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PILOTS FOR SPACE TOURISM

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ABSTRACT

This article sheds light on the key player needed for any space tourism adventure: the pilot who flies the spacecraft. The paper addresses the potential benefits of including a pilot at the controls when designing a space tourism spacecraft. It examines the basic qualifications and advanced skills required of space tourism pilots and discusses key training requirements for selected pilots and space pilots' pay and benefits. In addition, the research concludes that, just as the pioneers of passenger transport in aviation entertained and captured the interest of their passengers, the space pilot should have the skills of a tour guide.

Keywords: astronauts, human resources, pilot, space tourism, suborbital

INTRODUCTION

Suborbital space tourism is moving from the pioneer phase (e.g., Ansari X Prize flights in 2004 [1]) to the operational phase, with suborbital flights already planned (e.g., SpaceShipTwo entry into commercial service expected in 2013 [2]). Stimulated by the successes in the

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last decade, research in the field of space tourism has increased, but it has typically addressed only a few aspects of space tourism (e.g., spacecraft technology, business plans, market opportunities and limitations, laws, environmental pollution, passenger motivation and demand), while ignoring the topic of the pilot himself or herself. We believe that pilots are a key factor in the success or failure of the space tourism market, so this paper offers insights into this relatively unexplored arena and address such questions as:

- Do we need a pilot, or is an unpiloted spacecraft sufficient or even more alluring for such an extravagant and futuristic market environment?
- Assuming a pilot is needed, what skills are required? Should space tourism pilots have experience as test pilots, or should they be retired or active fighter pilots (Figure 1)? Are average private Cessna pilot skills sufficient in terms of stress stability, rational thinking, and reaction?
- What special training is needed to qualify space pilots?
- What is the role of the space pilot during the flight? Should there be interaction between the pilot and space tourists?
- How can the market attract potential pilots to become space pilots? Is the intrinsic motivation "to be a space pilot" sufficient?

The following sections address whether a pilot is needed and present required pilot skills, pilot qualifications, their role in flight, and remuneration. After a discussion we draw conclusions and make recommendations.

Figure 1. NASA Dryden's F-18 research aircraft [3]

SPACE TOURISM: WHAT IS IT?

Humans are explorative in nature, but space, while alluring, has always been out of reach for those of average means and abilities. As more functions of space operations transfer from government-run entities to commercially operated endeavors, costs will fall, making the new frontier of space tourism accessible to many more members of society. The space tourism industry is a burgeoning opportunity for companies that seek a new niche in which to expand their travel operations. With the advancements that can be expected in the near future, the dream of booking a flight that is "out of this world" may soon be reality.

To operate in orbit around Earth, a space vehicle must climb to the upper reaches of the atmosphere and accelerate to a speed that allows it to remain in orbit. Suborbital flight profiles operate similarly but do not attain the same altitude or speed. By flying a parabolic flight, rather than orbiting Earth, the craft is exposed to the associated hazards of spaceflight for only a short time while still providing the passengers with the spectacular vistas, apparent weightlessness, and other amazing phenomena that space tourism has to offer [4].

The considerable acceleration required to escape the Earth's atmosphere is accomplished by the use of massively expensive and complex rockets, so current suborbital operations often involve drop-ships to sidestep the adverse effects of the lower atmospheric density. Since approximately 75% of the Earth's atmosphere is compressed in the first 10,600 vertical meters, the use of a drop-ship reduces a significant portion of air resistance compared to a launch from the Earth's surface, reducing the size of the engine needed for acceleration [4]. The drop-ship still has to overcome the effects of the atmosphere, but doing so has no effects on the size of the spacecraft's payload. The practice has been carried out for decades, with B-29s and B-52s dropping X-planes over the southwestern deserts of the United States.

The costs associated with designing, building, testing and certifying a space tourism vehicle are massive but not insurmountable. With advancements in lightweight materials under development, the spacecraft will eventually be able to depart like an airplane, climb under its own power, arch over, and descend [5]. In an effort to be "green," at least half of the fuel is likely to be derived from natural domestic sources, including cellulosic ethanol and other plant-derived fuels [6].

WHO'S FLYING THIS THING?

As space tourism comes closer to being a reality, a number of fundamental questions emerge regarding technological development, growth as an industry, and sustainability. One important question in regard to spacecraft configuration concerns whether it is necessary or desirable to include a pilot or astronaut in the design.

History. Previous to Scaled Composite's winning of the Ansari X Prize with SpaceShipOne and their Tier One programme, many doubted whether a privately funded reusable manned spacecraft, considered a necessary precursor to space tourism, could be developed and flown. While manned spaceflight has occurred regularly since 1961, until recently these flights have been the exclusive domain of nation states because of their exorbitant costs. It was the high costs of manned spaceflight that the Ansari X Prize project attempted to address by promoting the development of cheaper, reusable technologies, but the winning concept, dubbed SpaceShipOne, incorporated a pilot in their design in pursuit of lowering cost. This manned design saved the Tier One team considerable budget, time, and effort by eliminating the extensive research and testing necessary to develop unmanned flight-control systems.

Controlling Costs. With its manned configuration, SpaceShipOne cost roughly $30 million to design and manufacture [7]. This cost is significantly less than a comparable design that uses remotely piloted systems or that is altogether autonomous. By comparison, a relatively "simple" remotely operated Predator Unmanned Arial Vehicle (UAV) cost over $40 million to produce [8], while on the other end of the spectrum, the Global Hawk, an autonomous high-altitude UAV, cost more than $70 million to develop [9]. The characteristics of SpaceShipOne and a typical UAV are different (technology demonstrator vs military mission; small vs large company; private vs government funding) and thus not directly comparable. Nevertheless, the piloted SpaceShipOne with a high-workload cockpit enables a relatively simple vehicle with hardly any new technologies, while an autonomous SpaceShipOne concept would require very advanced technologies resulting in high development cost. Had Tier One attempted to design and test their suborbital vehicle without a pilot, space tourism would have remained outside the financial reach of all but the wealthiest among us.

Safety Factors of Unmanned Systems. A piloted flight system is cheaper, but it is also currently safer. While 70-80% of airline crashes are still attributed to human error, the percentage of fatal airline crashes per 100,000 flight hours is still monumentally less than those experienced by remotely piloted or autonomous UAVs. The current fatal accident rate for airliners is roughly 0.015 per 100,000 hours flown [10], but UAVs suffer similar Classes A and B accidents rates exceeding 10 per 100,000 hours flown [11]. Figure 2 depicts this UAV accident rate. While Figure 2 also indicates that safety improves dramatically as experience is gained, at their current and best experience levels, UAVs continue to exhibit a rate of accidents that far exceeds those accepted for commercial air travel. Unmanned systems offer numerous advantages in flight and spaceflight, but their technological development has not closed the safety gap; until this safety gap is narrowed, it will be difficult to attract sufficient and consistent numbers of commercial spaceflight customers.

What Does the Customer Want? Lastly, unpiloted commercial spaceflight, while in many ways technologically feasible, may not yet be readily accepted by the general public. While this psychological aversion will no doubt change as more automation is introduced into our daily lives, there is still a deep-seated distrust of automation when lives are at risk. Even the railroad and shipping industries, whose environments are significantly more stable and which, unlike suborbital vehicles, have some ability to stop in the event of a malfunction, have only recently begun to entertain the notion of remotely piloted systems (e.g. London's Docklands Light Railway). As the aptly named Phlyer [[12], #6] suggested, "Until the average person can buy a computer that never requires control-alt-delete during the life of the computer, or never lose a cell-phone signal, or can drive a car that never breaks, they will prefer a human pilot aboard. Ground control is the next logical step, but not quite yet."

Although some wealthy adventurers are willing to pay large sums to participate in orbital and suborbital flight—Russian-brokered trips to the International Space Station (ISS) are quoted at $20-35 million [13] —in order to achieve a sustainable space tourist customer base, the costs must be reduced considerably to open the market to more people [14]. Current technology does not allow for the inexpensive development of complex UAVs or unmanned space vehicles. In addition, although thrill-seekers abound [15], one cannot reasonably expect to attract and maintain a sufficiently large customer base unless the customers can be assured of a reasonable level of safety [16]. "Historically, US launch vehicles have been designed to optimize the vehicle's flight performance" [17, p. 53], resulting in a reliability penalty. Penn and Lindley [17] propose a design philosophy for a space tourism vehicle to reach a reliability of less than one fatal accident per 10,000 flights—a value similar to the current loss rate for military aircraft. According to Bensoussan, "Available statistics for the future space tourism vehicles are scarce and prospective at best at this stage of the development curve but the most commonly referred reliability figure targeted is 1 fatal accident expected for 50,000 flights." [16, p. 1637]. Suspicious of automation, at the very least passengers will expect a "man in the loop" backup for when things go wrong.

Proposition 1. For financial, safety, and psychological reasons, space tourist vehicles developed in the near future should include a pilot at the controls.

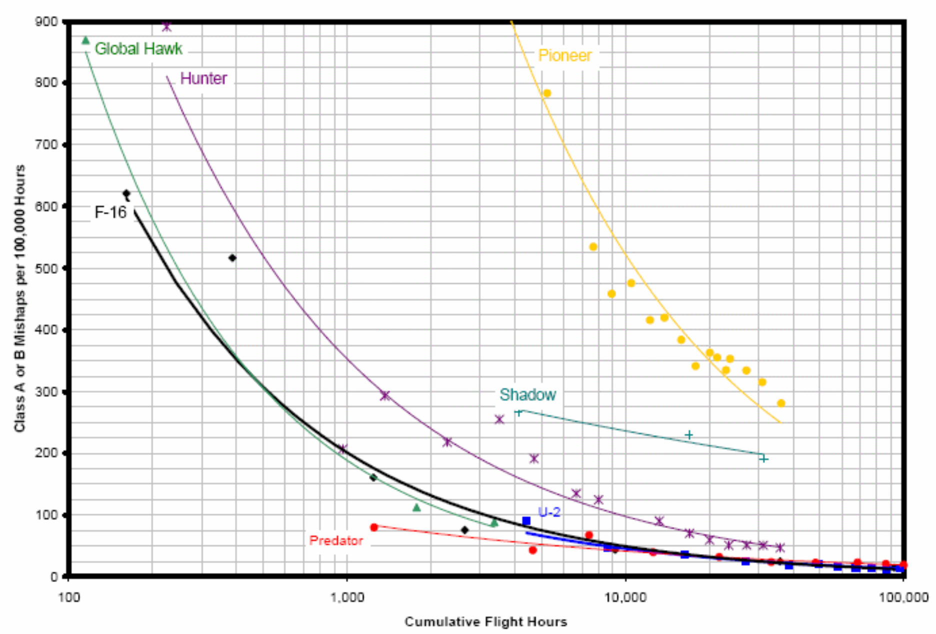

Figure 2. UAV mishap rates [11]

WHAT ARE THE SPACE PILOT'S QUALIFICATIONS AND SKILLS?

Suborbital space tourism pilots will be a new brand of commercial pilot. Some pilot qualifications and skills will logically transfer from traditional flying in the atmosphere, but suborbital flight has unique characteristics that require unique skills. This section addresses basic requirements for suborbital pilots, examines a suborbital flight phase by phase to illustrate the use of required pilot skills, and investigates where the space tourism industry will find pilots with most or all of these required qualifications and skills.

Basic Qualifications. The Federal Aviation Administration (FAA) has established a minimum set of requirements for pilots of human spaceflight, ruling that such pilots "must possess and carry an FAA pilot certificate with an instrument rating" [18]. In addition, a 2008 Aerospace Medicine Association working group determined that the current medical standards for the FAA Class I certificate were reasonable for crews flying suborbital profiles [19], suggesting that suborbital flight is not appreciably more strenuous than traditional flight. Given the high-altitude of suborbital flight, pilots and passengers will doubtless wear pressure suits, so previous experience and training in operating aircraft while wearing a pressure suit (as is the case for fighter pilots) will be a desirable pilot attribute. Another desirable qualification will be extensive training in emergency procedures and crew coordination, something shared by both commercial airline and fighter pilots. However, since suborbital flight involves high speeds, it could make sense to select pilots with experience in jet fighters, which also travel at high speed and require quick decision making.

Suborbital Flight Skills. Many organizations are working on developing space tourism vehicles, so several technologies and flight profiles are being considered. For the sake of simplicity, this research assumes that space tourism flight profiles will include a boost phase and a reentry phase and that they will glide to land. An example flight profile is shown in Figure 3.

Generically speaking, in the boost phase, the pilot pulls the nose of the vehicle to vertical and holds it there while accelerating at 3-4 g to approximately Mach 3 [20]. The challenge during this phase lies in constantly changing thrust and in understanding the aerodynamic qualities of the vehicle. The pilot of Virgin Galactic's SpaceShipTwo initially controls the vehicle using a manual stick and rudder inputs, but as the vehicle goes supersonic, he or she must transition to electronic trim tabs and, once the vehicle has left the atmosphere, must transition again to compressed air thrusters [20]. This last phase is unique to suborbital flight, and most pilots will require additional training to gain proficiency.

Specifics of reentry depend on vehicle design, but in suborbital flight the vehicle does not reach speeds that require a precisely flown re-entry profile: essentially, the vehicle falls back to Earth with little to no pilot intervention required. The most challenging part of re-entry is the 4-6 g of deceleration the pilot (and the passengers) must endure [20]. This level of g-forces is manageable for extended periods of time, but it requires training like that received by fighter pilots.

Once the vehicle has fallen back into the atmosphere, the aerodynamic control surfaces become effective again, and the pilot can make an unpowered landing. Unpowered landings are not uncommon in aviation: Gliders always make unpowered landings, and pilots of single-engine aircraft often practice an approach to landing at idle thrust to simulate an unpowered landing. To execute safe unpowered landings consistently, pilots need a complete understanding of the vehicle's glide ratio, the effect of winds, techniques to navigate through weather, and the effect of payload on approach airspeed. Test pilots will likely develop standard procedures for landing patterns to ensure the highest probability of success.

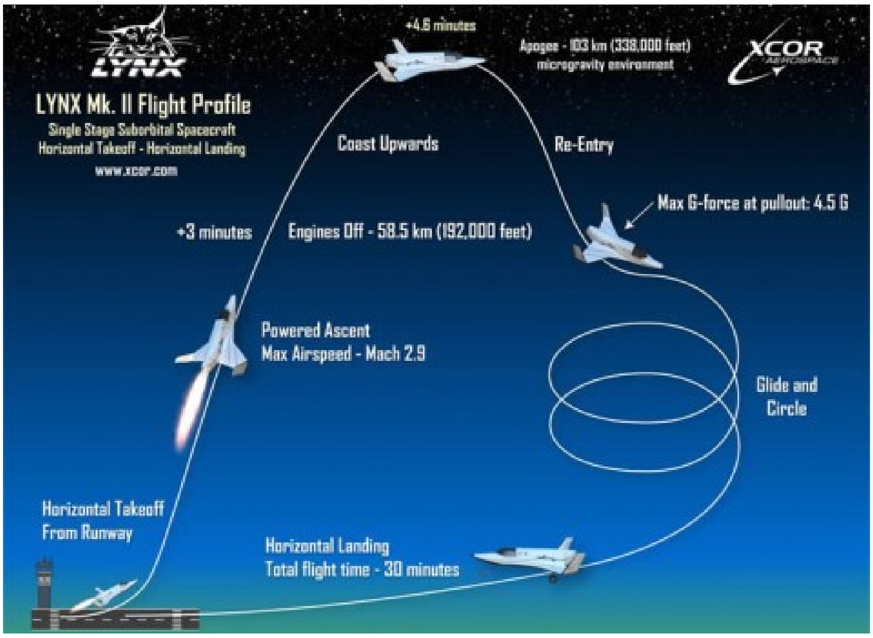

Figure 3. Example suborbital flight profile [21]

Sources of Pilots. If space tourism booms in popularity the industry will need to find pilots quickly. Table 1, which shows four possible sources of pilots, highlights the fact that single-engine fighter pilots and test pilots are generally the most qualified to be space tourism pilots. That said, Virgin Galactic has been recruiting pilots from its commercial airlines who have at least three thousand flight hours and experience in multiple aircraft [20].

Table 1. Pilot Sources vs. Qualifications and Skills

Qualifications and Skills	Airline Pilot	Fighter Pilot	U-2 Pilot	Test Pilot
Instrument Rating	X	X	X	X
Class 1 Physical	X	X	X	X
G Tolerance		X		X
Fast Jet		X		X
Pressure Suit		X	X	X
Emergency Procedure	X	X	X	X
Crew Coordination	X			X
Glide Landings		X		X

Proposition 2. Fighter pilots and test pilots are generally the most qualified to be space pilots.

WHAT ARE THE TRAINING REQUIREMENTS FOR SPACE PILOTS?

Selecting pilots with the proper backgrounds is important to achieving the goal of safe and proficient space tourism pilots, but because of the unique flight profiles and varying flight regimes of suborbital flight, pilots will need to be trained and proficient in each phase of flight, the unique physiological aspects of suborbital flight, and the aircraft itself.

FAA Regulations. Civilian and military pilot training programs are strenuous and typically consist of extensive academic training, numerous simulator flights, and flights in the actual aircraft with and without an instructor present. Minimum training requirements for pilots are regulated by FAA regulations and are used as a guideline for training programs. However, because space tourism is a comparatively new concept, few regulations concerning how a commercial suborbital pilot should be trained have been developed.

The latest FAA governing regulation, Title 14: Aeronautics and Space 2011, states only that a space tourism pilot must have an FAA pilot license and instruments rating; have the knowledge, experience, and skills to fly the aircraft; and receive mission-specific training for each phase of flight. The requirements are intentionally vague because of the various types of craft used for and in development for suborbital flight, any of which may or may not have flight characteristics similar to any other aircraft and may or may not fly in a traditionally understood manner. In order to meet these training requirements, training methods must be developed that impart the necessary knowledge to the pilot and provide assurance to passengers that they are in good hands.

Academic Background. Since the pilots' flight backgrounds may not be standardized, a comprehensive program must be developed to ensure uniform proficiency. Aeronautical knowledge is the foundation of all pilot training programs, but few pilots have any space experience, and extensive academics will be needed to teach the various aspects of suborbital flight. Advanced aerodynamics, rocket mechanics, aerospace physiology, high-altitude operations, ballistic flight, re-entry procedures, navigation, powerless flight, and emergency procedures should all be covered in detail. Once these basics are mastered, pilots should satisfy the knowledge requirement of Title 14.

Pilot Skill Sets. In order to achieve sufficient skill and experience to fly an aircraft like SpaceShipTwo, a pilot will need hands-on experience. Hands-on training in an actual aircraft is the best form of training a pilot can receive, especially in an environment so new and dynamic. However, such training is extremely expensive, and the costs and benefits of actual suborbital flight must be weighed against the need for experience. FAA regulations state that training tailored to each specific phase of flight may be used and accomplished in various ways, including through the use of simulators, aircraft with similar characteristics, flight testing, and other approved FAA processes [22].

The three phases of flight most common to suborbital vehicles are the boost phase, the re-entry phase, and the glide phase. Of the three phases, the boost phase is the most dangerous, and it requires the most pilot skill. When the craft accelerates above the speed of sound, it creates intense air pressure that could cause the craft to disintegrate if it remains low in the Earth's atmosphere. A timely 3-4 g pull up to begin the climb from a horizontal launch must be made to preserve energy for the ascent while not allowing pressures to build beyond safe limits, all while experiencing up to 4 g horizontally (Figure 4). As the air thins while the craft climbs, aerodynamic control surfaces cease to be effective and the pilot must use compressed gas or other types of thrusters to keep the craft oriented properly [20]. In the re-entry phase it is critical that the craft remain oriented properly. Some designs will be shaped to allow proper orientation to occur naturally, but in others the pilot may need to maintain a careful angle to avoid overheating the craft. During re-entry significant g-forces are sustained for nearly a minute, during which the pilot must be able to fly the craft safely. Finally, the glide phase involves navigating to the base of recovery without power and intercepting a glide path for a safe landing. This phase is the most similar to normal aircraft flight and is the easiest of the three phases to train on an actual aircraft.

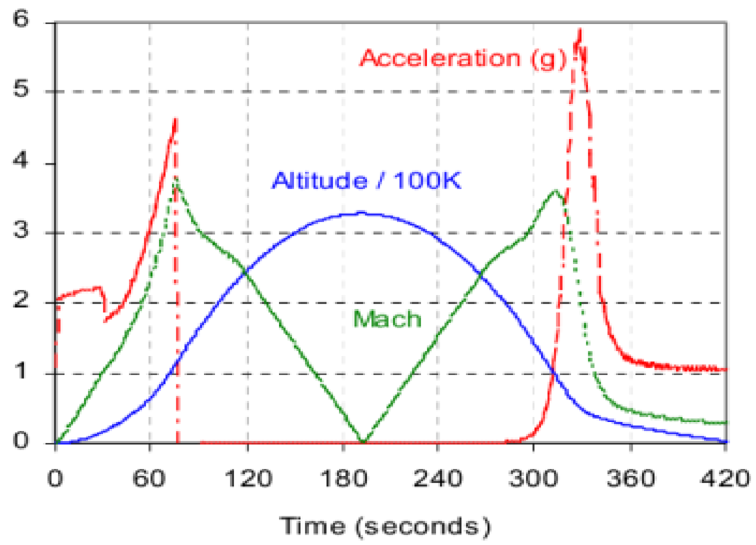

Figure 4. Altitude, speed and g-forces experienced by a suborbital craft [23]

How to Train Pilots. To keep training costs within a reasonable range, a flight simulator should be developed to teach the correct procedures, emergency operations, and control skills needed to fly the mission. However, because of the uniqueness of the suborbital craft, it may be difficult to develop a simulator that accurately represents its flight characteristics. In addition, the extreme physical forces exerted on the pilot cannot be replicated in a flight simulator.

It is important that pilots understand the physiological aspects of suborbital flight, so they should be required to undergo centrifuge training and microgravity training. The centrifuge gives pilots experience in the heavy g-forces they will encounter, although the g-forces experienced should be no more than what a normal fighter aircraft would experience, so previous fighter pilots are well qualified to withstand them. In order to simulate microgravity, an aircraft can be flown in parabolic arcs to allow 20-30 s of weightlessness so the pilot can become familiar with the sensation. NASA's KC-135 Weightless Wonder is one aircraft that already performs this function [24].

Black Sky Aero has developed a three-part concept as a way to train pilots in a suborbital craft in partial tasks [18]. The first phase, the most easily replicated phase, is the glide phase, which can be practiced by flying a commercially available glider or developing one specifically to reflect the flight characteristics of the spacecraft, and pilots can make many practice flights at relatively low cost. The second phase, the boost phase, can be replicated with a small-rocket-powered aircraft so pilots can experience the flight-control characteristics and physical forces experienced under rocket power. The third phase of training should require the pilot to fly the actual spacecraft through a complete mission profile. After accomplishing these goals, a pilot should have enough experience to fly the spacecraft safely.

Pilot proficiency and currency are important to maintaining safety, so pilots should continue to train using the simulators and partial-task trainers to keep their skills sharp. Since suborbital flights are not currently flown with any great frequency, remaining proficient using the tools available is critical.

Training requirements will be unique for each suborbital craft developed, as well as for each pilot. NASA astronaut and military pilot training take one to two years to become qualified, with significant focus on considerations related to the particular mission. Given the expected high level of experience of pilots selected for suborbital flights, three to four months should be sufficient to become qualified.

Proposition 3. Space simulator and zero-g parabolic and suborbital spacecraft flights without passengers are necessary training components to certify a traditional pilot to be a space pilot.

WHAT ARE THE PHYSIOLOGICAL EFFECTS?

Space travel affects human travelers physiologically, but since the duration of future space tourism flights will be minutes, rather than days, its effects on the cardiovascular system and vestibular health are the most relevant.

Physiological Effects on the Cardiovascular System. A major physiological system affected by spaceflight is the cardiovascular system. Once in orbit, astronauts experience microgravity, that is, a force of gravity so low that weightlessness occurs. This change greatly reduces the amount of physical exertion needed to carry out normal tasks.

Gravity forces the heart to work hard to pump blood to all parts of the body, with the brain the most difficult organ to reach. Without gravity, blood pools in the upper body rather than flowing, with gravity, toward the feet, so the brain can get ample blood flow with little effort from the heart. This effect is shown in the lower stroke volume post-flight, a difference of 12% on long flights vs. short ones. In contrast, blood pressure increases in space. With no gravity, blood does not need to reach large major muscle groups (like the legs) as much because they are inactive and does not demand as much blood. Because the heart is less efficient, blood tends to pool in the heart, which raises pressure. However, whether the flight is of long or short duration, once a person re-enters a 1 g environment, the blood that pooled in the upper body reverses flow, and the heart has to work harder at pushing blood to the head. This sudden lack of blood to the brain, called orthostatic intolerance is why many astronauts feel dizzy on re-entry [25]. The duration of suborbital tourism flights will be of short duration, with weightlessness achieved for a few minutes, so cardiovascular issues are unlikely to present a problem, although some space tourism pilots could suffer from ill effects.

Spatial Disorientation and the Vestibular System. Spatial disorientation is the mistaken perception of one's position and motion relative to the Earth [26]. It can be worse in a spacecraft because the vehicle can move side to side and up and down and can rotate in all directions [27].

The vestibular system is responsible for maintaining balance. It provides the ability to sense angular acceleration and linear acceleration, and to coordinate head and eye movements, and to maintain the antigravity and lower body muscles in relation to the head [28]. When one is in space, these normal signals are misinterpreted, forcing the brain to recalculate, resulting in (spatial) disorientation and the experience of Space Motion Sickness (SMS). This syndrome, a result of inadequate ambient orientation cues, is one of the first physiologic alterations noticed during a person's first hours in space [25]. Even on the short flights offered by tourism companies, some pilots may suffer from SMS. Passengers on Zero Gravity's "Vomit Comet," an aircraft modified to induce weightlessness, are treated to a series of parabolas that offer passengers the chance to experience several episodes of weightlessness, and many passengers suffer from SMS. Virgin Galactic will orient passengers to weightlessness by taking them for orientation rides in the launch vehicle during their training.

Proposition 4. A challenge for space pilots on relatively short suborbital flights is the physiological effects from weightlessness (e.g., SMS).

THE SPACE PILOT AS THE INSTRUCTOR

Because suborbital spaceflight is not as routine as commercial airline travel, training and preparation are required to ensure passenger safety, reduce passenger stress, and enhance the overall spaceflight experience [29]. The United States government created the Office of Commercial Space Transportation in 1984, and only seven commercial space tourists have flown since then [30]. As of early 2011, the FAA had only one regulation regarding the training required for commercial spaceflight participants.

A few companies now offer space training programs, whose main focus is on the customer's medical integrity. The programs train the customers in emergency medical procedures and, to some extent, emergency procedures for their suborbital space voyages. FAA 14 CFR Part 460.51 states, "An operator must train each space flight participant before flight on how to respond to emergency situations, including smoke, fire, loss of cabin pressure, and emergency exit" [22]. However, by far the most important person on the flights is the pilot. What are his or her tasks?

Pilot's Contribution. In our model, the pilot is in command of the spacecraft and is responsible for instructing space tourists prior to the flight. Therefore, the space pilots should have a good understanding of the human learning process. After becoming a pilot and then becoming experienced and proficient, many pilots become instructors in the aircraft, in the classroom, or both. In fact, many pilots start out as certified flight instructors (CFIs). We focus on the adult learning process because space tourists will be adults until the industry evolves into mainstream tourism.

The pilots will be responsible for instructing the space tourists using current aviation instructional techniques. This instruction is a key element of the space tourism experience because it allows the pilot to build rapport with the passengers from the beginning of the training process which rapport can have a profound effect on the flight. No matter which techniques are used in the instructional process, the end result must be that learning has occurred.

So what is learning in aviation terms? The *FAA Instructor's Handbook* defines learning as a change in the physical and overt, intellectual, or attitudinal behavior of the learner as a result of experience [31].

The Federal Aviation Regulations (FARs) Parts 61 and 141 outline how aviation training should be conducted, although they do not necessarily apply to training the passengers of a space vehicle. FAR Part 121 Subpart 417 [22] is most applicable to the needs of the space tourists, although it is specific to present-day commercial airline travel.

The Role of the Passenger. Like airline passengers, space tourists can range from astronauts to people with no aviation experience at all. The space tourist is a much more involved and integral part of the flight than a typical airline passenger is. The current briefing that flight attendants are required to give to the passengers takes about five minutes and covers eleven items. FAA Advisory Circular (AC) 121-24C covers the items listed in Table 2.

Most of the same items should be covered in a preflight training session with a space tourist, but there are some important difference—primarily the size of the spacecraft and the role of the passenger. In a small spacecraft, only a few people are on board with the pilot, so the passengers would be responsible to assist in an emergency. Therefore, accurate simulation of emergency situations and procedures is key to ensuring passengers' safety and performance during the flight.

Although, the odds are slim that a passenger would have to intervene to ensure the safety of a flight, if customers do not feel safe and capable of performing as required in an emergency, the industry may never get off the ground (so to speak).

Table 2. FAA Required Briefing Topics

Compliance with Signs and Placards	Exit Seating	Oxygen Equipment
Smoking	Passengers Needing Assistance	Supplemental Information
Exits	Floor Proximity Emergency Lighting	Extended Overwater Operations
Flotation Equipment	Portable Electronic Devices	

Source: Federal Aviation Administration [32]

The Pilot as a Tour Guide. Over the next twenty years the space tourism industry is expected to grow, and the job of a space tour guide should become a career. Our vision of a space tourism organization is unique in that it provides the customer a full-spectrum experience that includes not only training in how to function in microgravity and emergency procedures but a pilot as tour guide for the flight. In the early days of commercial aviation—and often even today—the captain provided commentary along the route of flight for the passengers, pointing out landmarks, history, and geology (for example) to capture the passenger's interest and make the flight more enjoyable. Since In-Flight Entertainment (IFE) and moving map displays have made their way into commercial airliners, the tour guide captain is becoming a nostalgic part of the past. However, the space pilot must not only possess a unique skill set but combine it with the ability to deliver those skills in an appealing manner to the client. To do so, the pilot has to be comfortable speaking in front of people, have good vocal projection to inspire confidence, and tailor his or her expression to the tourists' backgrounds and abilities in order to relay critical information about the spaceflight in a way that the tourists can understood.

Instructors and tour guides must be patient in dealing with a broad range of people in diverse situations. This quality is exponentially more important during a high-stress event like spaceflight training and especially during the flight itself. Given the level of required pilot involvement with the controls on space vessels, the ability to multi-task and maintain a level head regardless of how the passengers are reacting is essential.

Crew Qualities. In any aviation-related event, one of the keys to a successful and enjoyable flight is the ability of the pilot (or crew) to instill confidence in the passengers. Professionalism, charisma, and knowledge on the part of the pilot will help to achieve this goal and add to the credibility of the crew and the program as a whole. Pioneering space tourism companies like Virgin Galactic focus on pilots who have a wide breadth of experience and who can put anxious passengers at ease, from preflight training all the way through the landing after the spaceflight. It is even possible that pilots will be able to leave their seats to help a space-sick passenger prior to the 6 g re-entry [20].

Virgin Galactic anticipates accommodating approximately six passengers on its first space flights. With such a small passenger payload and given the high-stress environment in which the flights will occur, small-group dynamics will be important. The pilots must be able to master interpersonal relationships among the passengers, fill the role of leader and expert in the group, and guide everyone to synergize so the group has a pleasant experience.

Overall experience and a commanding knowledge of the spacecraft systems are requirements, as is the ability to provide an interesting and fulfilling experience for the tourists during the flight. After all, the space tourist is paying a lot of money to do what very few people have done, and he or she deserves to be well informed throughout the operation. The pilot's explanations of what they will be seeing in the surrounding environment, flight procedures, and any anomalies will help to put the passengers at ease.

Proposition 5. Space pilots must function as both pilots and tour guides.

CHARISMA

When you take a flight into orbit, you will be riding with a fighter pilot who has gone faster than the speed of sound on a daily basis and taken turns so tight that he literally weighs a ton! Let's enjoy a trip together to the edge of the atmosphere, where you will experience a world beyond your imagination.

Overall Experience. Having a charismatic individual who pilots the suborbital spacecraft is a large part of the experience. While the experience and the views are breathtaking in themselves, a leader who presents these experiences with charm and presence gives a human side to this "alien" experience.

What Is the Lure? What are space tourists looking for? Why are they willing to pay such an exorbitant amount of money? Is it the adventure? The g-forces? The weightlessness? The view? It is all these things and more, but the human element and the human interaction are significant parts of the experience. A leader is needed to answer questions, encourage confidence, and promote a positive public image for the industry. The suborbital experience is far from risk-free and is completely foreign territory for most people, so there will be questions and misgivings about whether the risk is worth the reward. Therefore, the presence of a pilot who is intimately familiar with the procedures and processes and who maintains a rational confidence is essential. What are the characteristics of this individual? No matter what problems or difficulties present themselves, the pilot should be able to calmly and confidently execute difficult skills with precision and consistency (Figure 5).

Figure 5. Pilots showing confidence [33]

Proposition 6. Space pilots must be charismatic leaders.

WHAT ARE THE SPACE PILOTS' SALARY AND BENEFITS?

One question most commercial space companies must answer concerns the pay and benefits the companies must offer to make the career of a space pilot attractive. The most obvious benefit, the chance to fly in space and to be a pioneer in an emerging market, will likely be the basis for most people's initial interest in becoming space pilots. However, to make the career financially attractive, companies must offer pay and benefits that are similar to those of competing career opportunities.

Pay and Benefits. The most likely place to find potential space pilots is among military and airline pilots. Military pilots typically reach a point in their careers when they decide whether to continue their military careers or pursue something else. A large number of military pilots who leave the service continue flying with the airlines, so the space pilot's pay and benefits must be at least comparable to those of an airline pilot. However, a space pilot must fly to extreme heights at extreme speeds with passengers and return the spacecraft and passengers to Earth safely. In exchange for that type of responsibility and danger, it is likely that space pilots will demand more in salary than they would get as military or airline pilots. Another option is to train space pilots who have no previous training or experience, in which case it may be possible to pay them less, at least for a time, because contracts would require a particular period of service in exchange for the training.

According to the U.S. Department of Labor, the median annual wage of a commercial pilot in 2008 was $65,340, although the lowest ten percent made less than $32,020 and the highest ten percent made more than $129,580 [33]. The large range in pay is due to many factors, including airline ratings and time with the company. Table 3 displays the salary range for a few popular airlines and illustrates the wide differences in pay in the airline industry.

Table 3. Pilot Salary Range for Major Airlines in 2008

Airline	Low Salary	High Salary
Delta	$59,495	$188,680
United	$117,916	$156,018
American	$76,295	$165,083
Southwest	$61,042	$154,477

Source: PayScale [34]

Proposition 7. Because of the nature of the job and the kind of person who is most likely become a space pilot, the pay and benefits should be similar to or somewhat better than that of military and airline pilots.

MAJOR LIMITATIONS

There are many critical limitations to our proposal for the operational requirements of sustainable space tourism pilot training, including the need to tailor training to a specific platform, the motivation of pilots to be involved in suborbital spaceflight, and whether a pilot will continue to be necessary as the technology advances. We are also limited in our ability, within the scope of this paper, to evaluate the economic climate and business model required to provide the necessary level of economic and psychological motivation for pilots. Finally, we cannot ascertain future levels of automated technology that could develop while the concept of major space tourism operations comes to fruition. It is important to acknowledge these limitations and other limitations that are sure to develop in any space pilot training operation.

Platform Limitations. There must be an established platform for which to develop a training schedule and system. Without such a platform, pilots will be “going through the motions” of training without knowing the specific emergency procedure and life-support training they will need. Facilities for the training of space pilots already exist, but commercial space tourism operators will need to use the resources of the commercial market in order to realize the vision of our proposal. Based on the technology as it stands today with the development of the Virgin Galactic project seen in Figure 6 [35], we made solid assumptions concerning the projected requirements for the spacecraft, and it is on these platforms that we must base our proposed training. In addition, we must rely on various USAF and NASA training programs as the foundation of our training proposals; we assume that these organizations are the peak of corporate knowledge in the training of aerospace/space pilots, but little precedent has been set for the suborbital pilot [36].

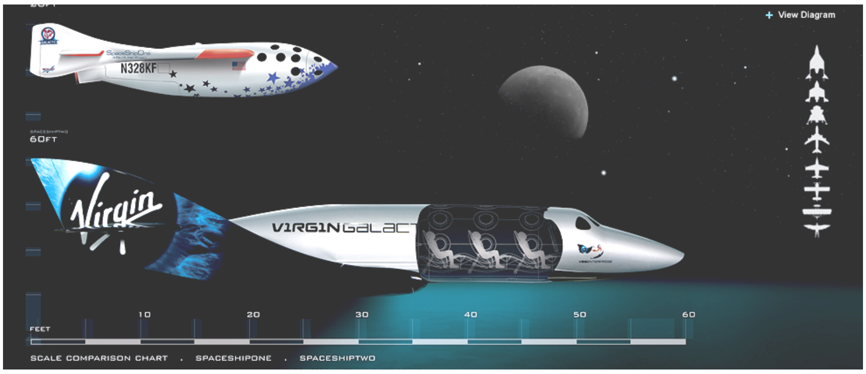

Figure 6. Virgin Galactic’s SpaceShipTwo [35]

Limitations of the Pilot Motivation Model. A second major limitation concerns the motivation required to generate interest among pilots. Certainly, initial suborbital spaceflight will provide sufficient personal motivation for many pilots. However, as operations expand, as currently predicted by suborbital operational proposals, this motivation will be reduced somewhat, but it is difficult to determine to what level. What is certain is that, as space tourism expands to become a more commonplace operation, the personal motivation of some pilots (e.g., to be the best, to fly the most advanced aircraft) will decrease. At this point in the future, to attract the required number of pilots, the requirements may have to be made less restrictive or financial motivation will have to increase, but it is not within the scope of this paper to determine exactly where the threshold of yearly space tourism flights is that will drive this economic change.

Limitations Related to Pilot Requirement. Finally, current projects all maintain that a pilot is required for a space tourism operation, and we must assume that this requirement will remain. However, in the upcoming decades of development of large-scale space tourism operations, the technology for unmanned craft will improve, and we cannot predict what level of comfort the normal consumer will have with unmanned craft as that occurs. It is possible that unmanned craft will become more economical and acceptable in the consumer psyche, but our proposal is limited to existing technology and the widely accepted requirement that a pilot must be on board to monitor systems and to provide the interactive experience that passengers expect from a professional space tourism operation.

RECOMMENDATIONS AND CONCLUSION

Our recommendations on the most important aspects of pilot selection and training when planning and/or operating space tourism flights include the need for a charismatic pilot with experience as a fighter pilot, an extensive training program, clear duties, and sustainable and competitive pay and benefits.

Pilot Needed. In order to sustain the space tourism momentum created by the success of SpaceShipOne, space tourist vehicles developed in the near term should incorporate a pilot. Including a pilot will result in substantially lower costs passed to the tourist, in satisfying the psychological need of the passengers, and in reducing the probability of the catastrophic accidents from which the space tourism industry would have a difficult time recovering. While maintaining safety is very much a team effort—with mechanics and flight controllers equally important—the pilot will be the visible face of reassurance to passengers.

Fighter Experience Needed. The space tourism industry should hire pilots with as much experience and training as possible in order to reduce the cost and time required to create proficient space tourism pilots and improve safety. The best sources of appropriately qualified pilots are likely to be test pilots, single-engine fighter pilots, and airline pilots with previous fighter experience. While maintaining safety is very much a team effort—with mechanics and flight controllers equally important—the pilot will be the visible face of reassurance to passengers.

Extensive Training Program Needed. As space tourism grows, the need for skilled pilots will grow as well. Training a pool of suborbital pilots is a unique challenge because of the varying flight profiles, the difficulty of simulation, the high cost of operation, and the very distinct differences from standard atmospheric flight. The training program will need to be tailored to the type of aircraft being used, the training devices available, and the pilots' backgrounds. Academics, simulations, time in trainer aircraft, and physiological training should be used to train pilots initially and to maintain their currency. Once fully trained, the new pilot should fly with an experienced pilot without passengers if the craft has two pilots, as is the case in SpaceShipTwo.

Charismatic Pilot Needed. We recommend not only having fighter pilots be in the first cadre of space tourist pilots but also ensuring that those fighter pilots have the right interpersonal skills and charisma to convey a dream to others. What is a dream if it is stale and monotone? It must be exciting, detailed, colorful, and memorable. Space tourism is the realization of a dream, and when tourists land from that flight, they need to be able to remember what the dream was about. If the pilot lacks the ability to generate the kind of confidence and excitement the passengers need and deserve, the dream could quickly become a nightmare.

Clear Duties for Pilots Needed. The pilots must be given a clear set of objectives for their roles and duties in the flight and the preflight phases. Because suborbital space travel is a new industry and there are very few space pilots and tourists, there is no historical perspective on which to base the pilot's job requirements. The closest model is commercial aviation, which provides the basis for the limited regulations we have. Just as in the early days of commercial aviation, space tourism will be subject to increasing government regulation and scrutiny, but only time and experience can yield the data on which to base the need for regulations. A recommendation based on the history of the aviation industry includes government oversight and regulation to ensure fairness and safety, but these regulations will be eased as the industry develops and public demand drives standardization.

Sustainable Health Program Needed. A space pilot works under difficult environmental conditions. To ensure that space pilots remain physically and psychologically fit over their careers so they can manage any unplanned circumstances while piloting the space vehicle, we recommend regular support and monitoring of pilots' health status.

Competitive Salary Needed. Our recommendation for determining what to pay the future space pilots is that their pay should be comparable or better than that of airline pilots since they may be flying more difficult missions and they will have high levels of experience. Careful calculations will be necessary to find the right salary plan that will attract pilots to the business and keep the company profitable.

Good pilots will be as essential to space tourism's success as the launch vehicles themselves, so the industry must be diligent in planning to acquire and keep good pilots. We believe that space pilots will be a new type of pilot who has all the basic skills that modern-day pilots have but who do things that current-day pilots never do: flying into space, piloting a rocket-powered vehicle, acting as a "tour guide," and taking people on a once-in-a-lifetime journey.

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