National Space Society

Position Paper:

Now is the Time: A Paradigm Shift in Access to Space

A Call to Action for Congress, the Administration, and NASA

April 2017

The National Space Society (NSS) declares that in consideration of the achievements by SpaceX, Blue Origin, and Boeing over the past few years, it is now obvious that a revolution in spacecraft technology, operations, and economics is occurring, and there is every prospect that privately owned re-usable spacecraft operating under service contracts will greatly lower the cost of reaching space. NSS calls on Congress, the Administration, and NASA to immediately begin a review of all current NASA space flight related programs with a view towards how the usage of commercially available launch vehicles and spacecraft that are at least largely reusable can lower costs and/or increase operational capability. In particular, NSS offers some ideas as examples of things which might be considered:

- With the advent of lower-cost access to space, what new missions can NASA undertake? One such plan that deserves a serious look is a lunar orbit outpost that serves as a transportation hub and fuel depot while supporting lunar surface mining, asteroid mining, and future Mars voyages.

- Working with DOE, DOD, and other agencies, NASA could re-evaluate the case for Space Solar Power for beaming energy to the Earth as well as for in-space usage for habitats, manufacturing, and propulsion.

- NASA could re-examine all current space operations and consider how the following might be used to lower costs and increase resilience:

    - On-orbit printing/assembly and testing of satellites—removing the need to build a satellite that can survive launch stresses or even survive gravity on Earth's surface. This approach can reduce required testing and lower the amount of mass that needs to be lifted.

- On-orbit automatic assembly of larger satellites from smaller satellites.
- Re-architecture of existing functions to use many smaller satellites rather than one large satellite.
- On-orbit refueling and re-use of satellites and removal/recycling of space debris.

- Currently the Space Launch System (SLS) is completely expendable and is planned to be operated at a slow launch cadence. The current side-mounted non-reusable solid rocket motors might be replaced by fully re-usable liquid fueled side-mounted boosters. Additionally, the expendable Exploration Upper Stage (EUS) of the SLS which has not yet been fully developed might be replaced with an in-space reusable upper stage using United Launch Alliance (ULA) ACES technology.

- Rather than building future space plans around a large number of SLS launches, NASA should reserve SLS for those applications that are a strong match for its unique capabilities (high terminal velocity, large payload fairing), while using commercially available vehicles to the maximum extent possible.

- NASA's purchase of launch services should be reviewed to ensure that there are no restrictions that will arbitrarily and without justification prevent NASA from flying payloads on flight-proven vehicles.

- Currently much NASA planning assumes that large heavy lift vehicles are preferred to minimize the amount of in-space assembly required for large projects. These assumptions about the value of in-space fuel depots and in-space assembly need to be re-examined in the light of the usage of lower cost reusable spacecraft.

- Current NASA assumptions about the size of boosters needed to supply future Mars mission need to be re-examined and future efforts should be built around the use of large numbers of launches of low-cost mostly reusable vehicles while using expendable vehicles only when truly essential.

- Current NASA planning often focuses on using a large spacecraft lifted by a large booster. All missions need to consider models based on many low-cost launches and in-space robotic assembly of large structures using standard interfaces and components.

- NASA could review plans for a cis-lunar outpost and ensure that the success of COTS/CRS/CC is extended to cis-lunar space.

- NASA should make the maximum usage of the type of Space Act Agreements that led to COTS/CRS.

This list is not exhaustive and merely suggests some examples for technical evaluation.

In conclusion, NSS calls on NASA to immediately begin a review of all current NASA spaceflight related programs with a view towards how the usage of commercially available reusable spacecraft can lower costs and/or increase operational capability.

Background and Rationale

Over the last few years, the NASA-led Commercial Resupply Services program has demonstrated how fixed price purchase of launch services from commercial providers jump-started by funded Space Act Agreements can revolutionize our access to space. Today, access to the International Space Station via the SpaceX Dragon/Falcon 9 and the Orbital ATK Cygnus/Antares has become routine. The advent of new ways of contracting combined with recent technological developments described below promise nothing less than the dawn of a new age in space access.

Space advocates have long believed that usage of reusable spacecraft would usher in a new era of lower-cost spaceflight and improved access to space. Alas, these hopes have not been realized practically in spite of considerable efforts. However, recent developments suggest that a new age of lower cost, re-usable commercially available space vehicles is dawning.

The Air Force is to be applauded for taking over the X-37 program and with the support of Boeing managing it to operational success. NASA deserves enormous credit for marshalling the resources needed to complete the ISS, and in contracting for private parties to supply the ISS with cargo and crew. This forward-looking program (COTS/CRS) has facilitated the development of reusable launch vehicles by SpaceX and Blue Origin. Over the last few years, these companies have seen increasing success in the development and operation of reusable spacecraft largely funded by private money, as exemplified by the list of milestones recently achieved:

SUB-ORBITAL VEHICLES:

- April 29, 2015: First flight of Blue Origin New Shepard; capsule recovered; booster lost.
- November 23, 2015: Second New Shepard flight; booster reaches Karman line[1] and returns to launch site [beats previous record of 3,140 m altitude followed by return to launch site set by DC-XA].

- January 22, 2016: First re-flight of a New Shepard booster; full success with 61 day turnaround.
- April 2, 2016: Second re-flight of a New Shepard booster; full success with 71 day turnaround.
- June 19, 2016: Third re-flight of a New Shepard booster; full success with 78 day turnaround. This flight demonstrated landing with a "test failed" parachute.
- October 5, 2016: Fourth re-flight (fifth and final flight of the same booster) of a New Shepard booster; full success with 108 day turnaround. This flight demonstrated in-flight activation of the capsule escape system. Both the capsule and the booster were successfully recovered and will be retired and publically displayed. It is currently expected that in 2017 crewed testing will begin with an upgraded version of the New Shepard.

ORBITAL LAUNCH VEHICLES [six first stages available to potentially re-use]:

- December 21, 2015: First return to launch site of a Falcon 9 first stage.
- April 8, 2016: First landing on a drone ship of a Falcon 9 first stage.
- May 6, 2016: First landing on a drone ship of a F9 first stage returning from a GTO launch.
- May 27, 2016: Second landing on a drone ship of a F9 first stage returning from a GTO launch.
- July 18, 2016: Second return to launch site of a Falcon 9 first stage.
- August 14, 2016: Third landing on a drone ship of a F9 first stage returning from a GTO launch. This was the first single-engine landing burn that puts less stress on the vehicle.
- January 14, 2017: First landing on a drone ship in the Pacific after a launch from Vandenberg to a polar orbit.
- February 19, 2017: First daytime landing and third return to launch site of a Falcon 9 first stage. First usage of historic Launch Complex 39A since Shuttle era.
- March 31, 2017: First re-use of the first stage of an orbital vehicle followed by drone ship recovery. Additionally, SpaceX made its first attempt at fairing recovery, which resulted in their return via parachute to a location at sea. Future attempts will target landing the fairings on inflatable barges.

ORBITING COMPONENT:

- April 22, 2010: The Boeing X-37B vehicle one first launch.
- December 3, 2010: Return of X-37B vehicle one (244 days in space).
- March 5, 2011: X37B vehicle two first launch.
- June 16, 2012: X37B vehicle two returns (469 days in space).
- December 11, 2012: X-37B vehicle one second launch.
- October 17, 2014: X-37B vehicle one returns (675 days in space).
- May 20, 2015: X-37B vehicle two second launch, currently in orbit.

We are on the edge of a new age of the re-use of the vehicles used to reach orbit. This new age of re-use will have the following characteristics:

- A significant part of the vehicle is re-used (first stage, second stage, fairing, or orbital component) although details of the re-use architecture may vary. In particular, the 2nd stage may be re-used in space. However, it should be noted that since the first stage comprises about 75% of vehicle cost, full first stage re-use will have a dramatic effect on our ability to access space.

- Re-use occurs with minimal refurbishment/maintenance between flights, i.e. the replacement of wearing parts, not the disassembly and re-building of the engines.

- Re-use occurs often enough that there exist substantial cost savings to the launch services provider. However, rocket re-use could be a major success at much lower re-use levels than those achieved by cars and airplanes.

- Re-usable vehicles achieve a much higher level of reliability as compared to current expendable vehicles. The ability to test a launch vehicle and eliminate "burn-in" problems will contribute significantly to this goal as many problems are detected on first use. Additionally, re-use enables regular examination of wear, which over time will lead to the incremental development of more reliable vehicles.

It is not claimed that SpaceX has already achieved this high level of reliability and re-usability, but that SpaceX is, via constant testing and improvement of the F9, on a path to achieving a much higher level of reliability than currently exhibited by expendable vehicles. Further, the SpaceX demonstration of first stage re-use suggests that the "battering" an orbital vehicle receives does not prohibit re-use.

Why Reuse Matters

Launch vehicle re-use meeting the criteria listed just above has three key characteristics with the potential to transform space operations:

- A re-useable, flight proven vehicle is anticipated to be much more reliable than an expendable vehicle which has never flown before since most problems generally appear on first usage of a new vehicle.

- The level of risk for a flight proven vehicle can be expected to follow a risk profile typical of other re-usable vehicles as the vehicle ages, allowing for appropriate pricing modifications, just as a car with 100,000 miles on it does not carry the same reliability expectations as a car with 10,000 miles on it. In particular, for re-usable vehicles the typical pattern is that risk will first decrease, then hold more or less constant, and eventually rise with time. The exact shape of this curve for a re-usable rocket will depend on a plethora of design choices and can be expected to change as engineering knowledge advances. The example given of car mileage is for illustrative purposes only.

- A re-usable vehicle that meets the above criteria is expected to significantly lower costs to orbit and raise potential flight rates for the range of payloads it optimally supports. This "optimal" range of payloads is that which is large enough to support re-usability economically, but smaller than the maximum payload that could be achieved in expendable mode.

What do these three characteristics imply for space operations? The examples given below could result from any technological advance that lowered the cost and increased the reliability of accessing space significantly, but assuming that re-usability achieves these two goals they all become more likely:

- There will be great value to fitting space projects into "chunks" that can be cheaply and rapidly lofted by available re-usable vehicles. Increased usage of standard-sized payloads has the potential to lead to higher flight rates and still lower costs. There is an analogy to the fashion in which standard shipping containers have dramatically lowered the cost of shipping freight on the Earth. The "cubesat revolution" demonstrates how much costs can be lowered when standard components, interfaces, and delivery systems are widely used instead of custom-built satellites.

- The usage of orbital self-assembly of standard "chunks" may dramatically enhance this trend. Current orbital integration techniques often require precise engineering and extensive testing of unique parts. A focus on universal use of standard and well-understood interfaces has the potential to greatly lower costs since the engineering/test effort need only be done once.

- Over time, a much higher level of proven reliability will be demonstrated, allowing for project planners to count on the availability of large numbers of launches from multiple providers.

- The usage of in-space refueling, whether via fuel depots or "distributed launch" architecture will be greatly enabled by the availability of a large number of relatively inexpensive launches of re-usable vehicles to loft fuel into orbit. Fuel is the ideal cargo to lift on re-used craft during a period in which engineering work is being applied to improve vehicle re-usability since fuel is easy to replace and inexpensive on the ground, yet extremely valuable once in orbit. Idle re-usable vehicles can be applied to flying additional fuel to depots, keeping the flight rate high.

- In-space manufacturing of satellites from bulk goods will also be greatly enabled by the availability of a large number of relatively inexpensive launches of re-usable vehicles to lift bulk supplies into orbit. Since bulk supplies are relatively inexpensive and easy to replace compared to complete satellites, the considerations mentioned above with regard to fuel apply here as well.

Overall, any in-space project is enabled via the availability of lower-cost, more reliable, re-usable commercially available launch vehicles, but only if the in-space project is architected to make maximum practical use of this new capability.

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[1] The Kármán line, or Karman line, lies at an altitude of 100 kilometres (62 mi; 330,000 ft) above the Earth's sea level, and commonly represents the boundary between the Earth's atmosphere and outer space.