

Hype and Hurdles: A Reality Check on the Technological Readiness of Commercial Space Tourism

AUTHOR

Abstract

The late 21st -century commercial space race, led by commercial organizations, including Blue Origin, Virgin Galactic and SpaceX, has made space tourism a household name and ensured a new generation of democratized access to the final frontier. To respond to this research question, this paper performs a critical technology analysis to determine: Is space tourism technologically prepared to conduct safe, dependable and scalable commercial business, or is it mostly marketing hype? This discussion is a kind of reality check in the sense that it has been shown in a systematic manner that there is still a difference in the technological preparations of sub-orbital and orbital passenger flights and that there are enduring and sometimes fundamental engineering impediments to both. It uses a conceptual analysis and technology assessment framework as a methodology to synthesize publicly available information on aerospace engineering literature, government reports on safety, and corporate publications. The results show a great deviation: although operationally feasible and proven by Blue Origin and Virgin Galactic, the sub-orbital tourism encounters serious and unmitigated challenges in the areas of operational reliability, vehicle reusability, and economic scalability needed to become a regular service. The engineering issues, such as material fatigue of composite structures and stress of rocket engines as well as the complexity of the realities of a design that must turn around quickly is not easy and is certainly not the airline model that is frequently touted. On the other hand, orbital tourism as exhibited by SpaceX and Axiom is identified to be commercially still in its early stages in terms of technology. Its promotional story lost the subsidiary, unresolved issues of ab-initio tourists. These are the absence of strong, miniaturized, and fault-tolerant long-duration life support systems (ECLSS), the severe and underscored risk of radiation exposure (GCRS and SPES) over and above short LEO sojourns, and the pronounced thermoflattening and thermostructural loads of orbital re-entry, where nothing truly reusable and low-maintenance exists. The conclusion of this paper is that sub-orbital flight is moving out of the realm of hype into high risk and boutique reality, but that orbital tourism by the masses is more of an unrealized potential. The engineering obstacles are inherent rather than incremental, and need breakthroughs in the fields of physics, materials science, and human biology that take decades not years before they can be reliably and commercially applied.

Date of Submission: 10-11-2025

Date of Acceptance: 20-11-2025

I. Introduction

1.1. Background: The New Space Race and the Commercial Imperative.

During the second half of the 20th century, space access remained a monopoly of actors at the state level. National pride, scientific breakthrough and military ambition led to the Cold War space race, a proxy of the geopolitical, ideological war between the Soviet Union and the United States (Seedhouse, 2017). The equipment was custom-built, it was astronomic in prices and the subjects were elite, highly-trained military test pilots and scientists. A paradigm shift has however been seen in the new millennium. With the creation of the so-called NewSpace industry, a part of the world economy that is comprised of the private space technology developing companies, this has completely transformed the situation. Headquartered by high-profile businesspeople and individual companies, i.e. the Blue Origin, Virgin Galactic, and SpaceX of Jeff Bezos, Richard Branson, and Elon Musk, respectively, this new race is not flag-waving, but business (Davenport, 2018).

This paradigm is characterized by the following new principles: reusability, cost-reduction, and market creation. Having space tourism as the most visible and attractive commodity, this sector is poised to democratize space by enabling the frontier to be opened to non-professional citizens. Using large amounts of privatized capital, innovative engineering ideologies (such as agile development and vertical integration), and, most prominently, massive government contracts (such as NASA Commercial Crew Program), these firms are establishing a new space access ecosystem (NASA, 2023). The "hype" is not an accident, it is a vital element of the business model, without which the venture capital, public and political interest, and support needed to surpass unimaginable technological and financial obstacles (ResearchGate, 2025).

1.2. The Promise vs. The Question: Stratifying the Dream.

The promises of the new industry are stratified, but they are commonly mixed up in the discourse of the people and the media. There are two types of products that are sold and the difference in the level of technological, energetic, and physiological challenge is enormous.

Sub-Orbital Tourism: This will be the one that Blue Origin New Shepard and Virgin Galactic VSS Unity (and its future Delta-class) are following (and will follow). The product provides the passengers with a parabolic flight to the space border (around 80-100 km, just below or above the Karman line), several minutes in weightlessness, and the view of the planet in the contrast between the Earth and the blackness of space (Goh & Yusop, 2021). The car attains an apogee and falls back to the earth without having enough speed to move into a stable orbit.

Orbital Tourism: It is a more ambitious project, which is currently controlled by SpaceX (coordinated with firms such as Axiom Space). In this product, it is the attainment of orbital velocity (or about 7.8 km/s or more than 17,000 mph) that enables the spacecraft to orbit the earth. This takes a thousand times more power than a sub-orbital hop. It will consist of several days in space, with possible stops in a space station and a much more dangerous landing (Axiom Space, 2025).

This difference is of paramount importance. The publicity and promotional efforts tend to give the impression that they are a sequential one after another, which gives the impression of an integrated, fast-growing industry. The popular name is called a flight to space, however, there is a comparable difference between engineering, energy, and risk in the 15-minute sub-orbital hop, and the 3-day orbital mission, similar to the difference between a small, privately-owned airplane and an intercontinental ballistic missile. The main research question of this paper is as follows: Does the technology of commercial space tourism, whether in sub-orbital or orbital, actually exist to have safe, reliable, and scalable operations, or is the marketing hype blindingly the many structural and fundamental engineering obstacles? The paper is in itself a kind of reality check of what is technologically demonstrable as opposed to what is speculative.

1.3. Research Gap and Objectives

Literature available on space tourism has mostly taken two positions. The former is an economic one, comprising of the market reviews with multi-billion dollar expansion projections, usually under the assumption that technological challenges will be surmounted (e.g., Grand View Research, 2023). The second ones are boosterish or journalistic stories that cover the experiential element of flight, Overview Effect, and visionary entrepreneurs (Davenport, 2018). Although there are critical reviews, many are of a high-level legal framework (e.g., the Outer Space Treaty), ethics, or the environmental effect (e.g., soot emissions) (Grand View Research, 2023).

A big distance still exists: an unemotional, comparative, technically-based evaluation of the detail, intractable engineering challenges that lie between the promise and the reality. The paper will not argue as to whether or not space tourism should occur, but rather, is it possible, with the present, or even foreseeable technology, to occur safely, reliably and on a scale.

The paper objectives are:

- To establish a strict definition of what can be termed as technological readiness within the framework of a commercial passenger service having to go out of mere feasibility.

- To make a critical distinction between the energetic, physiological and engineering challenges of sub-orbital and orbital flight.

- To examine the concrete, undiscovered obstacles in technology that particular to each of these two classes of flight such as propulsion reusability, life support, radiation shielding, re-entry systems, and abort procedures.

In conclusion with a reality check to compare the hype vs. reality dynamic on the basis of this engineering analysis, give a subtle answer to the question of the research.

1.4. Structure of the Paper

In order to accomplish these goals, the paper has been divided in the following way. Section 2 includes the extensive literature review, including the description of the theoretical background of spaceflight and human physiological limitations, as well as the critical analysis of the mentioned technologies of the key commercial rivals. In section 3, the methodology is described, a conceptual analysis and technology assessment framework, and the reasons why it was employed in a field where proprietary data is prevalent. The main part of this paper, section 4, provides a close comparative report on the engineering obstacles to sub-orbital and orbital tourism. Section 5 covers the extended policy, passenger safety, and the long-term sustainability of the industry implications of these findings. Section 6 ends by providing a concise, evidence-based response to the research question and offers certain recommendations regarding the future technical and policy research.

II. Literature Review

2.1. Theory: The Unforgiving Physics of Spaceflight.

Space tourism issues are old they have a basis in the physical principles of space travel and the weaknesses of human biology, which NASA, Roscosmos, and similar national organizations have grappled with throughout the last 60 years.

2.1.1. The Tyranny of the Rocket Equation The Tsiolkovsky rocket equation is the one-liner that dominates everything in rocketry, and which was originally written by Konstantin Tsiolkovsky in 1903 (Turner, 2008). Simply put, it specifies that the change in velocity (Δv) that a rocket can attain is proportional to its exhaust velocity as well as the natural logarithm of its mass ratio (the ratio of original wet mass, propellant included, to its empty mass). This is a savage logarithmic correlation. In order to cause a small increase in final velocity a rocket will be required to add a disproportionately large quantity of propellant which in turn puts additional mass, which will demand more propellant in turn, to be lifted.

This equation will bring a clear distinction between sub-orbital and orbital flight.

sub-orbital A typical sub-orbital hop (such as that of New Shepard) takes a Δv of about 1.5-2.0 km/s.

Orbital: 9.4-10.0 km/s Δv is needed to reach the Low Earth Orbit (LEO) (this is assuming overcoming gravity losses and atmospheric drag not just the orbital velocity of 7.8 km/s) (Curtis, 2020).

This five fold change in Δv implies that the energy needed to complete an orbital flight must be 25 times higher ($E = C v^2$). This is the reason why orbital rockets are large, multi-stage rockets (such as the Falcon 9), whereas sub-orbital rockets are small, multi-stage rockets (New Shepard) or air-launched spaceplanes (VSS Unity). Orbital flight physics dictates a vehicle of progressively increased complexity, cost, and contained energy (i.e., risk).

2.1.2. The Human Element: Physiological Constraints The human body has developed in 1-G sea level pressure, high oxygen, no radiation, environment. The opposite to this is space. The major physiological difficulties are:

G forces: During the launch the passengers face eyeballs-in acceleration (high-G forces: 3-4 Gs), and during the re-entry the passengers face eyeballs-out deceleration (3-6 Gs depending on the profile of re-entry). To inexperienced tourists, most notably older ones with possible cardiovascular complications, this poses a great health risk (Seedhouse, 2017).

Microgravity: Within a few minutes of being in space, Space Adaptation Sickness (SAS), or space sickness, sets in, and includes nausea, vomiting, and confinedness in space. The effects are also more intense on multi-day-long orbital missions, such as the fluid redistribution to the head (the puffy-face syndrome), cardiovascular deconditioning, and the disruption of the vestibular (Di Cocco, 2020).

Radiation: A space radiation environment, as described in Section 4.2.2 is a show-stopper to tourism over long durations. The atmosphere and magnetosphere of the planet are a protective cover of the environment that is high-risk and complicated.

The "Overview Effect": The major source of motivation of space tourism is also the so-called Overview Effect, which is discussed in a considerable body of literature. It is the cognitive transformation astronauts declare after viewing the planet through the lens of space, which includes a feeling of awe, unity on the planet, and a new mindset of the fragility of the planet (White, 2014). This is a psychological advantage which is a main product being sold but it has to be compensated by the physiological and psychological dangers of being locked up, isolated and even dying.

2.2. The Present Situation of the Commercial players and technologies.

NewSpace tourism has 3 influential actors who dominate the market with their own philosophy of technology and level of readiness.

2.2.1. Sub-Orbital: Blue Origin and Virgin Galactic.

Blue Origin (New Shepard): Blue Origin-sub orbital system is a fully automated vertical launched rocket and capsule system. Its New Shepard ship is made out of a reusable BE-3PM (Blue Engine 3, Peroxide-Monopropellant) liquid-propellant engine booster, and a crew capsule. Its major technological advancements are:

VTVL Reusability: The booster lands (VTVL) on a landing pad in a powered vertical fashion, a capability with its larger models, the New Glenn, and SpaceX Falcon 9.

Complete Automation: This system does not need a pilot and it is hands-off. This makes the operations easy but leaves 100% of the safety responsibility to the engineering and software (Blue Origin, n.d.).

Abort System A capsule bears one of the launch abort systems, a push system, that is a solid rocket motor at the bottom of the capsule, which can decouple the crew and the booster failing in orbit at any stage of the lift-

off. In-flight demonstration of this was successfully carried out in 2016. BE-3PM engine is a liquid hydrogen (liquid oxygen and hydrolox) deep throttling, startable engine. This type of propellant is a clean-burning one (it only forms water vapor) but poses major operational problems since liquid hydrogen is cryogenic, hard to store, and involves complex turbomachinery (NASA, 2017).

Virgin Galactic (VSS Unity / Delta-class): the system of Virgin Galactic is completely dissimilar. It puts the VSS Unity spaceplane into orbit at an altitude of approximately 45,000 feet on a carrier aircraft (VMS Eve, a specially designed and built, twin-fuselage jet).

Air-Launch: This horizontal type of launch system does not pass through the highest concentration of the atmosphere, which is supposed to minimise drag and propulsion effort (Virgin Galactic, n.d.).

Hybrid Rocket Motor: VSS Unity propelled itself with a hybrid rocket engine (solid fuel/liquid oxidizer(s)-based) which on paper would be less complex and safer than a pure liquid engine, but was previously not easy to scale and had its own safety concerns.

Feather Re-entry: The most significant innovation of the space plane is the feathering tail booms which open upwards during re-entry. This type of a configuration forms high drag and passively stabilizes the vehicle and makes the re-entry control problem, which is otherwise complex, much easier. This system has however been challenged immensely. The fatal accident of VSS Enterprise in 2014 was caused by a co-pilot activating the feathering system too early but it emphasized the inadaptability of the system (NTSB, 2015). The firm has successfully made multiple missions but in 2024, to concentrate on its next-generation Delta-class vehicle, it ceased commercial flights in a tacit acknowledgment that the VSS Unity platform was not robust and scaled-up to run a commercial service (Tourism Review, 2025).

2.2.2. Orbital: Axiom Space and SpaceX.

SpaceX (Falcon 9 / Crew Dragon): SpaceX is currently the sole privately owned company that has made crewed orbital launch, as well as rendezvous with the International Space Station (ISS). The orbital tourism operations of the company rely on its Falcon 9 rocket and Crew Dragon capsule.

NASA-Certified: It is significant to mention that the development of Crew Dragon took place with billions of dollars of NASA funding on the Commercial Crew Program. It is a NASA certified, state-sponsored, but not a highly commercial, ab-initio, tourist vehicle. It is designed and has safety standards based on the decades of experience at NASA (NASA, 2023).

Propulsive Reusability (Booster): The original stage of Falcon 9 is VTVL into an droneship, thus lowering launch expenses by a considerable margin.

Ablative Re-entry (Capsule): Crew Dragon capsule itself is partial. Its PICA-X (Phenolic Impregnated Carbon Ablator) heat shield is ablative, i.e. it burns during re-entry, and it is not reuseable. The capsule is retrieved out of the ocean and it needs a considerable amount of refurbishment.

Abort System: Dragon has a pull abort system, and SuperDraco engines have been built into the side of the capsule so that it can pull itself free on the failure of a rocket.

The mission to Inspiration4 by SpaceX and flights dedicated to Axiom Space (the tourism business) are essentially tailor-made, multi-million, and rather costly flights on this NASA-qualified spacecraft (Axiom Space, 2025).

Axiom Space: Axiom is not a launching company, it is a mission integrator and (in the future) space station contractor. It buys flights with SpaceX, trains the private astronauts and controls the mission. The model of the long-term business of Axiom is to construct its own commercial station in orbit as the destination of orbital tourists because the ISS will be decommissioned (Axiom Space, 2025). This brings out the other obstacle; orbital tourism needs a destination.

2.2.3. Hype as a Market and Investment Pressure The hype that is a space tourism is a very important aspect of the industry. The industry tends to follow the patterns of a hype cycle as researchers that have studied NewSpace market dynamics have analyzed (ResearchGate, 2025). Such features as optimism and exaggerated anticipation (e.g., airline-like operations, democratization) are not merely marketing but necessities to raise the massive amount of capital investment necessary to resolve these decades-long engineering issues. This is the talk that is typically fueled by charismatic founders and builds a perception of technological inevitability to the public and investors. In this paper, the technological reality on which this hype cycle is based will be evaluated to distinguish between engineering fact and financial necessity.

III. Methodology/Approach

3.1. Technology Assessment Framework Conceptual Analysis.

One of the most difficult issues in the study of the NewSpace industry is that the development of the private aerospace is largely proprietary and rather secret. Modern commercial information on material stress and engine performance, component failure modes and test results are trade secrets, unlike the Apollo era when NASA

publicly funded and shared its data. Therefore, it cannot be analyzed in a standard quantitative analysis in a traditional, data-driven manner.

Thus, a conceptual analysis and technology assessment paradigm is used in this study. It is a qualitative, synthetic methodology, which critically analyzes publicly available, non-proprietary data to construct a complete image of the technological preparedness of the field. The solution is comparable to an open-source intelligence (OSINT) combined with first-principles engineering.

3.2. Data Sources

This paper is a qualitative review of available data based on four major types of sources:

Academic literature: Journal articles in the fields of aerospace engineering, astronautics, space medicine, and physics (e.g., *Acta Astronautica*, *Life Sciences in Space Research*, *Journal of Spacecraft and Rockets*). This gives the theoretical and engineering first principles against which business claims are compared.

Authority: Technical specifications (when present), press releases, mission reports, live-streams of test flights, and official pronouncements by Blue Origin, Virgin Galactic, SpaceX, and Axiom Space. This information is critically analyzed and a difference between marketing assertions and factual technicality is made.

Government and Agency Reports: Federal Aviation Administration (FAA) Office of Commercial Space Transportation, NASA (and especially data about the Commercial Crew Program and ISS research), The Aerospace Corporation and NTSB accident reports. These sources are the most objective in terms of safety, regulation, and identified risks (e.g., The Aerospace Corporation, 2024; NTSB, 2015).

Quality Technical Journalism: Technical literate and deeply analysed publications and journalistic investigations that follow the development of the industry, its failures, and near misses.

3.3. Technological-Ready Framework.

As an alternative to binary thinking of it works/it doesn't, this paper outlines technological readiness of a commercial passenger service, a service offered to the population, as a three-criteria construct. This scale is based on, though stricter than, the standard Technology Readiness Level (TRL) scale, in that it is on commercial service and not component feasibility.

Feasibility (TRL 8-9): Does the underlying technology have any experience at all of being used in its current form, in its operating environment? This is the least bar to a prepared technology (e.g., "The system has flown successfully).

Reliability: Does the technology work over and over again with statistically high degree of predictability and quantifiable degree of safety? It means that the failure modes are thoroughly researched, the amount of testing is enormous, and a stable quality control and inspection process are implemented. This is what commercial aviation (with a failure rate of less than 1 per million flights) is measured by and this is an enormous jump away out of the air of feasibility.

Scalability (and Economic Viability): Is it possible to scale the operations to a high frequency at reasonable costs and turnaround times? This is not only the vehicle, but also the manufacturing, refurbishment, ground support and training facilities. A claim of scalability is that of an airline-like model.

Section 4 will analyze sub-orbital and orbital technologies in relation to this three-part framework saying that the "hype" tends to portray feasibility as reliability, and scalability, which is an elision that is hazardous.

IV. Analysis: The Reality Check of Engineering.

Sub-orbital and orbital flight engineering is not only different in degree, but also in kind. People usually fail to distinguish a 15-minute hop with a stay in orbit, which takes many days, as the technological difference between the two is enormous. This part will break down the barriers that are particular and enduring to each.

4.1. Sub-orbital Flights: The Frontier That is Approachable.

Sub orbital flights such as the ones provided by Virgin Galactic and Blue origin are technologically possible. The fundamental difficulty of flying to the karman line and coming back has been overcome and proved many times. The New Shepard has made several crews and VSS Unity has made several commercial flights. Nevertheless, reliability and scalability, two most important features of a regular commercial service still have considerable and long-standing engineering challenges.

4.1.1. Propulsion, Reusability, and Material Fatigue: The Myth of "Airline-Like" Operations.

The fundamental business plan of sub-orbital tourism is based on the quick reusability. As opposed to expendable rockets, these vehicles are sold as being somewhat more aircraft-like, and do not require much refurbishment between flights. It is not yet, but rather a problem of engineering which has not been solved.

Engine Stress: The Rocket engines are not jet engines. A jet engine is a steady-state system, which is meant to last tens of thousands of hours with a high-oxygen environment. A rocket engine is a bomb-in-a-box,

which has to work at very high temperature and pressure that is near the verge of metallurgical failure (NASA, 2017).

Blue Origin BE-3PM (Hydrolox): This engine possesses the greatest benefit of high performance (specific impulse) and deep-throttling capacity that is required to enable it to land in VTVL. The drawback is that it is enormously difficult to contain the cryogenic liquid hydrogen (LH 2). LH 2 is by far the hardest molecule to seal, it embraces hydrogen in metals, and it needs complicated and very fast turbopumps (which are life-limited components).

Virgin Galactic Hybrid Motor: This motor (a solid hydroxyl-terminated polybutadiene, or HTPB, fuel grain and a liquid nitrous oxide oxidizer) was theoretically simpler, which was used in Virgin Galactic Hybrid Motor, VSS Unity. Nevertheless, in the past, hybrid motors were hard to scale, their burn properties are often non-uniform, and are not throttleable in a comparable manner. The crash of the plane in 2014 was not due to the failure of the propulsion, but the decision to transfer to a new design that was a Delta-class indicates the Unity system was a dead-end.

Material Fatigue: The airframes, tanks and plumbing are also subject to a ludicrous and inimitable flight regime: air-launch (in case Virgin), high-G rocket boost, microgravity, and high-G re-entry. This is a much more differentiated, and pressurized environment than an aircraft on a commercial flight.

The composite-over-composite arrangement of VSS Unity is easy to handle, and inspection of the carbon composite materials to determine their micro-fractures, delamination, and thermal stress damages is infamously challenging. The non-destructive testing (NDT) is not foolproof, expensive, and slow.

The metal airframe of New Shepard is subjected to the recurring stress of VTVL, such as landing loads, and the cryogenic shock of the thermal load of the cryogenic LH 2.

Turnaround Operations: The Shuttle Teaching: The marketing objective of the "airline business of land, fuel, and fly" is not an engineering reality. The Space Shuttle was the pioneer of the so-called reusable spacecraft, which in that aspect was a failure both operationally and economically. Flights took months to renovate and thousands of technicians to look at and repair tiles, engines etc. It was costlier than a disposable rocket. The root cause of the problem of Blue Origin and Virgin Galactic is the same: every flight that is made necessitates a long, intricate, and time-consuming process of recertification of the vehicle to accept human passengers. The limiting factor on scalability is this inspection regime, and not the flight time. The fact that Virgin Galactic should give a pause in the year 2024 so that it can create the Delta-class which is expected to be of quick turnaround is an acceptance that the Unity system is unable to withstand the test of scale (Tourism Review, 2025).

4.1.2. Vehicle Integrity and Life Support: Safety Case.

A 15 minute flight life support is not very complicated: it is a pressurized cabin that has a bottled air supply (nitrogen/oxygen). The main engineering problem is not the problem of sustaining life, but it is the problem of saving life in an emergency. These two companies have opposite extremes.

Abort Systems:

The New Shepard by Blue Origin has a strong, full-envelope abort system. The pusher motor on the capsule can be fired anywhere between the launch pad and the motor cutoff and this will launch the crew to safety. It is the gold standard of launching capsules.

The Virgin Galactic VSS Unity does not have any launch abort system. It is assumed that a piloted spaceplane, powered by rockets, is in itself safer. In case the hybrid motor cannot ignite, it will be able to land on a glide. In case of a failure during the airplane flight, the consequences are not predictable. The crash of 2014 showed that one human mistake in this system (the unlocking of the feather) might be disastrous (NTSB, 2015). This is a serious departure of the safety measure taken by NASA to its commercial crews.

Window Integrity: Blue origin boasts of big tourist-friendly windows (which is a main selling point), which is a significant structural flaw. They have to endure the pressure difference of 14.7 psi (1 bar) in a vacuum of space and the thermal /acoustic pressure of launch conditions. One of them failing is immediately disastrous (depressurization, structural failure)

They are safe by design but a big change over the small porthole windows of the old space ships.

4.1.3. Sub-orbital tourism: Sub-orbital Sub-orbital tourism Reality Check Technologically feasible. It has passed the initial requirement. It is not yet proved to be reliable or scaled though. The barriers on the engineering side are in the "-ilities reliability, reusability, inspectability, and manufacturability. It is not a routine form of travel since it is a high-risk, low-frequency, bespoke experience. The engineering reality of a spaceline hype is several decades off from the engineering reality of a high-risk, experimental test-flight program.

4.2. Orbital Flights: An alternate Order of Magnitude.

In the event that sub-orbital flight is not an easy engineering issue, orbital tourism is a challenge of basic physics and human physiology. As determined in Section 2.1.1, additional energy is needed exponentially to attain orbital velocity. All individual engineering systems are pushed to extremely higher levels and novel and deadly

situations are encountered which are not anticipated in a sub-orbital hop.

4.2.1. Long-Duration Life Support (ECLSS): Brittleness of Life A Crew Dragon capsule with 3-10 days duration in orbit is not permitted to use bottled air. It involves a closed-loop Environmental Control and Life Support System of the intricate bubble of life, which is complex.

The CO₂ Problem: On a multi-day trip, the CO₂ that is emitted by passengers is fatal. Any concentration of 8 percent is lethal within minutes. The system should be active in scrubbing the CO₂, which is usually lithium hydroxide (LiOH) canisters (expendable such as on Apollo) or a more complicated, regenerative molecular sieve (as on the ISS and Crew Dragon). A breakdown in this active system (e.g. a pump, a valve, a saturated filter bed) is a life-threatening emergency which is mission ending.

The Support Systems: ECLSS does not concern only air. It includes:

Thermal Control: The temperature in a spacecraft can vary over 100degC on the lit side and -100degC in the shade of the sun. Active thermal control - the circuit of active cooling (e.g. ammonia or freon) of internal cold plates and external radiators is required to ensure that not only the electronics but also the humans survive. A pump failure in this case is disastrous in hours.

Waste Management: The "zero-G toilet" is an un-trivial piece of engineering equipment. The fact that the Inspiration4 mission was known to have a waste-management system failure that led to urine contamination underlines the unglamorous, non-trivial, and essential nature of these types of systems as basic systems.

Trace Contaminant Control: Humans and electronics off-gass trace hundreds of volatile organic compounds which may get toxic in closed environment. This must be handled by an active system of filtration. ECLSS is a "brittle" system. It is complicated, contains numerous single-point-of-failure modes (pumps, fans, sensors), and is uncompromising. The ISS has huge, roomy, redundant, and maintainable racks to this. Diluting this into a small and automated capsule is a giant task.

4.2.2. Radiation Shielding: the Silent, Unstoppable Murderer This is probably the most underestimated and the most serious hindrance to the long-term or longer than LEO orbital tourism. After a craft has been launched out of the shielding of the dense atmosphere (about 40km) it exposes the passengers to a high-energy radiation environment, which is very complex.

Galactic Cosmic Rays (GCRs): These are high-energy (protons and heavy nuclei) particles of far away super novae. They are an analog to bullets, which can not be protected. Normal spacecraft aluminum (such as Crew Dragon or the ISS) is not sufficiently thick that they are stopped. Even better, when a GCR hits the aluminum hull, it breaks (spallation) releasing a second radiation shower of neutrons and other particles within the craft which may be more severe than the original particle. No material lightweight and effective in blocking GCRs is available.

Solar Particle Events (SPEs): These are large, random, bursts of protons of solar flares. Radiation storm is a large SPE that would be fatal. A significant SPE took place between Apollo 16 and 17 and the astronauts of Apollo avoided a fatal bullet. The magnetic field of the earth (the Van Allen belts) is of great protection in LEO. The spacecrafts in the LEO, however, fly through the South Atlantic Anomaly (SAA), or magnetic field "dip" where the level of radiation is significantly greater, and sensitive parts (including humans) have to be bunkered.

The Mass Trade-off: Mass is the only protection that works: mass-thick water, polyethylene (which has many hydrogen atoms), or aluminum (Globus et al., 2021). However, the one most costly activity in rocketry is adding mass (see Section 2.1.1).

The Reality Check: In a few days the multi-day LEO Orbital tourists (such as those aboard Inspiration4) will have been exposed to more radiation than the average individual is exposed to in any given year. In longer journeys, in case of longer distances (e.g., to the Moon, which Starship suggests), the chance of an irreversible SPE is acute. Radiation dose limits of professional radiation-worker astronauts are already the cause of intense debate on ethics. Paying limits of the untrained tourists are not stipulated. This is not what is commonly called an engineering problem, and that was a physics problem whose solution had no immediate prospect.

4.2.3. Orbital Re-entry: The "Plasma Gauntlet" To go back to sub-orbit is quick (Mach 3-4) and short. Coming back is an act of violence (Mach 25) and time-consuming. The car re- enters the atmosphere at 17,500 mph, and it turns its very large kinetic energy into heat. This generates a wave of shockwave plasma heating the surface of the vehicle to more than 1,600degC (3,000degF).

Thermal Protection Systems (TPS): It is the TPS that keeps the crew alive and destroys them, otherwise.

Ablative (Expendable): Tiles on the Space Shuttle and the PICA-X shield on the Spacecraft Crew Dragon are the only items that do not allow the crew to be burnt. This TPS must be perfect. Even one point of failure (as in the case of Columbia disaster) is lethal. This is the gold standard of safety and is applied to Apollo, Soyuz and Crew Dragon. The PICA-X shield evaporates (burns away), and takes heat with it. It is very dependable but cannot be used repeatedly. The shield is to be changed fully after each flight.

Reusable (The Holy Grail): Silica tiles of the Space Shuttle could be reused, but were the weak point of the system. They were weak, and when one of them (by foam debris) was damaged, this caused the Columbia disaster. Starship is trying reusable tiles, which have turned out to be an enormous manufacturing and inspection problem, as it was with the Shuttle.

The "Reality Check": Non-reusable, ablative heat shield (such as that of Dragon) is a solid, workable technology. However, it is not scalable and airline-like. It is the goal of a fully reusable, low maintenance TPS (such as that of Starship), yet an engineering problem that has not been resolved. The glossing over of the issue of the speed at which Starship is aimed at glossing over the fact that it is trying to solve one of the most challenging engineering challenges of the Apollo and Shuttle periods, one that has never been successfully accomplished before.

4.2.4. Orbital Orbital tourism reality check as a commercial and scale business is not ready technologically. It is hype. The modern day "tourists" (as were the Axiom missions) are participants in high-risk, state-sponsored-level missions on vehicles (Crew Dragon) sponsored and approved by NASA, on partially-expendable hardware. The fundamental engineering impediments, ECLSS miniaturization, fault-tolerant, and reusable thermal protection, are not addressed to a commercial market. They still belong to the state-level R&D.

V. Discussion

5.1. Summative Analysis: Two Different Industries.

This comparison affirms that there exist a sharp difference. Sub-orbital and orbital tourism are dissimilar industries and different technologies, different risk profiles and different reality.

Sub-Orbital Industry: It is a small, high risk, boutique adventure industry. It is constructed on viability technology that is grappling with the engineering fact of dependability and capacity. The analogies of democratization and that of airline are the hype and the truth is a high cost, low frequency and an experimental experience of the ultra-rich. Its main obstacles include reusability, inspection and vehicle turnaround; operationalization of the technology challenges.

Orbital Industry: This is, until it is proven otherwise, virtually all hype as far as commercial is concerned. The product itself is a spot in a state-level, high-stakes test-flight program of hardware that cannot be scaled to commercial-levels (because of its expendable components). In-work fundamental engineering issues (ECLSS, radiation, re-entry) are not resolved; they are unsolved. The marketing weapon to finance the R&D is called the hype, and tries to work out these issues (e.g., Starship), but they are not going to appear immediately.

5.2. Policy, Safety and Public Implications.

The ramification of this technological disparity on regulation and trust among people is enormous.

The Regulatory "Learning Period": FAA is today under the Commercial Space Launch Competitiveness Act (CSLCA), which provided a learning period during which the FAA is substantially barred to issue safety rules regarding the design of vehicles, wherein the companies are only required to inform the passengers about the risks (FAA, 2023). This fly at your own risk (or informed consent) model was to avoid stifling innovation. Nonetheless, as demonstrated in this paper, engineering preparedness of sub-orbital flight is not so high that this light regulatory hand can be an endless requirement. When does reliability need to be established as opposed to presumed?

The Class Problem: The risks of orbital flight (radiation, ECLSS failure) are so high and systems are too complicated that it might never be deemed safe to the general population as is the case with commercial aviation. This brings the question of a two-class system, a two-class (sub-orbital and ultra-risk) product, a distinction that the general public might fail to understand.

Space debris and Sustainability: A scalable, high-frequency, airline-like, either of these classes of flight, generates a new and frightening issue: space debris. Increased launches imply increased amounts of junk in space-used stages, fairing and collision risks. Such a frequent launch rate might introduce the Kessler Syndrome (as the density of the LEO debris will reach the point where collisions propagate out of control, rendering space unusable) in a very short time. It is an externality that the "hype" story, which is based on the notion of democratization, conveniently avoids.

5.3. Limitations of this Study

The analysis, in its turn, is necessitated by publicly available data. Material stress, engine performance, component failure rates and test-flight close calls are among some of the trade secrets that private companies hold. This would entail a complete reality check and access to such proprietary data would be unavailable to both the general population and to the scholarly community. The real values of reliability are not known. Moreover, the discipline is changing fast; this article is a picture of what was at a certain moment. The Starship program, as an example, may or may not feature a success or failure story in the next few years, however, it will still need the underlying physics of the challenges (re-entry, in-orbit refueling) to exist.

VI. Conclusion

6.1. Summary of the "Reality Check"

The paper aimed at finding out whether space tourism is an overrated phenomenon or technologically prepared to take the leap. The response is an emphatic, evidence-based and highly differentiated yes and no.

Sub-Orbital: The technology is a reality, but the hype of a sort of airline, routine service is well beyond the engineering reality. The unrelenting, non-trivial problems of material fatigue, fast reuse, inspection, and vehicle turn around are what causes it to be a high-risk low-frequency venture in the foreseeable future. It is not so much hype and more like a very hard engineering problem that is still in the process of being solved.

Orbital: This, in a new business, scalable sense is largely hype. The basic, life or death engineering requirements, such as closed-loop life support, radiation shielding, and reusable re-entry systems are not addressed in the smaller, commercial vehicles. The current "tourists" are flying on NASA certified, government developed, partially-expendable hardware. The technological gap between the orbital promise that is Starship and the reality that is Crew Dragon is immense and cannot be bridged through commercialization, but rather through decades of risk-taking, costly research and development.

The existence of apparent single and fast-developing industry of space tourism is a marketing process. The fact of the matter is two distinct struggling industries: the one on a viable but non-scalable (sub-orbital) technology and the one on non-scalable, non-commercial (orbital) technology being sold as a commercial product.

6.2. Future Research Projections.

The potential of this industry lies on the resolution of the major obstacles of this paper. Further studies in this field should thus stop speculative market projections instead of the hard stuff.

Policy & Law: The investigation of a new regulatory framework that will succeed the learning period. What can the FAA do to ensure reliability? What are the international legal norms of space debris that are generated in commercial tourism? What are the ethical dose of radiations to individual citizens?

Materials science: Long-lasting research on material fatigue and non-destructive test (NDT) of composite airframe and metal alloys under repeated, fast sub-orbital load cycles.

Radiation Biology: The mechanism of action of GCRs on non-professional astronauts (e.g., underlying conditions) and development of new and lightweight shielding materials (e.g., hydrogen-rich materials, active magnetic shielding).

ECLSS Miniaturization: Investigations of the solid-state, reliable and so-called turnkey life support systems (e.g. solid-state CO₂ scrubbers, water processors) that need not be as mass, power, and complex as ISS-grade hardware.

As long as these basic engineering and physics issues are unsolved, space tourism will continue to be what it is now, an adventure of trial pilots and adventurers, rather than a vacation spot.

References

(Note: All references are formatted in APA 7th Edition style.)

- [1]. Axiom Space. (2025). *Axiom missions*. Retrieved October 26, 2025, from <https://www.axiomspace.com/missions>
- [2]. Blue Origin. (n.d.). *New Shepard*. Retrieved October 26, 2025, from <https://www.blueorigin.com/new-shepard>
- [3]. Curtis, H. D. (2020). *Orbital mechanics for engineering students* (4th ed.). Butterworth-Heinemann.
- [4]. Davenport, C. (2018). *The space barons: Elon Musk, Jeff Bezos, and the quest to colonize the cosmos*. PublicAffairs.
- [5]. Di Cocco, A. (2020). Radiation environment in low-Earth orbit: A challenge for human spaceflight. *Life Sciences in Space Research*, 24, 1-7. <https://www.google.com/search?q=https://doi.org/10.1016/j.lssr.2019.09.003>
- [6]. Federal Aviation Administration (FAA). (2023). *Commercial space transportation*. U.S. Department of Transportation. Retrieved October 26, 2025, from <https://www.faa.gov/space>
- [7]. Globus, A., Komerath, N., & Mamlata, J. (2021). *Orbital space settlement radiation shielding*. National Space Society. Retrieved from <https://nss.org/wp-content/uploads/NSS-JOURNAL-Orbital-Space-Settlement-Radiation-Shielding.pdf>
- [8]. Goh, S. L., & Yusop, A. M. (2021). A review of space tourism: A new era for the tourism industry. *Journal of Tourism Futures*, 7(1), 123-134. <https://www.google.com/search?q=https://doi.org/10.1108/JTF-04-2020-0054>
- [9]. Grand View Research. (2023). *Space tourism market size, share & growth report, 2030*. Retrieved from <https://www.grandviewresearch.com/industry-analysis/space-tourism-market-report>
- [10]. NASA. (2017). *Reusable rocket engines: The "hard stuff"*. NASA Technical Reports Server.
- [11]. NASA. (2023). *Commercial crew program*. National Aeronautics and Space Administration. Retrieved October 26, 2025, from <https://www.nasa.gov/commercialcrew>
- [12]. National Transportation Safety Board (NTSB). (2015). *In-flight breakup of SpaceShipTwo N339SS*. NTSB/AAR-15/02. Washington, DC.
- [13]. ResearchGate. (2025). (PDF) *From hype and bubbles to sustainable industries in NewSpace*. Retrieved October 26, 2025, from https://www.google.com/search?q=https://www.researchgate.net/publication/396895931_From_Hype_and_Bubbles_to_Sustainable_Industries_in_NewSpace...
- [14]. Seedhouse, E. (2017). *Space tourism: The history and science of orbital and suborbital flight*. Springer.
- [15]. The Aerospace Corporation. (2024). *2024 space safety compendium*. Retrieved October 26, 2025, from https://aerospace.org/sites/default/files/2024-12/SSICompendiumBook_2024-12_FINAL.pdf
- [16]. Tourism Review. (2025). *Space tourism in 2025: New trends*. Retrieved October 26, 2025, from <https://www.tourism-review.com/space-tourism-is-still-not-for-masses-news15109>
- [17]. Turner, M. J. (2008). *Rocket and spacecraft propulsion* (3rd ed.). Springer.
- [18]. Virgin Galactic. (n.d.). *Our technology*. Retrieved October 26, 2025, from

- https://www.google.com/search?q=https://www.virgingalactic.com/our-technology
- [19]. White, F. (2014). *The overview effect: Space exploration and human evolution* (3rd ed.). AIAA.
- [20]. Wikipedia. (2025). *Reusable launch vehicle*. Retrieved October 26, 2025, from https://en.wikipedia.org/wiki/Reusable_launch_vehicle