has been designed from the beginning with those goals in mind, and it has demonstrated these ideas in flying hardware.

Conclusions

As we have seen, current space launch vehicles have a number of drawbacks. The Space Shuttle is expensive to fly and requires months to ready for new missions. Expendable launch vehicles also suffer from high launch costs and long build times. The United States' future in space demands a cheaper, safer, and faster space transportation system. The idea of a single stage, reusable rocket is certainly not new. Jules Verne's 'From the Earth to the Moon' had astronauts traveling to the moon in a single stage rocket shaped like a bullet and fired from a cannon. More recently, Space Shuttle design studies in the early 70's considered the possibility of building a shuttle with only a single stage.

Over the years NASA has studied the concept and initiated more than one program with the eventual goal of building a fully reusable rocket. The X-33 project was once such attempt. The VentureStar, as the full-scale version was to be called, would have took off like a rocket and landed like a plane. Despite a budget of $941 Million, no rocket ever flew under this program. NASA's next major attempt to replace the Shuttle is the current Space Launch Initiative program. Under this program the dream of a single stage reusable ship has been lost. The Orbital Space Plane is supposed to reach orbit atop an expendable rocket.

The Delta Clipper program demonstrated the capabilities needed for a truly reusable single stage rocket. It did this both quickly and cheaply. The DC-X was a great start to answering the question of how the United States will get to space in the coming years.

Recommendation

It is the recommendation of this paper that a private corporation, not under the control of any investing company's board of directors, be formed for the sole mission of finishing the work started by McDonnell Douglas and the US Air Force. This company will complete the design of a full-scale, orbital DC-X single stage to orbit, reusable launch vehicle. The company will then provide launch services to NASA and the commercial launch industry. NASA will be a technology collaborator with the project, but will not have direct control over the progress of the project. Major investors to be sought include NASA and the major Aerospace corporations. These entities will be allowed to purchase non-voting shares in the company, allowing for a return on investment but prohibiting their culture from polluting the company spirit.

Two versions of the Delta Clipper will be designed initially. A light lift version will be built first. This version will be targeted towards lifting unmanned payloads to Low Earth Orbit. This will also be the vehicle used for any global package delivery service. The second version will be a heavy lift Delta Clipper with a modular payload bay. This payload arrangement will allow a manned cockpit module to be installed, along with a smaller amount of cargo. Future versions would include a Clipper modified for moon landings.

This company should be formed as soon as is feasible. Given the current state of the Shuttle Fleet (grounded following the Columbia incident), and the potential that is being unlocked with the ISS, the need for such a vehicle is substantial. Finally, the current level of technological progress in the Aerospace industry leaves no readily apparent reason why development and construction of the new Delta Clipper could not commence in the very near future.

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