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WHAT'S NEXT: VULCAN AEROSPACE

Charles Beames
Vulcan Aerospace, ChuckB@vulcan.com

Kyu J. Hwang
Vulcan Aerospace, KyuH@vulcan.com

ABSTRACT

Vulcan Inc. continues the innovative legacy of its founder Paul Allen, playing a key role in forging the new commercial space industry. Paul Allen's investment in SpaceShipOne and his commercial space project Stratolaunch Systems is facilitating a shift from the current orbital launch model to a flexible and less expensive model. Stratolaunch is an air launch system capable of transporting payloads to low Earth orbit, with a carrier aircraft acting as a mobile launch range. This new architecture will expand mission and operational flexibility for various payloads by decoupling launch service from its dependence on traditional ground launch ranges. Currently, choices are limited for ranges capable of supporting orbital launches and are operated solely through government entities. Locations of launch pads and support equipment are fixed, wait times are long, delays and scrubs are common and revenue streams delayed. Regardless of advancements in launch vehicle systems, range and operational infrastructure is often the bottleneck in space access. Stratolaunch's system features reduce total launch costs and offer an attractive option for customers requiring highly responsive launch in either time or inclination. The world continues to witness SpaceShipOne's impact on "New Space", and Vulcan Aerospace remains committed to leading the movement into "Next Space" with Stratolaunch.

INTRODUCTION

Vulcan, Inc. is a company founded in 1986 by Paul Allen and Jody Allen. The company's mission is to find effective solutions for some of the world's toughest challenges, including improving access to space. Paul Allen believes "the drive toward new frontiers is integral to our humanity" and with Vulcan's diverse projects he strives to keep stretching the boundaries of the possible.

In that spirit, Vulcan Aerospace is the company within Vulcan that plans and executes projects to shift how the world conceptualizes space travel through cost reduction and on-demand access. Vulcan Aerospace has its heritage in SpaceShipOne and oversees the Stratolaunch Systems project. Additionally, Vulcan Aerospace collaborates across Vulcan Inc. for projects dealing with space.

CHANGES IN SPACE TRANSPORTATION INDUSTRY

When Vulcan, Inc. was founded 30 years ago, the space industry was significantly different. It was a government capitalized industry focused on combined military uses of space and general exploration of the cosmos. The technology was advanced for the time but the challenges of those days are apparent in retrospect:

- The Space Shuttle program was designated to provide all orbital transportation for the United States, including all government and commercial payloads (until the first Commercial Space Launch Act of 1984 and Challenger disaster).
- The Soviet Union was trying to catch up with the United States with the Buran reusable launch vehicle.
- The European Space Agency had developed and started launching their first launch vehicle, Ariane-I.
- President Reagan announced the plan for Space Station Freedom, which eventually evolved into the International Space Station program.

- Boeing, McDonald Douglas, General Dynamics (Convair), Hughes, Rockwell International, Lockheed and Martin Marietta existed as separate entities.
- There were early attempts at commercial space launch services in the U.S. by Space Services Inc. of America (SSIA) with Percheron and Conestoga.
- GPS was allowed in civilian commercial aircraft to improve navigation and air safety after the USSR shot down Korean Air flight 007.

Paul Allen and Vulcan played a key role in forging the new commercial space transportation industry with the investment in SpaceShipOne. The project is considered one of the greatest breakthroughs in the space industry; winning the Ansari X-Prize in 2004. Today, SpaceShipOne is displayed in the Milestones of Flight in the Smithsonian Air and Space Museum, next to the Wright Flyer, the Spirit of St Louis and the Bell X-1. The success of SpaceShipOne was followed by the emergence of entrepreneurial and private space companies that are now considered serious system providers within the industry. Before SpaceShipOne, other trailblazers including Pacific American Launch Systems, Space Services Inc. of America, Orbital Sciences, Microcosm and Kistler Aerospace advocated the importance of a commercial launch for space access. More recently, companies like Virgin Galactic, SpaceX and Blue Origin made strides in the same spirit, establishing commercial space transportation as forces of change for the entire space industry.

Exhibit 1: Flight of SpaceShipOne in 2004

The back-to-back suborbital flights of SpaceShipOne not only demonstrated that spaceflight can be achieved by private entities, but that it can be done differently. Before SpaceShipOne, all spaceflights (including suborbital) followed established rules and dated procedures. By operating and launching out of Mojave Airport with minimal government oversight, the team was freed from the shackles of space "tradition." Using an aircraft as a "first stage", aero-breaking with an adjustable wing configuration and using a hybrid rocket motor; SpaceShipOne incorporated a series of tailored solutions to meet the challenges of spaceflight. The project focused on making a high risk leap tempered with a methodical "build-test-fly" approach. The entire process publicized that a complex space system could be built and flown by a small group of people, within a comparatively small budget, in a short amount of time. SpaceShipOne truly launched the New Space Era.

To offer perspective, consider a few key elements that have changed in the prior decade:

- The Space Shuttle retired in 2012 and expendable launch vehicles provided all space transportation, including human space transportation to ISS.
- The last Titan launch was 2006 and last Delta-II launch was 2013.
- Former Soviet Union countries and the European Space Agency became the primary provider for commercial launch services (Proton and Ariane).
- ISS assembly is complete and rebranded as a national laboratory; with plans to retire by 2024.

- ULA (joint venture by Boeing and Lockheed Martin) provides launches for all DoD / NSS payloads, and SpaceX is in the process of being certified to offer the same service.
- Falcon 9 has 16 successful launches in 16 attempts, impacting global launch prices.
- The New Space approach is becoming mainstream. Multiple entrepreneurial space companies have raised investment capital from institutional and strategic investors (e.g. Google acquires Skybox for est. $500M in 2014).
- GPS is widely used throughout the global economy.

And here is what has not changed in 30 years:

- Big primes still provide the majority of systems and service as an extension of the government direction.
- There are limited profit margins set by government contracting rules.
- The workforce size in traditional aerospace companies far outnumbers New Space companies.
- There are limited launch range options for U.S. operators (still controlled by government entities).
- Long lead times from booking to launching payloads into space are still measured in years.
- High launch costs still prevent most entrepreneurial space systems from getting to orbit.
- GPS is still USAF asset.

COLD WAR LEGACY

The current structure of the mainstream space transportation industry remains one of the last remnants of the Cold War economy. Not coincidently, the current high cost of government-dominated U.S. launch services led to the near complete loss of commercial launch sales throughout the 1990s and 2000s. In many ways, space launch technology and infrastructure have changed little since the early days of the U.S. space age, allowing other countries to reach technical parity and provide services at more competitive prices.

LESSONS FROM OTHER INDUSTRIES

Looking at how other innovative industries have evolved helps to understand and predict how the space industry could change in the near future. Consider the evolution of the digital computer from large mainframes, to personal computers, to mobile computing. At each step computing became increasingly democratized, with growing numbers of people accessing latest technology.

The space business appears to be heading down this path, with more companies developing small satellites and a new push toward cheaper launches. However, several obstacles remain.

1) Limited launch ranges for U.S. operators:
    - Though there are new commercial or civil spaceports emerging throughout the country, launch operators are still generally limited to the Eastern Range (Cape Canaveral), the Western Range (Vandenberg AFB) and Wallops Flight Facility (NASA Wallops) in the continental US (CONUS) for orbital launches.
    - Other alternatives outside of CONUS are Kodiak Launch Complex, Reagan Test Site (Kwajalein, Marshall Islands) and Pacific Missile Range Facility (Hawaii), and all include substantial logistical challenges.
    - SpaceX is currently building its own private launch facility in Brownsville, Texas.
2) Time from booking to flight:
    - It takes an average of three years from booking to flight for orbital space launches and can take as many as five years depending on payload size, complexity and destination.
    - Companies such as Spaceflight Services have changed the model for providing rides as secondary payloads, but the secondary payloads are tied to the schedule of the primary and lose revenue while their assets await their ride to orbit.
3) Launch support infrastructure:

- Though there has been a number of new launch vehicle development programs over the years, there has been relatively little investment in lower-cost launch infrastructure.
- One technology that would significantly reduce the cost of flight safety, the automatic flight termination system, has been proven to work but is still not adopted.
- The Cape has been a historical location for space launch due to low inclination, but population growth in Florida is creating new safety concerns. Increasingly, boats under the flight path have caused many scrubs and launch delays.
- Too much customization of payload interfaces, integration and mission assurance add to total launch costs.

Gwynne Shotwell, President of SpaceX, recently remarked, "We have found that crowded launch sites are a single point of failure of any launch organization."

TOWARDS MORE RESPONSIVE AND AFFORDABLE LAUNCH

The focus on achieving responsive and affordable space transportation has significantly increased recently, as the demand from emerging commercial space markets is increasing the pressure to overcome launch inefficiencies. Some government entities like the Air Force Operationally Responsive Space (ORS) office has been at the forefront of these efforts, and programs like the DARPA's, ALASA and XS-1 are motivated by similar needs. Trying to satisfy the entire spectrum of being "responsive" and "affordable" can be very challenging, and the ultimate success of these government programs has yet to be determined. Providing frequent and reliable access to space is perhaps one of this century's greatest challenges. Success in the field will expand the economic potential of the high frontier and transport humanity beyond Earth.

STRATOLAUNCH PROGRAM

In 2011, Paul Allen initiated his commercial space program called Stratolaunch to challenge the current model of orbital launches and to explore a more flexible and less expensive option. Under the oversight of Vulcan Aerospace, Stratolaunch marches toward demonstrating an air launch system capable of transporting payloads to low Earth orbit, using a large carrier aircraft acting as a mobile launch range. This new architecture will expand mission and operational flexibility by decoupling launch service from its dependence on the traditional ground launch ranges.

Stratolaunch's ability to launch from variable locations will enable satellites and humans to be efficiently inserted into their most optimal orbit at a time of the customer's choosing. Launching far away from populated areas (i.e. middle of the ocean) also significantly reduces public safety risk. Flexibility will be greater when the Stratolaunch system is adapted to launch various types of launch vehicles. The carrier vehicle is being developed by Scaled Composites and the launch vehicle by Vulcan Aerospace. An illustration of the carrier aircraft is shown in Exhibit 2.

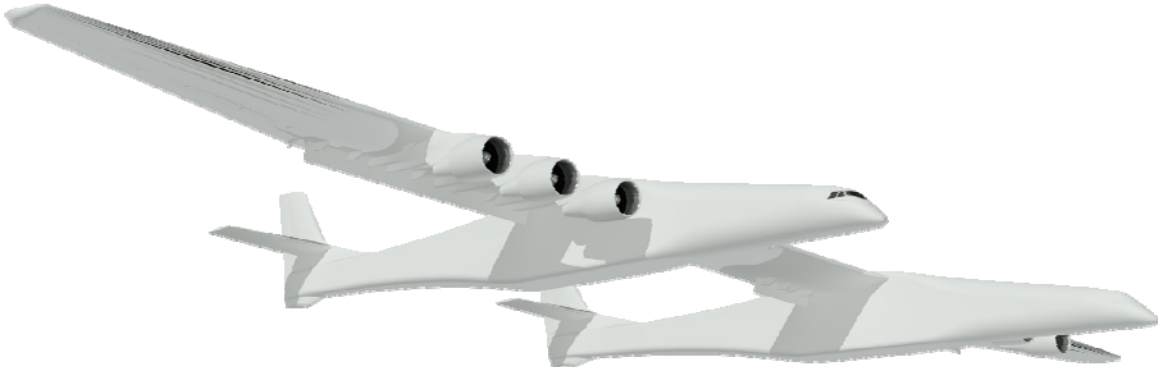

Exhibit 2: Stratolaunch Carrier Aircraft

The total capable take-off weight of the Stratolaunch system, including launch vehicle and payload, is 1.3 million pounds. The aircraft has a wingspan of greater than 380 feet, the largest of any aircraft ever made. The multi-stage booster will sit in-between the two fuselages, below the central wing, and can weigh up to 500,000 pounds. The aircraft is powered by six 747 engines and will use a runway of at least 12,500 feet in length. The carrier aircraft has an outbound range of 1,000 nmi and deploys the launch vehicle at the desired location and azimuth for the specific orbital mission. The goal is to launch the rocket at approximately 30,000 feet altitude with a gamma of 22-25 degrees. Loiter time on station is nominally one hour, with additional margin possible before returning to base and landing (with a fully-loaded rocket in the event of a scrub). In sum, these system features reduce total launch costs and offer an attractive option for users requiring highly responsive launch in either time or inclination.

The Stratolaunch aircraft assembly is currently 40 percent complete and is on track for first flight in 2016. The aircraft will be flown by two pilots and one operator and is designed for an operating life of 20 years. Two hangars were built for the carrier aircraft; an 88,000 square foot fabrication facility was opened in October 2012 and a 103,000 square foot hangar was opened in March 2013.

Exhibit 3: Inside of Stratolaunch Hangar in Mojave, CA

ENABLING GREATER USE OF SPACE

As the commercial satellite market grows rapidly with newly proposed disaggregated architectures, launch is quickly becoming the bottleneck for industry growth.

SpaceX is making huge strides reducing launch costs, with a profound impact on the industry. Reusability will drive costs down further. If the launch problems are solved and launch costs get low enough (under $1000/kg), another exciting chapter in the evolution of space will be opened. There are several other trends that will help.

- Additive manufacturing and advanced materials (composites)
- Miniaturization and reliability of avionics
- True interest from non-aerospace investors
- Government control relinquished

Vulcan Aerospace believes this new chapter in the evolution of space could allow:

- Fuel depots to allow storing energy from other places than Earth
- Servicing to extend the life of space assets
- Tugs to either place assets in higher orbits or dispose them
- Habitats other than the ISS
- Use of space-derived resources and raw materials
- Construction capabilities that can manufacture bigger things to send beyond LEO (whether it's for exploration or commercial utilization)

Exhibit 4: Future utlization of space

Vulcan Aerospace is focused on increasing the rate, accessibility and convenience of space launch to enable manufacturing in space, rather than increasing the size of launch vehicles. This is the key to increasing the utilization of space and will be the next seminal enabling development for space transportation and exploration. Vulcan believes this is reasonably attainable within the next 20 years.

BEYOND NEW SPACE

The world witnessed the impact that SpaceShipOne had on what is now called New Space. Vulcan Aerospace remains committed to the commercialization movement with Stratolaunch. New Space is no longer radical; the "revolution" discussed for over 20 years is underway. It is time to move away from using terms like Old Space and New Space that are divisive in the community. Like all of Paul Allen's projects, Vulcan Aerospace asks "What's next?" and aims to include everybody to be part of the shift towards a new era in expanded utilization of space. We call this "Next Space". Vulcan Aerospace is forward-thinking and risk-taking, while remaining cognizant of discipline and lessons of the past. Much like the evolution of the integrated circuit chip from a huge mainframe to a mobile device has altered the course of human history, Vulcan believes that versatile, low-cost access to space will do the same for the expansion of the physical boundaries of humankind.