Risking Space in the Next 50 Years – Perspectives for Space Tourism

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1. Introduction

A new era in mankind's awareness began 50 years ago with the first launch of a man-made spacecraft into orbit. Sputnik 1 was soon followed by animal space travelers and then by the first astronauts and cosmonauts. The general public has however remained on the sidelines up to now, having had to observe all the wonders of space vicariously through the reports of the governmental space travelers. All of this is changing as the first paying public space travelers are beginning to enjoy their orbital experiences. The pace will quicken when the sub-orbital industry begins flying its much longer list of potential space travelers.

This paper provides some initial preparation of the space tourism industry for handling possible early setbacks via accidents. As with any new mode of transportation or human endeavor, accidents are inevitable. Historically, where loss of life of astronauts was involved (eg Apollo 1, Challenger, Columbia accidents), this led to a long period when flights were suspended, and where even a sense of national grief and loss resulted. Some people (eg Ref 9.31) believe that we are destined to see a replay of this when the first space tourism accidents happen. Others, such as one of the great rocket engineers from von Braun's team Konrad Dannenberg, (Ref 9.32), believe that times and circumstances have changed, and with the private space industry, comparisons will be more with NASCAR than with NASA. This paper begins to set the stage for a different, and more appropriate, response in the case of the first space tourism accidents.

We shall see that, after 50 years of waiting, the new generation of space explorers really wants to go, and they understand, and are willing to accept, the risks.

2. General Risk Data

Edward R Murrow, in 1954, said "We are not descended from fearful men" (Ref 9.29). This point was well demonstrated when during the 'sixties the nation took extraordinary risks and succeeded in sending men to the Moon. President Kennedy led by example when he took the extreme political risk of committing the US to the Moon landing within a decade, at a time when the total US human spaceflight experience was the 15 minute sub-orbital lob of Alan Shepard. John Glenn began the orbital experience when he was willing to be flown on the sixth Atlas, when two of the previous five had blown up. Since that time, the country has seemed to become more risk-averse. The first space tourism flights are taking place against this new background. It is important, therefore, to be aware of comparative risk statistics in order to set these early ventures in a relevant frame of reference.

Figure 1 has been derived, for consistency, largely from a single source (Ref 9.12) to provide this background frame of reference. The table has only been based on US data. There are of course countless other sources of this kind of data, and other references have been provided, for those who might be interested, which give detailed breakdowns of various parts of the accident statistics (Ref 9.1, Ref 9.4, Ref 9.5, Ref 9.6, Ref 9.7, Ref 9.8, Ref 9.9, Ref 9.10, Ref 9.11).

FIG 1 GENERAL RISK DATA FOR UNITED STATES

CATEGORY	MAIN CONSTITUENTS	DEATHS/YEAR
TOTAL DEATHS	Diseases	2.3 million
	Criminal	49K
	Accidents	109K
	Total	2.5 million
TOTAL ACCIDENTS	Road/Motor	49000
	Drug	11000
	Fire	3000
	Choking	4000
	Falling	2000
	Drowning	800
	Ladder	400
	Lightning	47
	Skydiving	22
	Mountaineering (Ref 9.3)	30
	Skiing/Avalanche (Ref 9.8)	23
	Sailing/Boating (Ref 9.6)	725
	General Aviation (Ref 9.10)	556
	Total	109000

Source: Ref 9.12 unless otherwise indicated.

We observe from the table that of course the only certainties in life are death and taxes, and the vast majority (92%) of deaths each year is of course due to natural causes. But 109K of the deaths is due to accidents. And of course nowhere is entirely safe; even lying in bed is risky (Ref 9.12 even indicates 594 deaths per year from falling out of bed). About 8K of the accident deaths each year happen in the home. It is perhaps surprising to note that the adventurous sports, like skydiving, skiing and mountaineering, provide only a tiny part of the overall totals. These data provide us with the background against which to assess the consequences of fatalities in space tourism.

3. **Risky Vacations and Activities**

Perhaps in part because of the absence of a military draft, many young people have begun to develop pleasure and skills in a range of hazardous activities. Examples of these are apparent when we consider the popularity of the X-games. Companies now offer adventure sports vacations, and the range of these activities is considerable. During the conduct of The Adventurers' Survey (Ref 9.27), the thousand people who responded, by filling in a questionnaire on the web site of the travel firm Incredible Adventures, reported that they had collectively taken part in the list of activities summarized in Figure 2. Other data (Ref 9.2) informs us that about 2000 people have climbed Everest since it was first conquered in 1952. Clearly, these climbers and these survey respondents at least do not fear risk, but welcome it as part of the experience of living life to the fullest. However, as we have seen from Fig 1, more people in the US die each year from being struck by lightning, and from accidents in the home, than from either skydiving, skiing, or mountaineering. It would appear that individuals make a decision, based upon a balancing of risk, which underlies their enjoyment of adventure sports. This perspective will be important in considering the first accidents in public space travel.

FIG 2 RISKY VACATIONS AND ACTIVITIES
(RESPONDENTS TO THE ADVENTURERS' SURVEY)

	Survey query	Respondent Experience
Quantified Data	Mountain Climbing	30%
	Car Racing	28%
	Sky Diving	22%
	Fighter Jet Flight	12%
	Zero-g flight	7%
78 other activities listed, but not quantified, including:		
Scuba	Paragliding/Hang-gliding	Rope climbing
Caving	Motor rallying	Roller derby
Snow Skiing	Motorcycle Stunt Driving	Gymnastics
White Water Rafting	Drag racing	Zorbing
Parasailing	Street Luge	Horse racing
Air Racing	Go-Kart Racing	Canyoning
Mountain Bike Racing	Offroad 4X4	Stunt driver
Bungee Jumping	Sea Kayaking	Long distance racing
Base Jumping	Submarine adventures	Powered parachute
Sailpane/ Glider	Distance Swimming	Bull riding
Paint Ball	Quad Biking	48hr D&D Marathon
High Power Rocketry	Power Lifting	Aircombat adventure
Jet Ski	Cliff Diving	Visiting active volcanoes
Aerobatics	Wind Surfing	Civil Air Patrol
Snowboarding	Water Skiing	
Rock climbing	Wildlife Trecking	
White Water kayaking	Hot air ballooning	
Ocean Yacht Racing	Helicopter rides	
Motocross	Luge/Bobsledding	
Private Pilot	Dog sledding	
Microlight	Jousting	

Source: Ref 9.27

4. **Survey Data**

There have been some attempts to quantify the attitudes to risk of potential space tourists, and to find out how they rate the risks of space tourism compared with other risky activities. Figure 3 provides the findings obtained from the Futron/Zogby survey (Ref 9.26), and Figure 4 captures the data on the same subject obtained from the Adventurers' Survey (Ref 9.27). Note that in making comparisons, these surveys were examining different groups of people. For Figure 3, the target pool of respondents was a statistically valid random sample of 450 millionaires, with no previous bias towards risky activities, whereas for Figure 4, the respondents were 1000 folks who had an *a priori* interest in adventurous activities.

FIG 3 ATTITUDES TO RISK - FUTRON/ZOGBY SURVEY - HIGH RISK DATA RESPONSES

RISKY ACTIVITY	% of RESPONDENTS WHO REGARD ACTIVITY AS HIGH RISK
Skydiving	72%
Mountain Climbing	57%
SpaceTravel	45%
Private Aircraft Flying	14%
Skiing/Snowboarding	12%
Sailing/Boating	2%

Source: Ref 9.26

We note from Fig 3 that the respondents to the Futron/Zogby survey (Ref 9.26) considered that space travel was risky. In fact they considered it more risky than skiing or sailing or general aviation. They rated skydiving as the most risky activity, and they assumed that public space travel will be about as risky as mountain climbing. Interestingly, we know from Fig 1 that skydiving in fact only results in 22 deaths per year in the US, and mountaineering contributes a further 30 of them. Private aircraft flying is much more risky at 556 deaths per year. And sailing/boating accidents claim 725 lives a year. So, it appears that the respondents to the survey (who while rich were in other ways a representative sample of the population), while accepting that space tourism will be risky, base their risk assessments on factors other than simple annual fatalities statistics.

FIG 4 ATTITUDES TO RISK - ADVENTURERS' SURVEY RESPONSES - LEVEL OF RISK ACCEPTABLE FOR SPACEFLIGHT

RISKY ACTIVITY	% RESPONDENTS WHO WILL ACCEPT DIFFERING PERCEIVED RISK LEVELS
Risky as Space Shuttle	28%
Risky as Jet Fighter	25%
Risky as Airliner	19%
Risky as Hang Gliding or Skydiving	14%
Risky as Mountaineering	10%

Source: Ref 9.27

With the data of Fig 4, we again observe that the respondents base their ideas of risk on factors other than true accident statistics. These respondents, it should be remembered, are in any event pre-disposed to doing risky activities. They were a sub-sample of visitors to the web site of the adventure travel firm Incredible Adventures. They were asked about how safe space tourism would need to be before they would consider partaking in the experience. While for some (19%), they would insist on the prospective flight experience as being as safe as airline flight, others would be quite happy so long as it was as safe as skydiving or mountaineering.

From the data in Fig 3 and Fig 4, we could therefore probably assume that the demand for space tourism flights will not be affected so long as the accident rate does not exceed that of mountaineering or skydiving. At its most basic level, this would suggest that the industry might tolerate a death rate of up to 20 to 30 per year in the US by this comparison. Of course this comparison is much too simplistic, not only because it ignores the number of participants in each activity, but because the industry is new, and there will be some very well-known people involved in the early space tourism flights, and an accident will therefore bring related publicity. We need to look deeper.

5. **Survey Comments**

In addition to the numerical findings reported in the previous section, there were a number of verbal accounts of risk perception that were recorded as part of the Adventures' Survey (Ref 9.27). Figure 5 gives a selection of a few of the responses that provide specific insights into the thinking of these potential space tourists. Note that the full list of comments numbered 340, and they are all included in the full report of The Adventurers' Survey.

FIG 5 – SOME COMMENTS RELATED TO RISK FROM THE ADVENTURERS' SURVEY

General Comments about taking a Space Adventure	"The chance to go would outweigh any fear, as long as the company could show all reasonable precautions were in place, since risk is inherent." "Hey, I would have gone up the day after the Challenger accident!" "It'd be more than worth the risk." "Would depend on a demonstrated safety record, and modest risk." "Safety is a matter of opinion - I think once a person is informed of the risks it is a personal choice". "The whole space thing appears scary, yet so intriguing!" "I'd risk everything for a trip to space."
Comments related to offering a Space Adventure as a corporate prize.	"Not until the risks are much more manageable. It will remain too easy to get sued if anything goes wrong for the foreseeable future." "Everyone courageous should get a chance to visit space." "Only when a safety record has been established. I would of course be willing to take a much greater personal risk than I would with potential clients." "Too risky. The last thing you'd want to do is associate your company with a space disaster. There are safer ways to advertise." "I would take any amount of risk personally to go to space, but I would be uneasy about the liabilities in offering something that dangerous to other people."

Source: Ref 9.27

There is a yearning amongst many people to go and experience the space environment, and to see the Earth from outside the atmosphere, that has only increased during the period of 50 years of spaceflight developments, whose outset in 1957 we celebrate this year. They recognize that this will incur some risk, yet they appear to be willing to take the risk. It would appear that the FAA –AST approach, of requiring that all potential passengers must be informed of the level of the risks, is a good one. It may be difficult in practice to prepare the necessary data to inform the future public space travelers, but clearly this must be attempted. Some have argued (See eg Ref 9.30) that non-numerical data may be more important than estimates of accident frequency. For example, it might be of more immediate benefit to know whether the owners of the business, and their families and engineers, are flying in the space vehicles. This is a new kind of experience that will bring new kinds of performance criteria.

Note that of particular interest is the fact that the respondents would be willing to take a higher degree of personal risk to experience space tourism, than to which they would be willing to place their clients and fellow colleagues, eg via corporate or gaming arrangements. This indication would suggest that initially there might be some difficulty in getting the corporate side of public space travel started.

6. **Risk Reduction**

How can the potential space tourism operator work towards reducing risk, while still having a viable financial operation? How will the risk management process of a commercial space tourism operator differ from that of a government agency such as NASA? How does the risk regime within NASA itself differ today, if at all, from the way it was during Mercury/Gemini/Apollo?

Figure 6 has been provided to give some perspective about the risk perspective of NASA in the ‘sixties compared with today.

FIG 6 - ATTITUDES TO RISK AMONG SOME PIONEER NASA ASTRONAUTS

SPEAKER	QUOTATION	REF.
Gus Grissom	"We're in a risky business, and we hope if anything happens to us, it will not delay the program. The conquest of space is worth the risk of life."	Ref 9.2
John Young	"Reliability calculations? We didn't have any!"	Ref 9.23
T.K. Mattingley	"Every great success is preceded by failure. So, don't be afraid of failure."	Ref 9.2
Dave Scott	(Voting against a doubling of the walk-back limit in case there was a failure of *both* the lunar rover *and* a PLSS life support backpack): "No. That's just going to hamper us too much. That's going to hamstring us. If we have *both* a rover *and* a PLSS failure, then we're just going to have to expect a bad day."	Ref 9.2
Jim Lovell	"We only trained for single-point failures. Had we tried to develop recovery techniques for all possible combinations of failures - well, we'd still be at Cape Canaveral waiting for the first take-off."	Ref 9.2
Gene Cernan	"We are now risk averse and we all want a guarantee. I had no guarantee when I went to the Moon, that I'd ever come back, but I went."	Ref 9.24
Mike Foale	"Sometimes you just have to use good judgment. You use your intuition. I feel we may have strayed off course concerning our approach to risk in some areas."	Ref 9.2
Shannon Lucid	(Quoting reply from fellow cosmonaut on board the Russian space station Mir, when a problem arose): "Procedures? We don't have any procedures."	Ref 9.2

Risk assessment was not a well established discipline back in the sixties, and the limited computing power back then would not in any event have allowed for a complete evaluation of all possible failure modes. In its stead, the NASA management, and that of the major manufacturers, relied upon good design judgment. Parallel paths were used whenever possible, but ultimately the missions all carried some degree of single point failure mechanisms that could not be backed-up. The crews knew this and flew anyway. They relied upon the combined good judgment and work ethic of the early engineering design and fabrication workforce. Gus Grissom's only plea to the assembled launch vehicle manufacturing teams during a visit to California plants before his flight was "Do good work!" The early failures such as Apollo 1 led to changes and learning experiences, which some (eg T.K.Mattingley in Fig 6) claim were an essential part of the learning process that made the Moon landings possible.

Since that period, we note that there has been a considerable firming-up of the attitude to risk in the intervening years. A new discipline of risk management has emerged, enabled by the vastly increased capability of computers since those of the Apollo era, which requires enormous sets of analyses to be carried out to consider every possible combination of error and accident before a design can be approved. The author in Ref 9.22 describes some of the associated processes and even standard software of the new discipline. In Ref 9.14, the authors provide a good overview of the philosophy while pointing out its limitations. The report in Ref 9.21 identifies some of the flaws in the process of conducting risk assessments mandated by the Federal government. Ingham (Ref 9.19) identifies the important but unquantifiable human factors in space mission success. The GAO (Ref 9.20) indicates the need for Federal safety oversight of the emerging space tourism industry (something with which the Wright Bros did not have to contend!), and Ref 9.16, Ref 9.17, and Ref 9.18 are representative examples of the products of this oversight function at the Office of Commercial Space Transportation at the FAA.

This risk management process is, of course, a very time consuming and costly activity, and inevitably relies on vast numbers of data assumptions that are fed into matrices to enable the risk calculation to take place. If the error limits on some of these input parameters are high, which is almost inevitable, then the error limits on the outcome can consequently be similarly high. This calls some to question the worth of the discipline itself. The author in Ref 9.3 addresses what he calls "rampant risk management" and says that it leads to making us "a nation of victims, looking to blame everyone but ourselves when something bad happens." He asserts that "in modern American society it thus becomes easier and easier to rely on others (experts, regulators, bureaucrats) to look out for personal safety issues that are surely matters of common sense."

Nowadays, it is not uncommon for systems engineers in the major aerospace companies and at NASA to evaluate 1000 alternative design variants or architectures before being able to make a decision on the preferred way forward. Even then, the managers are nervous about their recommendation, because they know the extent to which the analyses depend upon matrices filled with data which cannot always be robust. This state of affairs has come about partly because of the virtual cessation until recently of the building of any new US space vehicles since the introduction of the space shuttle in 1981. Much resource has been used instead on evaluating the relative merits of "paper study" vehicles. As an inevitable consequence, many senior engineers in the major aerospace firms, and at NASA, these days must measure their experience by the number of paper studies to which they have contributed, rather than by real hardware they have designed, built and flown into space.

The public's, and Capitol Hill's, reactions to the Challenger and Columbia accidents have focused the current NASA leadership on above all else avoiding more accidents, which are considered as failures rather than as learning experiences. The quote by Shannon Lucid in Fig 6 reflects the different attitudes to space flight in Russia and the USA. The Russians were constantly fixing things that went wrong with their space station Mir by allowing the cosmonauts to make decisions on the spot in orbit. The American crew members were generally more uncomfortable with trying anything that had not been previously simulated many times during training.

The new space firms that have emerged, as a consequence of the potential business model represented by space tourism, are very different from both the traditional aerospace firms, such as Boeing, Lockheed Martin, and Northrop Grumman, and from NASA. They are entrepreneurial companies, funded generally by personal wealth and venture capitalism. They have more in common with the Internet firms that emerged during the 1990's than with the traditional aerospace companies. They have small staffs (usually not more than about 100). They need to make their decisions based on commercial viability. Safety is an area of very great importance to them, but they cannot spend infinite funds to achieve it. Senior management knows how to make decisions without the need for "analysis paralysis". They are action oriented. They believe in rapid prototyping and flying and fixing. There is a trade-off involved in deciding how many test-flights, which are not allowed to be revenue earning, are needed in order to meet the government regulator's demands, and in order to improve the chances of protecting the lives of their crew and paying passengers. More is always better, but ultimately passengers must be flown or the enterprise will not be successful financially.

Figure 7 has been prepared, therefore, to give some perspective on the risk management approach that is probably going to be put in place by the future space tourism operators. Their approach is designed to give confidence that the public space travelers will have a reasonable degree of confidence that their flight will be successful. The space tourists, we have seen, will not be seeking a 100% guarantee, but in any event, the operators need to be able to continue operating their reusable vehicle, so they have the highest possible motivation to fly safely.

FIG 7 PROPOSED SPACE TOURISM OPERATORS' RISK MANAGEMENT APPROACHES

COMPANY	VEHICLE	TESTING REGIME	REF
Virgin Galactic	SpaceShipTwo	About 100 test flights, from mid 2008	9.25, 9.30
Rocketplane-Kistler	Rocketplane	About 25 to 50 test flights. 1 in 10,000 chance of failure published target.	9.30
BensonSpace	Dream Chaser	"Heritage hardware already flown and reentered" HL 20 basis.	
SpaceX	Dragon	Falcon nearing success. Dragon to have 3 demo flights in 2008/2009 as part of COTS contract.	
X-Cor Aerospace	X-Cor	30 to 50 test flights to give 1 in 10,000 chance of failure. This target will increase to 1 in 100,000 Later, under competitive pressure.	9.30
Blue Origins	New Shepard	No published information	
Planet Space	Silver Dart	No published information	
t/Space	CEV	No published information, but drop tests have been performed.	

There is a discussion in Ref 9.13 about a range of new services and training regimes that will need to be established as part of the development of the space tourism business. The author draws a contrast between the characteristics of the government astronauts who have flown before, and of the new commercial space passengers, and points out that there will be a degree of increased risk due to the lack of qualification standards. He also reminds us that, with NASA, an astronaut is an asset representing a national investment, so we all assume the risk. By contrast with commercial spaceflight, the risk is assumed by the operator and the passenger, and to an unknown extent, the insurer. Ref 9.15 explores the insurance environment and the extent to which waivers vary from state to state.

7. **Preparing for the Worst**

It is inevitable that there will be accidents during space tourism flights, and so it will be necessary to prepare in advance for what will need to be done in that eventuality. The government, via the FAA, has seen its responsibility as protecting the uninvolved general public from risk of space tourism accidents. They have also insisted that all public space travelers will have been fully informed in advance of potential risks. The space tourists themselves will probably have signed some kind of waiver such as is common in adventure sports. Specialist risk insurance may have emerged, but it is not yet clear that this will be so. So this is the background to a potential accident.

Of course, senior management of the operator will be called upon by the press to comment, and naturally will express sympathy for those injured and or killed, and their families. Beyond this obvious first step, however, it will be important to bring context to the public reporting of the event.

First of all, we should note that there will be a significant difference in reaction depending on whether the flight in question is part of the development series, or is a fare-carrying trip.

During the test phase, the public will need to be reminded that the flight in question was indeed a test flight, being flown by a test pilot, who was exploring the boundaries of the flight envelope to ensure that future passengers will be flying in a safe regime. Test flying is a hazardous occupation, and generally recognized as so. It is to be expected that the public reaction to an accident will therefore be relatively muted. In dealing with any press queries, the CEO, COO and/or PAO will be able to refer to the need to continue testing the flight regime thru the remainder of the test flights to make sure the spacecraft performance has been fully characterized, before passengers go up.

For an accident that occurs during the passenger carrying phase, however, the context needs to be that of an adventure sport. The press briefers, whether CEO, COO, and/or PAO, will ideally need to be aware of the kind of comparative statistics of Fig 1. It will probably be the case that the owner, the owner's family, and senior managers of the company will have previously flown in the vehicle, and this can be recalled during the press briefing. It will of course be important to mention that the design and operation of the space tourism vehicle has been in accordance with all government regulations (ie FAA-AST) and that the operator, and the management teams of competing space tourism ventures, will be offering their full support of the accident investigation. At this point it will be worth referring to the Personal Spaceflight Federation, and its commitment to work together to encourage safety of passengers.

8. **Conclusion**

Space tourism is the very embodiment of the "American Way". It is an approach to making money while taking risks and pushing back boundaries and experiencing fun in the process. It is in fact part of the "pursuit of happiness" that is embodied in the Declaration of Independence. Almost all astronauts who have returned to Earth testify, furthermore, to the transforming effect of the experience. People perceive their lives, and our home planet, in ways that are not otherwise possible. The development of the space tourism industry will inevitably lead to progress in spacecraft design, reliability and cost which will benefit all potential uses of space; therefore, space tourism is an enabling technology.

This paper has looked at risk in the context of space tourism. We have seen that the early space explorer pioneers during the 'sixties were willing to undertake great personal and political risks to enable progress. Now, 50 years on, the new generation of potential space tourists is also willing to take risks to achieve their ambition of getting into space, and we have seen the extent to which they report this. The new space tourism operators may thereby take some comfort, because it becomes possible to prepare for service with a level of safety that will be less than the norm in, say, undertaking airliner flights today. Comparisons are more likely to be made with the accident rate of high risk sports than with airliner operations.

Nevertheless, since it is never a good idea to plan on injuring, or worse killing, even a small percentage of one's customers, particularly when they are high net worth clients, therefore all potential space tourism operators will be taking steps to minimize risk of accidents, and this paper has provided some insight into how they can do this. When accidents do begin to happen, however, it will be important to handle the event correctly, and in the right context, and this paper has provided background statistical information and guidance to assist in this process.

The new spacecraft are now being designed to bring space tourism opportunities to thousands of eager travelers. The operators will do everything they can reasonably do to make them safe as they venture outside the atmosphere, but accidents will nevertheless happen. This paper has addressed the ways to deal with this eventuality, because it has been said that, after all, "A ship in harbor is safe – but that's not what a ship is for!"(Ref 9.28).

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