An engineer's view of what low-cost, reusable, commercial passenger space transportation means

By Mike Snead

The apparent intention of the Trump administration to reestablish the National Space Council has raised expectations that important improvements in national space policies and America's space enterprise will be forthcoming. One crucial area is improving the ability of Americans to travel to and from low Earth Orbit (LEO). In various forums, recommended policy changes focused on these key human space transportation system characteristics: passenger space travel, safety, reusability, low cost, and commercial. While these may sound self-descriptive, as an engineer, I think it is important for those making these recommendations, as well as those drafting updates to overall national space policy and space transportation policy, to use these terms consistent with commonly understood meanings.

Passenger space travel

The term "passenger" is increasingly slipping into discussions of human space travel. For example, when mentioning NASA's commercial crew program to transport astronauts to and from the International Space Station, some describe this as a commercial passenger system when it is not. Similar comments arise when discussing commercial suborbital human spaceflight. Perhaps unknowingly, "passenger" is used generically when, in fact, it has a very specific legal definition that substantially impacts how a true passenger space transportation system would be built and operated. Incorrect use in policy, legislation, regulation, advertising, and commentary could significantly hamper achieving commercial passenger space travel and misinform the public.

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Humans have been traveling on commercial transportation systems for thousands of years. They book passage and pay a fare to be transported to their desired destination. The reason for the travel is unimportant. Over time, it became a matter of common law that the provider of the commercial transportation system—referred to as a common carrier—was implicitly responsible for the safety of the passengers. In other words, the passengers had a legal expectation that the common carrier, as part of offering service, was faithfully meeting its "duty to care" for their safety. If a passenger came to harm, the common carrier could be sued for damages. If negligence is proven, punitive damages and criminal liability could be incurred. Hence, to state that a transportation system is intended for passenger use brings with it a legal duty to care obligation by the common carrier. Every public transportation system builder and operator, from escalators to airplanes, falls within this passenger duty to care model. Commercial passenger space travel must as well.

So far, there has been no commercial passenger space travel. Further, it is my understanding that no American company has announced that they are developing a true passenger transportation capability for use by a common carrier. Yet, this is exactly what is needed for America to transition into a true commercial human spacefaring nation. Thus, updates to national space policy addressing passenger space travel must reflect the proper legal use of the term “passenger” so that, as discussed below, acceptably-safe American passenger space transportation systems are brought into operation. We cannot afford another lost opportunity to set America on the path to becoming a true commercial human spacefaring nation.

Acceptably-safe passenger travel

As mentioned, common carriers have legal liability for the safety of the passengers they transport. Society does not demand that these passenger transportation systems be perfectly safe, only that they be acceptably safe. This is achieved through independent safety certification.

As legal tort cases involving passenger harm grew in the late 1800s and early 1900s, especially involving steam-powered mechanical transportation, a regulatory approach was initiated to establish a legal definition of what constituted the duty to care obligation and how this obligation could be met. This is referred to as certification. Both the manufacturer and operator of the passenger system demonstrate, to an independent body of engineering experts typically from a government agency, that the duty to care obligation was faithfully executed. Essentially, society has placed trust in the engineering profession to protect public safety by independently certifying only those systems that achieve an acceptable level of demonstrated safety. Formal certification then provides the manufacturer and operator with a legal shield which, generally, protects them from lawsuits claiming harm, provided the system was properly operated and maintained. Such claims are then, generally, handled administratively, such as through insurance.

This change was very important and beneficial. Under tort law, redressing alleged harm was the central focus of government oversight efforts. Under certification law, producing passenger transportation systems with acceptable safety was the focus of government efforts. This enabled a robust transportation industry to make remarkable technological advances while adequately protecting public safety. American passenger space travel now needs to be brought under certification law if comparable improvements are to be achieved.

Certification process

The use of the term “passenger” implies “duty to care,” which has legally evolved into independent safety certification. What does this mean?

This safety certification process involves two steps. In the first step, the design of the passenger transportation system is shown through analyses, inspections, tests, and demonstrations to comply with accepted safety specifications and standards; is shown though tests and demonstrations that it operates correctly as designed during normal and emergency operations; and is shown through analyses and tests that it will operate safely for a prescribed period of time or number of usage cycles. This last point is very important as it relates to reusability, as discussed below.

The safety certification process begins with the start of developing a new passenger system. Pertinent standards are identified and tailored specifications, such as design criteria, are developed to translate the general need for safety into specific design, analysis, test, demonstration, and inspection actions. When the development process ends, independent examiners review the specifications, engineering analyses, and test, demonstration and inspection results to determine if a sound design has been developed. If the examiners agree, a "type certificate" is issued and the design is frozen. It is important to understand that safety is not blindly "tested" into the system. Safety certification is not an afterthought to the system development.

Once a type certification is obtained, serial production of the certified design begins. Each production unit is inspected and operationally tested to show that it has been built and assembled per the certified design and that it operates correctly. An operating certificate is issued for each production article that passes the acceptance examination which, for flight systems, includes checkout flights. Only then can the article enter commercial passenger service with a common carrier. Periodically, each system's certification is renewed by a thorough reexamination of the system to check for degradation and damage.

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As mentioned, these two certification steps are undertaken by or overseen by independent examiners, usually government personnel. The builder or operator does not self-certify the safety of the system. For commercial airliners, this is the airworthiness certification process and is the model that should be used for passenger space transportation systems. Thus, changes in national space policy, legislation, and regulation should extend airworthiness certification to human space travel, transforming it into proper passenger space travel.

Reusable space travel

From the above discussion, it should be apparent that safety certification can only be practically achieved with a transportation system that is fully reusable or, simply, "reusable." This does not mean, however, that the generic use of the term "reusable" implies safety.

Several space transportation companies are now developing staged launch vehicles that have provisions to recover and reuse one or more stages. General commentary on these systems has referred to these as reusable space transportation systems, often with the implication that they would be suitable for passenger space travel. Absent certification, this implication is not correct.

It is notable that the commercial jet age and the space age both started at the same time. While commercial jet aviation has advanced significantly, especially with respect to achieving acceptably-safe and low-cost operations, human space transportation has not.

Reusing a stage of an otherwise expendable launch vehicle is an economic decision by the customer where the decreased cost is weighed against the increased risk of failure. There is nothing inherently wrong with this for robotic missions. Companies make such cost-versus-risk decisions all the time. It is, however, important to distinguish between a reusable and a reused stage. If the recovered stage requires more than a walk-around visual inspection, such as pilots do before takeoff, is it really reusable? The need for a detailed tear-down inspection after every flight, followed by a determination to either repair any damage or scrap the stage, does not appear to be consistent with the aircraft-like reusable model needed for routine, acceptably-safe, passenger space transportation. My impression is that the term "reusable" is being used inappropriately and is creating confusion. What's needed are fully-reusable, airworthiness-certified passenger transportation systems.

Low-cost space access

When making space transportation recommendations, the term "low-cost" is quite often used as a general expression of hope that, through some means, human space transportation will become significantly less expensive per person than what has been the case for the last half-century. Since the advent of mechanical transportation in the 1800s, I can't think of another example where high costs for human transportation have persisted for such a lengthy period of time. I believe that there were two primary reasons for this.

First was the necessity of relying on modified ballistic missiles—expendable munitions—to transport the first American astronauts to LEO as part of the Cold War with the Soviet Union. In the spring of 1961, after the failure of the CIA's Bay of Pigs invasion of Cuba followed shortly by the Soviet Union's historic first human space mission (Yuri Gagarin), President Kennedy found it politically necessary to embolden America's fledgling human spaceflight program. Thus, he announced the goal of landing an American on the Moon within the decade—a goal that could only be achieved through the use of expendable space capsules launched on expendable vehicles.

Second, and more of a long-term consequence, was ending the military's involvement with human spaceflight. US Air Force interest in human spaceflight, for both exploration and military uses, began in the mid-1950s. Their interest was in developing partially and fully reusable human transportation systems that were “aircraft-like” in operation. Two significant efforts were underway in the late 1950s: the DynaSoar reusable spaceplane to be launched on a modified ballistic missile, and a fully-reusable aerospaceplane. The former became a major system development program that was canceled in 1963 after $5 billion (current dollar value) had been expended. The latter became a series of research efforts that led to scramjets and high temperature materials that, twenty years later, reemerged as the National Aerospace Plane project.

The key to achieving low-cost human space transportation will not be found from the starting point of expendable launch vehicles, but will arise from achieving aircraft-like flight to and from LEO. Had the Cold War necessity of using modified ballistic missiles not arisen, it is quite possible that the DynaSoar spaceplane would have entered operation by the early 1970s. A fully-reusable, two-stage military system could have followed by the mid-1980s with commercial derivatives being built to enable common carriers to provide airworthiness-certified passenger transportation.

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While this is obviously speculation, it makes the point that significant technical contributions by the military to achieve fully-reusable human space access were missed due to senior policy decisions excluding the military from human space operations. This is exactly the opposite of what happened with America’s commercial jet aviation industry. Key technical advances in jet-powered military aircraft, developed in the late 1940s and early 1950s, jump-started the commercial jet age by enabling the Boeing 707 and Douglas DC-8 jet airliners to enter common carrier service in 1958 and 1959, respectively. It is notable that the commercial jet age and the space age both started at the same time. While commercial jet aviation has advanced significantly, especially with respect to achieving acceptably-safe and low-cost operations, human space transportation has not.

For commercial airliners, the key to low recurring costs are aircraft that have long economic lives lasting decades and that can operate routinely and frequently, without the need for post-mission inspections beyond the traditional pilot walk-around to perform a general visual inspection. The long economic life of the aircraft enables the high upfront aircraft cost to be amortized across thousands of missions. The lack of need for intense post-mission inspection enables the touch labor costs per mission to be low. Together, these translate into the lowest seat cost and one of the safest means of medium- and long-distance passenger travel by an industry where safety is highly regulated. The path to low-cost human space travel is to extend the commercial aviation model into space using fully-reusable, airworthiness-certified systems. Updates to the national space transportation policy should make this a national policy.

Commercial space access

America's successful transition into a true commercial human spacefaring nation will require robust commercial passenger transportation to and from LEO, then, within the Earth-Moon system, and, finally, extending into the central solar system. From the above discussions, low-cost commercial passenger space transportation systems will have these characteristics:

- They will be airworthiness-certified to enable manufacturers and common carriers to discharge their duty to care obligation through independent safety certification.
- They will be fully-reusable flight systems produced from type-certificated designs and operated according to approved maintenance and repair procedures.
- They will be highly durable to enable years, if not decades, of service before retirement.
- They will be damage tolerant to enable continued safe operations with non-remote occurrences of damage within the fleet lifetime.
- They will operate routinely and frequently with minimal post-mission inspection or servicing and with traditional airliner-like periodic safety inspection intervals to maintain the overall integrity of the system.

It is very important that updates to national space policies, led by a new National Space Council, define a sound and constructive path for America to establish common carrier passenger space transportation. For engineers engaged in developing this capability, it is important that terminology be used properly so that acceptably-safe, low-cost, commercial passenger space transportation systems can be developed and brought into operation.

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