THE EMERGING COMMERCIAL SUBORBITAL REUSABLE LAUNCH VEHICLE MARKET

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

WEDNESDAY, AUGUST 1, 2012

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Wednesday, August 1, 2012

THE EMERGING COMMERCIAL SUBORBITAL REUSABLE LAUNCH VEHICLE MARKET

WEDNESDAY, AUGUST 1, 2012

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 2:24 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Steven Palazzo [Chairman of the Subcommittee] presiding.

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U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6301
(202) 225-6371
www.science.house.gov

Subcommittee On Space and Aeronautics

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Wednesday, August 1, 2012
2:00 p.m.-4:00 p.m.
2318 Rayburn House Office Building

Witnesses

Ms. Carissa Christensen
Managing Partner, The Tauri Group

Dr. Alan Stern
Chairman, Suborbital Applications Researchers Group

Mr. George Whitesides
CEO and President, Virgin Galactic LLC

Mr. Bretton Alexander
Director, Business Development and Strategy, Blue Origin

Mr. Andrew Nelson
Chief Operating Officer, XCOR Aerospace

Dr. Stephan R. McCandliss
Research Professor, The Johns Hopkins University

SUBCOMMITTEE ON SPACE AND AERONAUTICS
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U.S. HOUSE OF REPRESENTATIVES

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Wednesday, August 1, 2012
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

Purpose

Suborbital launch operations - rockets that travel into space but do not have the energy to orbit the Earth - have traditionally been used to conduct missile tests and scientific research for the government sector. The introduction of new commercial suborbital reusable launch vehicles (SRVs) in the private sector has enabled the emergence of new markets. A number of these new companies are already testing their vehicles and plan to initiate commercial operations within a few years. This hearing will examine the potential launch markets and applications for SRVs, the unique benefits that SRVs offer the scientific community for research, and the regulatory uncertainties that currently have the most impact on the emerging commercial SRV industry.

Witnesses

- **Ms. Carissa Christensen**, Managing Partner, The Tauri Group
- **Dr. Alan Stern**, Chairman, Suborbital Applications Researchers Group
- **Mr. George Whitesides**, CEO and President, Virgin Galactic LLC
- **Mr. Bretton Alexander**, Director, Business Development and Strategy, Blue Origin
- **Mr. Andrew Nelson**, Chief Operating Officer, XCOR Aerospace
- **Dr. Stephan R. McCandliss**, Research Professor, The Johns Hopkins University

Overarching Questions

- What are the emerging launch markets for SRVs? When will the SRV companies begin commercial operations?
- What are the types of issues that need to be addressed when deciding on the merits of proposed research and the appropriate platform for that research (e.g. balloon, sounding rocket, ISS, SRVs)?
- What are the unique benefits that SRVs offer the scientific community and STEM education teachers?
- What is the current demand for research and development, scientific, and educational payloads on SRVs? What is the timeframe for flying these payloads?
- How does the SRV industry currently collaborate with the Federal Aviation Administration (FAA) in developing draft guidance for test flights and current operations?

SRV Quick Summary

- SRVs are spacecraft capable of reaching outer space for a short period of time, measured in minutes, but cannot orbit the Earth.
- Companies developing SRVs are planning commercial operations for human spaceflight and also cargo - such as scientific experiments and research – and some companies have announced plans to develop a capability to launch small satellites into orbit.
- SRVs could begin operational commercial flights within the next few years for both human spaceflight and cargo.

Background

The development of SRVs that could access outer space, return to Earth and be used repeatedly began to surge during the competition to win the Ansari X-Prize. The $10 million prize was a competition, modeled after 20th century aviation prizes, for the first non-government organization to launch a reusable manned spacecraft into space and repeat the launch within two weeks.

The prize was awarded to Mojave Aerospace Ventures in 2004, launching a reusable spacecraft called SpaceShipOne, which was developed primarily with funding provided by Microsoft co-founder Paul Allen. At the height of the competition for the Ansari X-Prize, there were 26 teams investing a total of $100 million to develop vehicles to win the prize.[1]

To date, six companies have made significant progress developing different concepts for SRVs that are all powered by rocket engines. Some of these concepts can be either launched vertically from a launch pad like a traditional rocket or horizontally from a runway similar to an airplane. Chart 1, provided below by the FAA,[2] illustrates the companies that have SRVs currently under development and are expected to begin commercial operations within a few years.

Reusable suborbital launch service providers overview

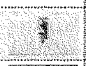
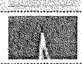
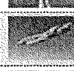
Company	Main Vehicle		Year of Test Flights	Launches From	# of Seats
Armadillo Aerospace		Hyperion	2014	Spaceport America	2
Blue Origin		New Shepard	TBD	West Texas	3+
Masten Space Systems		Xaero	2011	Mojave Air and Space Port	0
UP Aerospace		SpaceLoft	2006	Spaceport America	0
Virgin Galactic		SpaceShipTwo	2010	Spaceport America	8
XCOR Aerospace		Lynx	2012	Mojave Air and Space Port	2

Photo credits: (From top to bottom) Armadillo Aerospace, Blue Origin, Masten Space Systems, UP Aerospace, Virgin Galactic, and XCOR Aerospace

Chart 1

[1] FAA Report, The U.S. Commercial Suborbital Industry: A Space Renaissance in the Making, October 2011
[2] Ibid, page 5

In addition to the vehicles illustrated in Chart 1, there are a number of U.S. and international companies that are in the early development stages for their own SRVs. The U.S. companies include Rocketplane Global, Sierra Nevada Corporation, Space Exploration Technologies Inc. and Whittinghill Aerospace. Additionally, three European companies are developing SRVs including Copenhagen Suborbitals, Dassault Aviation and EADS Astrium.

Funding

According to the FAA, total investment in suborbital ventures is estimated to be approximately $500 million.[3] The primary source of funding for the development of commercial SRVs has come from company founders and individual investors. John Carmack invested $2 million starting Armadillo Aerospace, Microsoft co-founder Paul Allen invested approximately $20 million in SpaceShipTwo, Sir Richard Branson has invested about $100 million in Virgin Galactic, and Amazon founder Jeff Bezos has contributed to Blue Origin.[4]

The companies that intend to offer human spaceflight opportunities have also received deposits from individuals for future flights, sometimes referred to as space tourism. To date, more than 900 people have reserved seats and paid deposits with companies developing SRVs for future suborbital flights. Additionally, some of the SRV companies have also signed contracts and agreements with organizations and corporations that want to use their service for science applications.

SRV companies have also received government funding from NASA, the Department of Defense, and the FAA. NASA's Flight Opportunities Program has allocated $10 million over two years for SRV flights and DoD small business contracts have provided about $2 million in funding for technology development at three SRV companies.[5]

On July 2nd, NASA announced the selection of 14 technologies for development and suborbital flight demonstrations under the Flight Opportunities Program. The new technologies will develop such areas as active thermal management, advanced avionics, precision landing, and advanced in-space propulsion. NASA is planning to spend nearly $3.5 million on the payloads (approximately $125,000 to $500,000 each) which are expected to launch in 2013 and 2014.

As mentioned, prizes have also facilitated the development of SRV technology. The Ansari X-Prize in 2004 and the Northrup Grumman Lunar Lander X Challenge in 2008 and 2009 provided approximately $12 million in total awards to companies developing SRV specific technology.

Spaceports

The FAA's Office of Commercial Space Transportation (AST) licenses commercial spaceports and operations in the United States. These sites are dedicated facilities traditionally used to launch orbital and suborbital spacecraft. To avoid conflicts with air traffic and ensure safety,

[3] FAA Report, The U.S. Commercial Suborbital Industry: A Space Renaissance in the Making, October 2011
[4] Ibid, page 32
[5] Ibid, page 34

spaceport operations are supported by the FAA's air traffic control (ATC) and typically use a dedicated U.S. Air Force range that is cleared of aircraft prior to a launch.

In the United States, there are currently eight FAA-licensed spaceports that support orbital, suborbital or both types of launches. Of these, five can conduct suborbital flight operations that support SRVs. They are: Cape Canaveral Spaceport, Florida; Cecil Field Spaceport, Florida; Oklahoma Air and Space Port, Oklahoma; Spaceport America, New Mexico; and Mojave Air and Space Port, California.

Experimental Permits and Licensing

The Commercial Space Launch Act of 1984 (CSLA), as amended, authorizes the Secretary of Transportation to oversee, license and regulate commercial launch and reentry activities carried out by U.S. citizens or within the United States. In 2004, the Congress enacted the Commercial Space Launch Amendments Act of 2004 (CSLAA 2004) which expressly authorized the Secretary to regulate and promote commercial human spaceflight. However, in order to allow the SRV industry to develop an experience base upon which FAA could fashion reasonable regulations, the same bill imposed an eight year moratorium on issuance of final regulations on SRVs. Industry officials frequently refer to the moratorium as a 'learning period.' Like all commercial space transportation oversight, the Secretary has delegated this authority to the FAA's Office of Commercial Space Transportation (AST).

Under the CSLAA, the FAA can issue experimental permits on a case by case basis rather than licenses for the launch and reentry of reusable suborbital rockets for the purpose of vehicle testing and other non-revenue flights. The FAA also allows smaller vehicles to fly under an "amateur rocket" exemption from the requirement to obtain a license or permit, but they cannot carry a human being.

In May 2005, the FAA issued the Guidelines for Experimental Permits for Reusable Suborbital Rockets document specifying key aspects of the permit regime. The guidelines identify the safety measures that the FAA would expect a company with an experimental permit to comply with during flight test operations. The guidelines include a variety of safety measures that protect the public including; hazard analysis, operating area containment, key flight-safety event limitations, and anomaly reporting.

Under an experimental permit, a company may test new design concepts, equipment or operating techniques, and demonstrate how their system complies with safety requirements. The company may also conduct crew training but is prohibited from generating revenue (i.e., selling seats) from permitted flights. While companies must still demonstrate financial responsibility for third party damages, they are not eligible for regular launch and reentry indemnification while conducting testing under an experimental permit.

Companies will be required to obtain a license prior to initiating a commercial service. Once a test program is completed, the operator can apply for either a launch license or an operator license. The key difference between the two is that a launch specific license authorizes only a specific number of launch or reentry activities.[6]

[6] FAA's Implementation of the Commercial Space Launch Amendments Act of 2004 – The Experimental Permit

The regulatory strategy currently used by the FAA to license the launch of SRVs combine safety approaches to protect the public through three different means.

- A licensee must demonstrate that the risk from a launch falls below specified quantitative collective and individual risk criteria,
- A licensee must have a comprehensive system safety program consisting of both system safety management and system safety engineering, to identify hazards and reduce risks to the public, and
- A licensee must comply with several operating requirements, developed by the FAA from lessons learned in the launch vehicle industry.[7]

Crew and Spaceflight Participant Safety

The CSLAA established an informed consent regime in which licensees must provide passengers that have purchased tickets for suborbital flights (referred to as spaceflight participants) with information about the safety record of their vehicles and other risks, must ensure that participants meet basic health standards, provide them basic training regarding their vehicle, and inform them that the federal government does not certify the vehicle to be safe, after which participants must sign a legal consent document.

The current "learning period" was recently extended as a provision of the FAA Modernization and Reform Act of 2012. The law stipulated that a final regulation could not be issued until October 2015 but the legislative report language accompanying the bill stated that "nothing in this provision is intended to prohibit the FAA and industry stakeholders from entering into discussions intended to prepare the FAA for its role in appropriately regulating the commercial space flight industry when this provision expires."[8]

As a result of the Congressional intent in the legislative report, the FAA has initiated a collaborative dialogue with industry to begin collecting technical data and inputs from the companies that are currently testing (or planning to begin testing) their vehicle designs. In a recent Space News article, the FAA/AST senior technical advisor Pam Melroy explained how the FAA would collaborate with industry.

> "We're going to be setting up monthly public telephone calls to ask [industry] about certain topics," Pam Melroy, former NASA astronaut and senior technical adviser in the Federal Aviation Administration's (FAA) Office of Commercial Space Transportation (AST), said in a July 16 interview. "We do plan on having these once a month for the foreseeable future. We really want maximum participation, and we want technical people to really help us understand what the thinking is out there."[9]

The FAA intends to share findings from the industry collaboration with the Commercial Space Transportation Advisory Committee (COMSTAC) on an ongoing basis, beginning this October.

[7] Ibid
[8] House report 112-381
[9] SpaceNews, *FAA Commercial Space Office Navigates Legal Maze To Start Safety Dialog,* July 20, 2012

The COMSTAC is the FAA's federal advisory committee comprised of industry experts that provide policy and programmatic recommendations to the Associate Administrator for Commercial Space Transportation at the FAA.

According to the FAA, once the learning period is over in October 2015, it could take more than a year to finish gathering the necessary technical data to write final regulations.

Market

The market for SRVs is expected to mature as vehicle development advances from flight testing to licensing and commercial operations. Customer demand for space tourism is already building. To date, there are more than 900 individuals who have made deposits and reservations for commercial human spaceflights aboard SRVs and this sector of the market is providing substantial funding to some of the SRV companies. The "early adopters" of commercial human spaceflight include private individuals and researchers from corporations, academia, and institutions which are enabling the development of other potential market sectors for SRVs by partially funding the development of the vehicles.

While costs remain high and competing alternatives to SRVs already exist in many sectors, the market that analysts expect to emerge for suborbital SRVs consists of a combination of commercial human spaceflight, basic and applied research, aerospace technology test and demonstration, remote sensing, education, media and public relations and point-to-point transportation.

- Commercial Human Spaceflight - Individual consumers (spaceflight participants), in-space training for astronauts and crew, and government or corporate sponsored human tended research.
- Basic and Applied Research - Scientists, researchers, and engineers seeking access to the space environment, upper atmospheric regions, and microgravity for investigations of biological and physical R&D, Earth science and human research.
- Aerospace Technology Test and Demonstration - Demonstrations and testing of aerospace engineering payloads and components.
- Remote Sensing - Imagery acquisition that cannot be met with traditional satellite or aerial surveillance platforms. SRVs may provide a unique resolution or field of view for certain applications.
- Education - Flight opportunities for STEM education and training within K-12 and undergraduate education budgets.
- Media and Public Relations - Public relations and media firms, filmmakers, and broadcasters promoting products or brand awareness.
- Point to Point Travel - High-speed transportation of cargo or people.

In addition to the market sectors listed above, several SRV companies have recently announced plans to build dedicated small satellite launcher systems. The launch systems would utilize the SRV to place satellites ranging from 1 kg to 500 kg into low Earth orbit at a price per kilogram that is predicted to be less expensive than traditional expendable rockets.

Science Applications

Suborbital expendable sounding rockets have been a critical component of scientific research for over 50 years, yet the emergence of new SRVs offers the potential for new research applications in astronomy, physics, planetary science, atmospheric science, biology and human research. Commercial SRVs have significant potential for use by the scientific community to obtain measurements unavailable by other means or to collect data in a low cost, more time responsive, and routine manner.

The operating characteristics of the various SRVs under development could offer the scientific community a unique opportunity to obtain measurements in and from a region of the atmosphere currently not well understood. SRVs could enable scientific investigations in relatively unexplored regions of the atmosphere that is defined as the upper reach of high altitude balloons to the lower reach of orbital satellites.

SRVs could also enable in situ measurements in the upper stratosphere and mesosphere at altitudes rarely sampled by any vehicle. These in situ measurements include sampling of the gas and particle populations along the vehicle flight path. Aircraft and balloon borne observations have proven decisive to our understanding of the atmosphere and climate. However, many critical chemical and dynamic atmospheric processes and phenomena occur in the region of the atmosphere that is commonly referred to as the "Ignorosphere" because it is not sampled on a regular basis.

While ground and space based observations have provided important data on some of these processes, in situ measurements at specific locations may help scientists fully understand the various processes and validate models. An increased geographical availability could also be an important variable for science applications. If the SRV market expands, the number and location of spaceports could be global while some SRVs could operate from any sufficiently large airport. SRVs may be able to repeat flights to the same region of the upper atmosphere on a regular basis and provide a constant record for a particular investigation. As a result, there may be a complementary and supportive nature of SRVs to the existing research conducted by sounding rockets, satellites and ground based instruments.

Chairman PALAZZO. The Subcommittee on Space and Aeronautics will come to order. Good afternoon and welcome to today's hearing entitled, "The Emerging Commercial Suborbital Reusable Launch Vehicle Market."

In front of you are packets containing the written testimony, biographies, and truth in testimony disclosure for today's witness panel.

I recognize myself for five minutes for an opening statement.

I would like to thank our many witnesses for agreeing to testify before our Subcommittee. I know that considerable effort goes into your preparation, and I want to thank you for taking the time to appear today to share your knowledge with us.

Today's hearing will look at the emerging commercial suborbital reusable launch vehicle market. Suborbital vehicles can cross the thresholds of space and travel to the upper reaches of the atmosphere, typically above 62 miles for brief periods of time but not orbit the earth. Our hearing will provide an opportunity to receive testimony from researchers, market analysts, and some of the companies that are vying to build the vehicles to compete in this emerging marketplace.

We are going to learn about a newly-released ten-year forecast of market demand. Many in the research community are hopeful to exploit the unique microgravity environment of suborbital flight with economical, routine access that enables expanded human research, atmospheric research and microgravity biological and physical research.

Space tourism proponents are optimistic that a safe operational system will be developed to support their business ambitions, yet there are significant technical, financial, and regulatory challenges to be overcome before these hopes can be realized. Companies can perform test flights with an experimental permit from the FAA but cannot sell their services and become full-fledged commercial entities without first obtaining an FAA launch and reentry license.

In addition, current law prohibits the FAA from issuing regulations on human spaceflight until October, 2015. Until then the FAA will engage with the industry participants who can share their views on how to improve safety without proposing burdensome regulations.

I encourage industry to work closely with the FAA so that they will be able to draft effective regulations in 2015, and diminish the chance that these regulations will stifle the industry.

I look forward to hearing from our experts about their plans to develop a profitable and sustainable business. It is my hope they will be successful bringing these new markets into the mainstream, recognizing that the commercial suborbital launch vehicle business faces significant technical challenges as new designs are introduced. I am optimistic they will perform safely and profitably while reducing costs and increasing the quality of suborbital research.

We have a lot of ground to cover today. I want to thank our witnesses again. I look forward to today's discussion.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF SUBCOMMITTEE CHAIRMAN STEVEN M. PALAZZO

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Companies can perform test flights with an "experimental permit" from the FAA, but cannot sell their services and become full-fledged commercial entities without first obtaining an FAA launch and reentry license. In addition, current law prohibits the FAA from issuing regulations on human spaceflight until October 2015. Until then, the FAA will engage with industry participants who can share views on how to improve safety without proposing burdensome regulations. I encourage industry to work closely with the FAA, so that they will be able to draft effective regulations in 2015, and diminish the chance that these regulations will stifle the industry.

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We have a lot of ground to cover today. I want to thank our witnesses again, and I look forward to today's discussion.

Chairman PALAZZO. I now recognize Ms. Edwards for her opening statement.

Ms. EDWARDS. Thank you, Mr. Chairman, and I will be brief. I also join you in thanking the witnesses and also thanking them for their patience. Sometimes our schedules are a little bit unpredictable, but I want to welcome all of our witnesses because I anticipate that this is going to be a really interesting and informative hearing on the emerging commercial suborbital transportation market.

And Mr. Chairman, this Subcommittee has been heavily involved in commercial space transportation issues, including suborbital systems. It is also clear that developing commercial suborbital systems has been a challenging undertaking. At a 2003 joint House/Senate hearing on commercial space transportation, companies predicted that commercial suborbital flights could be anticipated as early as 2006. A few years later at a hearing held by this Subcommittee in April, 2005, an industry representative estimated that service could begin in 2008 or 2009.

Based on the prepared statements provided by the industry witnesses, I am encouraged by the progress that is being made by competing designs, and I look forward to continuing accomplishments. I would like to also better understand what challenges this emerging industry has encountered in getting to where it is today and what hurdles remain.

And further, I hope to hear from our witnesses on what challenges have been overcome, what opportunities lie ahead, the potential impacts on NASA research activities, and what steps will be needed to ensure that this can be done safely, and I would add to that what it is that this Congress needs to do to ensure your success.

And so thank you, Mr. Chairman, and I yield back the balance of my time.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF RANKING MINORITY MEMBER DONNA F. EDWARDS

Good afternoon. I'd like to join the Chairman in welcoming our witnesses to what I anticipate will be an interesting and informative hearing on the emerging commercial suborbital transportation market.

Mr. Chairman, this Subcommittee has been heavily involved in commercial space transportation issues, including the suborbital systems.

It is clear that developing commercial suborbital systems has been a challenging undertaking. At a 2003 joint House-Senate hearing on commercial space transportation, companies predicted that commercial suborbital flights could be anticipated as early as 2006. A few years later, at a hearing held by this Subcommittee in April 2005, an industry representative estimated that service could begin in 2008 or 2009.

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Thank you and I yield back the balance of my time.

Chairman PALAZZO. Thank you, Ms. Edwards. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time I would like to introduce our panel of witnesses, and then we will proceed to hear from each of them in order.

Our first witness is Ms. Carissa Christensen, a Founder and Managing Partner of the Tauri Group, an analytic consulting firm based in Alexandria, Virginia. Ms. Christensen is a recognized expert with over 25 years of experience in analysis of space systems, industry economics, regulatory requirements, and underlying demand.

Our next witness is Dr. Alan Stern. Dr. Stern is an Associate Vice President of the Southwest Research Institute, and in 2011 was appointed Director of the Florida Space Institute. Dr. Stern is the Principle Investigator of NASA's Pluto Kuiper Belt Mission, and in 2000 and 2008, he served as the Associate Administrator of NASA's Science Mission Directorate.

Our next witness is Mr. George Whitesides, the CEO and President of Virgin Galactic, the space tourism company founded by Sir Richard Branson. Prior to Virgin Galactic Mr. Whitesides served as Chief of Staff of the current NASA Administrator and before that as Executive Director of the National Space Society.

Our next witness is Mr. Bretton Alexander, Director of Business Development and Strategy for Blue Origin, a developer of human spaceflight systems founded by Amazon.com's Jeff Bezos. Prior to that Mr. Alexander was the Chair of the Commercial Space Committee of the NASA Advisory Council. Since 2008, Mr. Alexander has served as a member of the FAA's Commercial Space Transportation Advisory Committee, COMSTAC.

Our next witness is Mr. Andrew Nelson, Chief Operating Officer and Vice President of Business Development for XCOR Aerospace. Mr. Nelson originated the space vehicle wet lease concept that is at the heart of XCOR's market strategy. Prior to XCOR Mr. Nelson spent approximately 15 years in the aerospace sector and a total of nine years with two Wall Street firms; Morgan Stanley and Lehman Brothers.

The last witness on our panel, Dr. Stephan McCandliss, is a Research Professor at the John Hopkins University, Department of Physics and Astronomy and is currently Principle Investigator of a Sounding Rocket Program. Since coming to the John Hopkins University, he has launched 15 sounding rocking borne for UV spectroscopic instruments. Dr. McCandliss has been Principle Investigator and Co-Investigator on several NASA grants to develop space mission technologies and served as a member of NASA's Sounding Rocket Working Group from 1999 to 2003.

Welcome to you all.

As our witnesses should know, spoken testimony is limited to five minutes each. After all witnesses have spoken, Members of the Committee will have five minutes each to ask questions.

I now recognize our first witness, Ms. Christensen, for five minutes.

STATEMENT OF MS. CARISSA CHRISTENSEN, MANAGING PARTNER, THE TAURI GROUP

Ms. CHRISTENSEN. Chairman Palazzo, Congresswoman Edwards, Members of the Committee, thank you for the opportunity to testify today on emerging markets for suborbital reusable vehicles. On a personal note, it is an honor to be part of this, and to be testifying today. I spent my career in commercial space, and I am delighted that Congress is interested in this important subject.

My firm, The Tauri Group, recently completed a six month study to forecast ten-year demand for suborbital reusable vehicles or SRVs. The FAA Office of Commercial Space Transportation and Space Florida jointly funded the study.

Our purpose was to develop an objective and rigorous forecast of SRV demand and market dynamics. Equally importantly, we sought to identify the ways current realities could change, positively or negatively, in order to help decision makers understand and manage future outcomes. Our research and analysis-focused process included 120 interviews assessing budgets, market studies, and other data and surveying more than 200 high net-worth individuals who can afford current prices for suborbital flights.

We used this data to develop our forecast and to describe future uncertainties and our assumptions about them. My testimony describes results of that study.

Our study concluded that demand for SRV flights at current prices is genuine, sustained, and appears sufficient to support multiple providers. We estimate baseline demand, reflecting predictable trends that exist today, at about 400 to 500 seat equivalents each year, for people and for cargo. Our growth scenario sees that number nearly triple. Our constrained scenario sees it halved. Additional potential demand is possible from unknowns such as research discoveries, commercial applications, or a viral consumer response. Price reductions would also increase demand.

The largest market by far in our analysis is commercial human spaceflight for individuals. We estimate it at more than 80 percent of the total. Given current prices most of these individuals will be wealthy. Many will be from outside the United States.

These individuals enable a new SRV industry with capabilities that can benefit researchers, educators, and others.

Specifically, we identified five additional markets active in our ten-year forecast period. Basic and applied research, aerospace technology test and demonstration, satellite deployment, education, and media and public relations. Our baseline for these markets shows initial demand for about 30 seat equivalents that grows to 130 annually. Our constrained scenario grows more slowly, and our growth scenario increases to nearly 400 seat equivalents, representing thousands of payloads.

As of this moment purchases of SRV services in most of these markets have already begun.

SRVs have unique capabilities for basic and applied research. We identified currently funded research areas that are better served by SRVs than by existing alternatives. We predicted some of the funding in these areas would shift to SRVs. These areas are atmospheric research of the poorly understood upper reaches of the atmosphere that affect weather and climate, suborbital astronomy to get access to infrared and ultraviolet observations from outside the atmosphere, longitudinal human research on space travelers to understand things like vascular and immune response to microgravity and acceleration, and microgravity research where the unique combination of SRV capabilities may energize the research community and attract new organizations.

SRVs can also be used for test and demonstration of certain types of technology, and may also serve as launchers for small satellites, which are increasingly used for research.

Finally, our analysis suggests SRVs may be widely used for STEM education. Student-built projects can fly to space and return, frequent launches aligned with academic calendars, and schools can likely afford SRV prices for small payloads. Based on analogous hands-on STEM programs, we estimate that after ten years as many as 600 K through 12 schools and more than 100 universities could be flying small student payloads.

SRVs will create a different kind of space transportation industry than we have seen before. This space marketplace will be heavily influenced by individual consumers with government potentially around a tenth of total demand. An important regulatory challenge is developing an effective approach for these unprecedented new dynamics.

In closing, I would like to thank you for the opportunity to speak today, and I look forward to your questions.

[The prepared statement of Ms. Christensen follows:]

Statement of
Carissa Bryce Christensen
Co-Founder and Managing Partner
The Tauri Group

Before the Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
United States House of Representatives
August 1, 2012

Chairman Palazzo, Ranking Member Costello, Members of the Subcommittee, thank you for the opportunity to testify on emerging markets for suborbital reusable launch vehicles. On a personal note, it is an honor to be testifying—I have spent my entire career in commercial space, and I am pleased Congress is interested in this important subject.

My partners and I founded The Tauri Group based on the belief that objectivity and rigor are critical to effective decision-making. Our business model is to provide independent analysis to government and industry. I lead our space and technology practice, which focuses on the space industry, advanced technologies, and related emerging markets.

The Tauri Group recently completed a 6-month study to forecast 10-year demand for suborbital reusable vehicles, or SRVs. The Federal Aviation Administration Office of Commercial Space Transportation and Space Florida jointly funded the study.

Our purpose was to develop an objective and rigorous forecast of SRV demand and market dynamics. Equally important, we sought to identify the ways current realities could change, positively or negatively, in order to help decision makers understand and manage future outcomes. Our research and analysis-focused process included interviewing 120 potential users and providers; polling 60 researchers; and assessing budgets, market studies, and other data. We also conducted a structured survey of more than 200 high net-worth individuals.

My testimony describes results of that study.

Emerging Markets

Our study concluded that demand for SRV flights at current prices is genuine, sustained, and appears sufficient to support multiple providers. We estimate baseline demand—reflecting predictable trends that exist today—at between 400 and 500 seat equivalents each year, for people and cargo. Our growth scenario sees that number nearly triple; our constrained scenario sees it halved. Additional potential demand is possible from unknowns such as research discoveries, commercial applications, or a viral consumer response. Price reductions would also increase demand.

The largest market by far is commercial human spaceflight for individuals—we estimate it is more than 80 percent of the total. Given current prices, most of these individuals will be wealthy. Many will be from outside the United States.

These individual consumers enable a new SRV industry with capabilities that can benefit researchers, educators, and others.

Specifically, we identified five additional markets active in our 10-year forecast period: Basic and Applied Research, Aerospace Technology Test and Demonstration, Satellite Deployment, Education, and

Media and Public Relations. Our baseline for these markets shows initial demand for about 30 seat equivalents that grows to 130 annually, while our constrained scenario grows more slowly. Our growth scenario increases to nearly 400 seat equivalents each year, representing thousands of payloads.

As of this moment, purchases of SRV services in most of these markets have already begun.

It is important to recognize that this forecast predicts outcomes related to experiences that, for the most part, do not yet exist. If SRV services vary from today's expectations, demand could increase or decrease from forecasted levels. Our forecast also identifies and includes assumptions about uncertainties such as consumer behavior, researcher interest and institutional response, and media and public opinion influences. We used research and analytic judgment to calibrate assumptions, and we explain our analysis fully. Understanding uncertainties is a critical aspect of framing discussion about how the market will ultimately unfold.

Unique Benefits for Research and Education

SRVs have unique capabilities for basic and applied research. We interviewed researchers and analyzed program activity and grants from organizations like NASA, NOAA, NSF, NIH, non-U.S. space agencies, non-profits, universities, and commercial firms. We identified currently funded research areas that are better served by SRVs than by existing alternatives; we predicted some of the funding in these areas would shift to SRVs. These areas are:

- Atmospheric research of the poorly understood upper reaches of the atmosphere that affect weather and climate
- Suborbital astronomy to get access to infrared (IR) and ultraviolet (UV) observations from above the atmosphere
- Longitudinal human research on space travelers to understand things like vascular and immune responses to microgravity and acceleration
- Microgravity research where the unique combination of SRV capabilities may energize the research community and attract new organizations

SRVs can also be used for test and demonstration of certain types of technology, including vehicle components, life support systems, and mechanical parts like pumps and valves. Some SRVs may also serve as launchers for small satellites, which are increasingly used for research.

Finally, our analysis suggests that SRVs may be widely used for science, technology, engineering and math (STEM) education. Student-built projects can fly to space and return, frequent launches allow alignment with academic calendars, and schools can afford likely SRV prices. Based on analogous hands-on STEM programs, we estimate that after 10 years as many as 600 schools (K-12) and more than 100 universities could be flying small student payloads.

Regulatory Challenges

SRVs will create a different kind of space transportation industry than we have seen before. This will be a commercial marketplace heavily influenced by individual consumers, with, based on our estimate, the government at less than 10% of total demand. There is a lack of precedent for regulating consumer-driven space transportation. An important regulatory challenge is developing an effective approach given these new dynamics.

Thank you for the opportunity to speak today. I look forward to your questions.

MAJOR POINTS FROM
Statement of
Carissa Bryce Christensen, Co-Founder and Managing Partner, The Tauri Group
Before the Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
United States House of Representatives
August 1, 2012

- Tauri Group study of 10-year demand for suborbital reusable vehicles (SRVs)
    - Funded by the FAA AST and Space Florida
    - Purpose was to describe industry dynamics and estimate demand

What are the emerging launch markets for suborbital RLVs? When do you anticipate they will begin to purchase commercial launches from the companies?

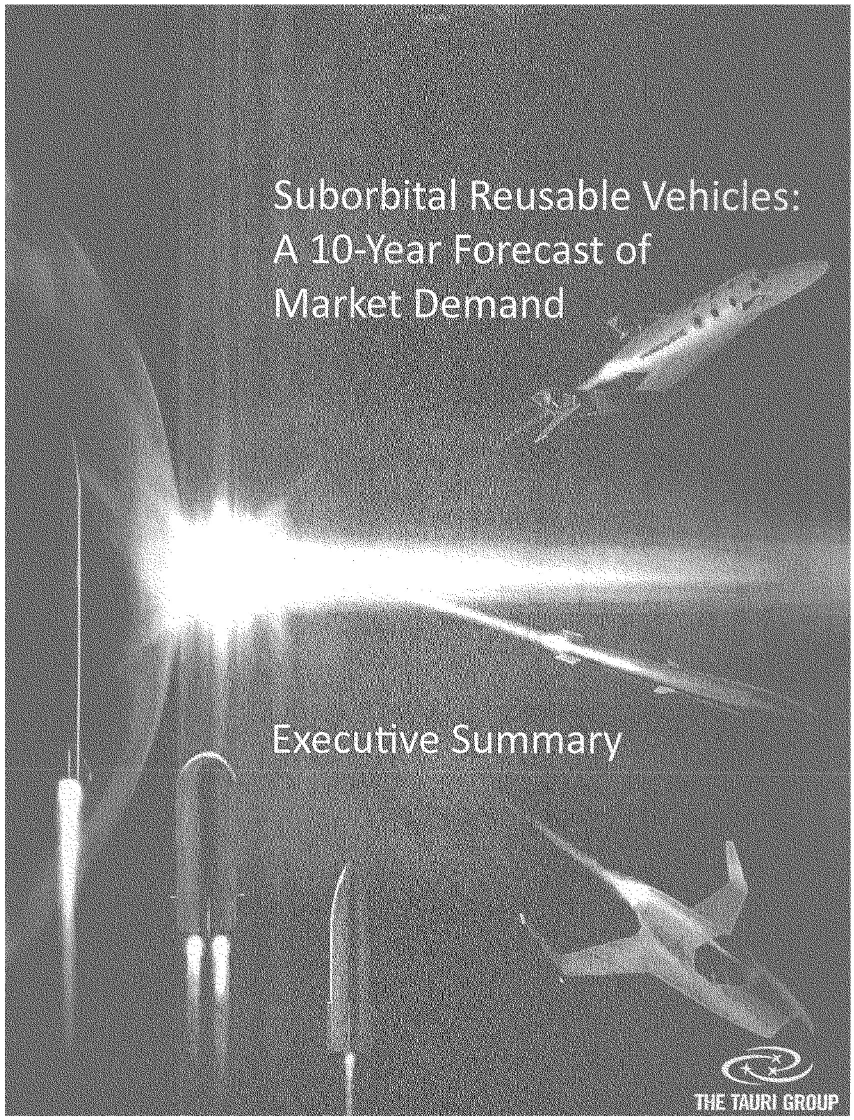
- Demand for SRV flights at current prices is genuine, sustained, and appears sufficient to support multiple providers
- Largest market is Commercial Human Spaceflight, more than 80% of total
- Five additional markets
    - Basic and Applied Research
    - Aerospace Technology Test and Demonstration
    - Satellite Deployment
    - Education
    - Media and Public Relations
- Purchases have begun
- Forecast includes important uncertainties
    - SRV experience does not yet exist
    - Other assumptions

What are the unique benefits that suborbital RLVs offer the scientific community for research? How can these new vehicles be applied to STEM education?

- Basic and Applied Research
    - Atmospheric research
    - Suborbital astronomy
    - Longitudinal human research
    - Microgravity research
- Aerospace Technology Test and Demonstration
- Small Satellite Deployment
- STEM Education
    - Students build payloads that return from space
    - Frequent launches align projects with academic calendars

What are the regulatory uncertainties or challenges that have the most impact on the suborbital researchers that intend to fly experiments on future RLVs?

- SRVs will create a different kind of space transportation industry
    - Government is less than 10% of total demand
    - Commercial marketplace heavily influenced by individual consumers
- Lack of precedent for regulating consumer-driven space transportation
- Regulatory challenge is developing an effective approach given these new dynamic


Suborbital Reusable Vehicles:
A 10-Year Forecast of
Market Demand
Executive Summary
THE TAURI GROUP

[illegible]

the Federal Aviation Administration Office of Commercial Space Transportation

[illegible]

Space Florida.

Executive Summary

Suborbital reusable vehicles (SRVs) are creating a new spaceflight industry. SRVs are commercially developed reusable space vehicles that may carry humans or cargo. The companies developing these vehicles typically target high flight rates and relatively low costs. SRVs capable of carrying humans are in development and planned for operations in the next few years. SRVs that carry cargo are operational now, with more planned.

This study forecasts 10-year demand for SRVs. The goal of this study is to provide information for government and industry decision makers on the emerging SRV market by analyzing dynamics, trends, and areas of uncertainty in eight distinct markets SRVs could address. This study was jointly funded by the Federal Aviation Administration Office of Commercial Space Transportation (FAA/AST) and Space Florida, and conducted by The Tauri Group.

[illegible]

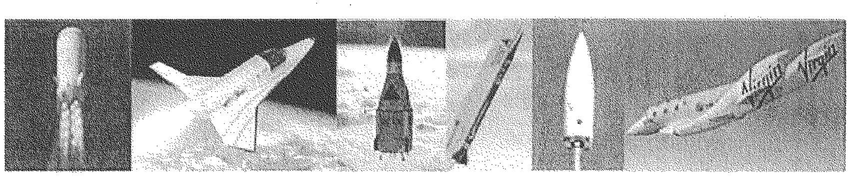
Eleven SRVs are currently in active planning, development, or operation, by six companies. The payload capacity of these SRVs ranges from tens of kilograms to hundreds, with the largest currently planned vehicle capacity at about 700 kilograms. A number of SRVs can carry humans, with current designs for one to six passengers, in addition to one or two crew members in some cases. Some will also launch very small satellites.

[illegible]	[illegible]	[illegible]	[illegible] (estimated)	Cargo (kg)	[illegible]	Announced Operational [illegible]
UP Aerospace	SpaceLoft XL	--	0.5	36	$350k per launch	2006 (actual)
Armadillo Aerospace	STIG A STIG B Hyperion	-- -- 2	1 2 12	10** 50** 200**	Not announced Not announced $102k per seat	2012 2013 2014
XCOR Aerospace	Lynx Mark I Lynx Mark II Lynx Mark III	1 1 1	3 3 28	120 120 770	$95k per seat $95k per seat $95k per seat, $500k for small sat. launch	2013 2013 2017
Virgin Galactic	SpaceShipTwo	6	36	600	$200k per seat	2013
Masten Space Systems	Xaero Xogdor	--	4	25	Not announced	2012 2013
Blue Origin	New Shepard	3+	5	120**	Not announced	Not announced

Table 1: SRV status details

* Maximum number of space flight participants, exclusive of crew (several vehicles are piloted)

** Net of payload infrastructure



This study analyzes SRV demand in eight markets, which were identified and grouped by similarity of applications, purpose, activities, and customers. Figure 1 summarizes and defines those markets.

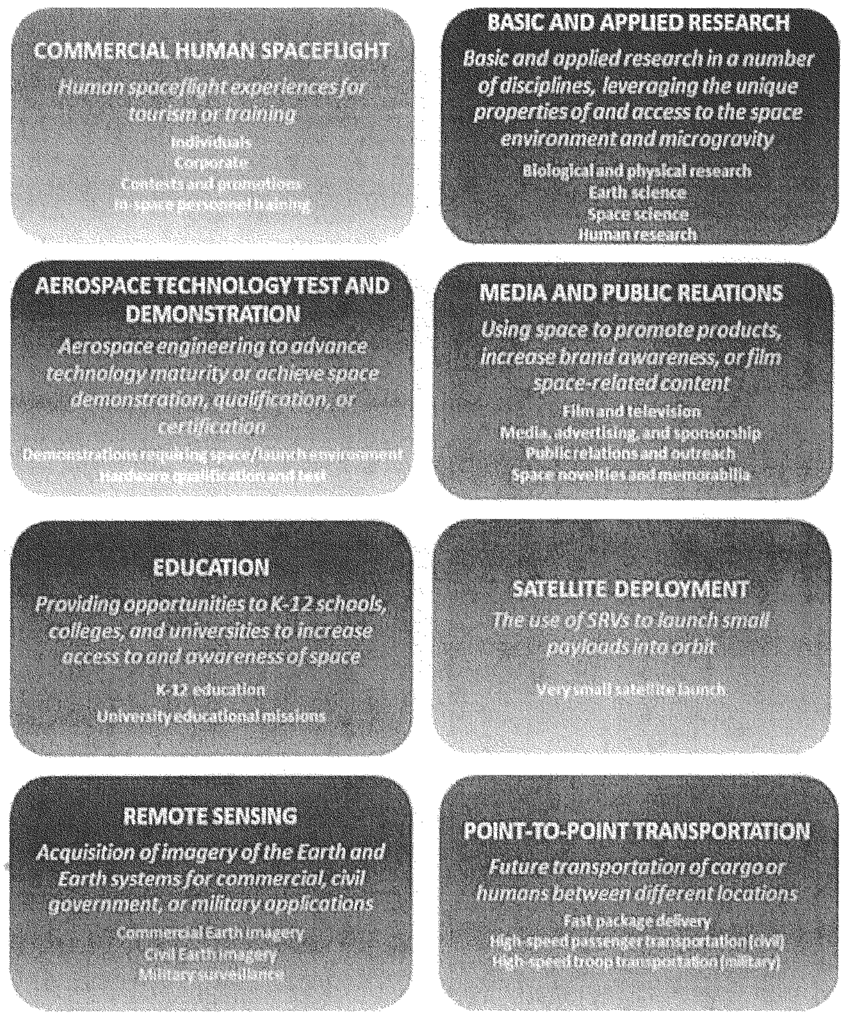


Figure 1: SRV market definitions

Methodology

One seat/cargo equivalent can equal =	1 seat
	3 1/3 lockers

Table 2: Seat/cargo equivalents

The Tauri Group combined primary research (more than 120 interviews, a survey of high net worth individuals, and a poll of suborbital researchers) and open source materials (such as market studies and data on analog markets, government budgets, and performance information on competing platforms) to build a full and objective picture of SRV market dynamics. The forecast results are in seat/cargo equivalents based on average capacity of SRVs (see Table 2).

Demand in each market was forecast for three scenarios:

- **Baseline scenario**: SRVs operate in a predictable political and economic environment that is relatively similar to today's. In this scenario, existing trends generate demand for SRVs.
- **Growth scenario**: This forecast reflects new dynamics emerging from marketing, branding, and research successes. Commercial Human Spaceflight has a transformative effect on consumer behavior, and more customers purchase SRV flights. SRV research results are highly productive and attract significant new government, international, and commercial interest for future experiments.
- **Constrained scenario**: SRVs operate in an environment of dramatic reduction in spending compared to today, due, for example, to worsened global economy.

[illegible]

Total projected demand for SRVs, across all eight markets, grows from around 370 seat/cargo equivalents in Year 1 to over 500 seat/cargo equivalents in the tenth year of the baseline case. (Year 1 represents the first year of regular SRV operations.) Demand under the growth scenario, which reflects increases due to factors such as marketing, research successes, and flight operations, grows from about 1,100 to more than 1,500 seat/cargo equivalents over ten years. The constrained scenario, which reflects significantly reduced consumer spending and government budgets, shows demand from about 200 to 250 seat/cargo equivalents per year (see Table 3).

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Baseline Scenario	373	390	405	421	438	451	489	501	517	533	4,518
Growth Scenario	1,096	1,127	1,169	1,223	1,260	1,299	1,394	1,445	1,529	1,592	13,134
Constrained Scenario	213	226	232	229	239	243	241	247	252	255	2,378

Table 3: Total projected demand for SRVs across all markets

Demand by Market

As shown in Figure 2 below, which compares forecasts for all markets by scenario, demand for SRVs is dominated by Commercial Human Spaceflight. Our analysis indicates that about 8,000 high net worth individuals from across the globe are sufficiently interested and have spending patterns likely to result in the purchase of a suborbital flight—one-third from the United States (based on global wealth distribution). The interested population will grow at the same rate as the high net worth population (about 2% annually). We estimate that about 40% of the interested, high net worth population, or 3,600 individuals, will fly within the 10-year forecast period.

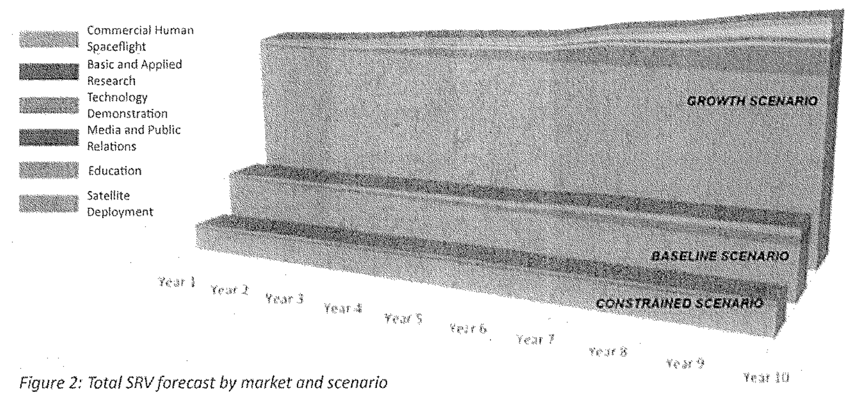


Figure 2: Total SRV forecast by market and scenario

We expect space enthusiasts outside the high net worth population will generate an additional 5% demand.

The resulting baseline forecast is 335 seats in the first year, growing to nearly 400 seats by year 10, totaling about 4,000 over 10 years. The growth scenario predicts a total of 11,000 seats, the constrained scenario a total of 2,000. (About 925 individuals currently have reservations on SRVs.)

Demand for Commercial Human Spaceflight is presented here as a relatively steady state in each scenario, reflecting current levels of interest in the population, assuming individuals are equally likely to choose to fly in any given year within the 10-year time frame.

This convention is useful because of the uncertainty associated with the dynamics of demand as it responds to future events. It is not to suggest that demand will always be steady state; demand may evolve in different, unpredictable ways. For example, demand may shift from the baseline level to the growth level after flight operations have begun. Demand may grow, as we have noted previously, more rapidly than predicted based on viral or "me too" effects, as a function of the social dynamics following successful launch experiences. Demand could decline for similar reasons. Figure 3 shows illustrative demand growth patterns that could emerge for Commercial Human Spaceflight.

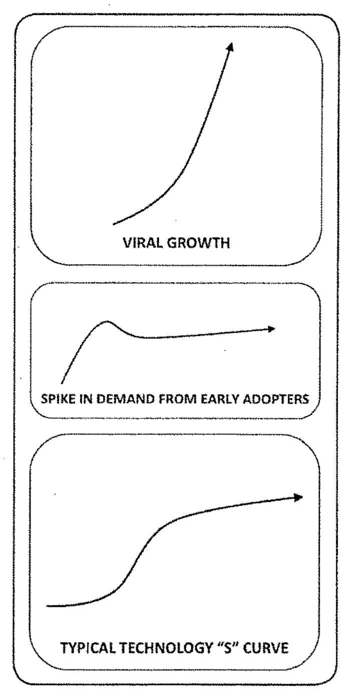


Figure 3: Possible trends over time -- individual demand for Commercial Human Spaceflight

If prices drop, demand will increase. Figure 4 is a demand curve for individuals with at least $5 million in investable assets, showing the effect of changing prices on demand. Additional demand (not shown) would result from individuals with lower levels of net worth.

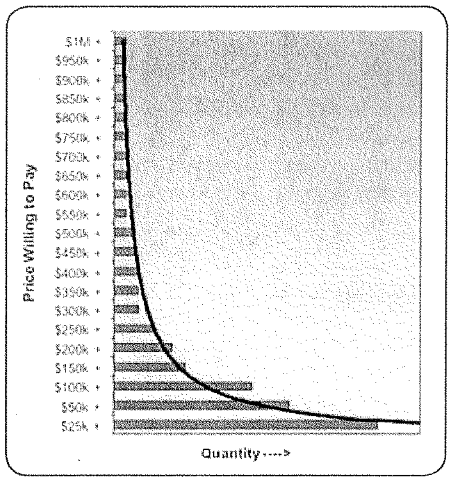


Figure 4: Price elasticity of suborbital tickets for [illegible]

The second largest area of demand is Basic and Applied Research, funded primarily by government agencies, and also by research not-for-profits, universities, and commercial firms. Basic and Applied Research accounts for about 10% of baseline demand. SRVs can support a wide range of possible activities, but offer unique capability primarily in four areas: atmospheric research, suborbital astronomy, longitudinal human research, and microgravity. These areas enable investigations that would be of immediate interest to space and science government agencies. Commercial firms will seek to test SRVs as research platforms as reflected in the forecast. They could be a source of additional growth (beyond what is forecast) if an economically valuable application emerges. In the growth scenario, demand about doubles due to new government programs, doubled commercial activity, and more rapid uptake by international space agencies, driven by demonstrated research successes. In the constrained scenario, demand about halves.

The remaining 10% of demand is generated by Aerospace Technology Test and Demonstration, Education (which will see hundreds of schools and universities flying low cost, small payloads to provide students a learning tool), Satellite Deployment (which includes the launch of very small satellites), and Media and PR (through what we have predicted to be a small but influential number of flights for advertisements, documentaries, and television programming). In the growth scenario, demand in these markets doubles or triples. In the constrained scenario, demand is about half or less of baseline levels.

Two markets are not forecasted to drive launches. SRVs can provide a platform for Remote Sensing activities, but do not offer a competitive advantage over competing satellites, aircraft, and unmanned aerial vehicles (UAVs). Finally, in coming decades, SRVs could evolve into hypersonic airliners to support a market for Point-to-Point Transportation. However, this technology will not be available in the time horizon of this forecast.

Demand by User

The majority of SRV demand comes from individuals (see Figure 5); the SRV market is a consumer market. Consequently, the capability and viability of SRV ventures will be heavily influenced by individual decision makers.

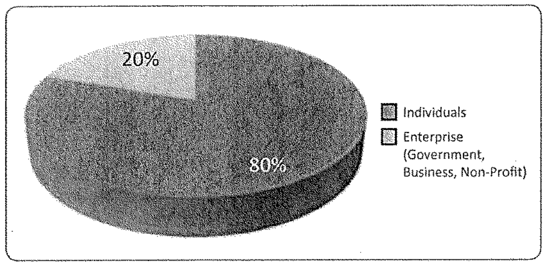


Figure 5: Enterprise demand and individual demand in baseline case

Unlike enterprise users who typically have lead times for decision making measured in years (reflecting annual budgeting processes and government program timelines), individuals can make purchasing decisions quickly. This market is likely to be sensitive to perceptions of risk, and how expectations and shared experiences of SRV flights disseminate.

The behavior of consumers in the future remains uncertain. Marketing and visibility resulting from the approach of flight operations, or successful and publicized flight experiences, could significantly – and rapidly – increase demand. Alternatively, those that have purchased tickets already may represent an early adopter population with different motivations and risk disposition from the broader market. At least some portion of tickets sold to date are refundable or deposits rather than full payments, creating a possibility that not all ticket holders will convert to passengers.

Enterprises

Enterprise users include government, commercial, non-profits, and school and university SRV users, and represents about a fifth of total forecasted SRV demand. Most enterprise demand is for cargo, rather than seats (see Figure 6). About half of enterprise demand is from government agencies, followed by commercial entities (more than one-third), with schools and non-profits accounting for the remainder (see Figure 7). Over 40% of government demand is NASA. (Note that this means that our forecast projects that NASA represents less than 5% of total SRV demand.) About 10% of enterprise demand is from non-US agencies, mainly in the Research and Technology Test and Demonstration markets. Finally, about one-third of enterprise demand is from commercial entities – about 30% Research, with the rest from Media and PR, Commercial Human Spaceflight, and very small satellite launches.

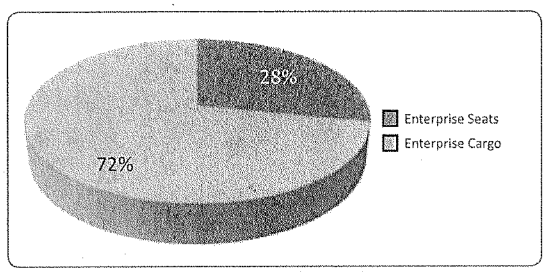


Figure 6: Enterprise demand by type of payload

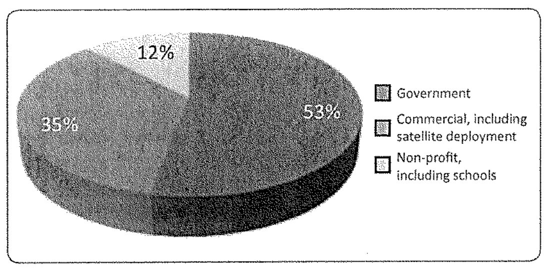


Figure 7: Enterprise demand by type of user

[illegible]

Our forecast roughly translates a total of $600 million in demand over 10 years in the baseline case. The growth scenario totals $1.6 billion, and the constrained scenario totals $300 million.

There are important caveats to these estimates. They do not reflect all related expenditures associated with demand (such as, for example, budgets for developing experiments hardware and paying researchers, or revenues from spaceport activities for family and friends of those flying). They also do not represent predicted SRV flight revenues, but rather the potential revenue associated with SRV demand. The interplay of supply with demand is unaccounted for. For example, there is near-term demand for satellite launches at SRV prices and reflective of SRV capabilities, but no SRVs capable of launching satellites are anticipated until 2017.

Actual revenues will depend on when vehicles become operational, the pace of operations overall, the relative flight rates of providers, ancillary sources of revenue, and future price levels. If, in Year 1, reservations occurred at roughly the rate at which they have recently been announced (150 in 2011 and 185 in 2012, and a total of 925 since 2003), sales to fulfill our demand forecast in the baseline would grow at about 18% annually. In the growth scenario, sales would increase at about 40% each year. The constrained scenario would grow at about 4%. Announced historical reservations, compared to this possible trend of future reservations, are shown in Figure 8.

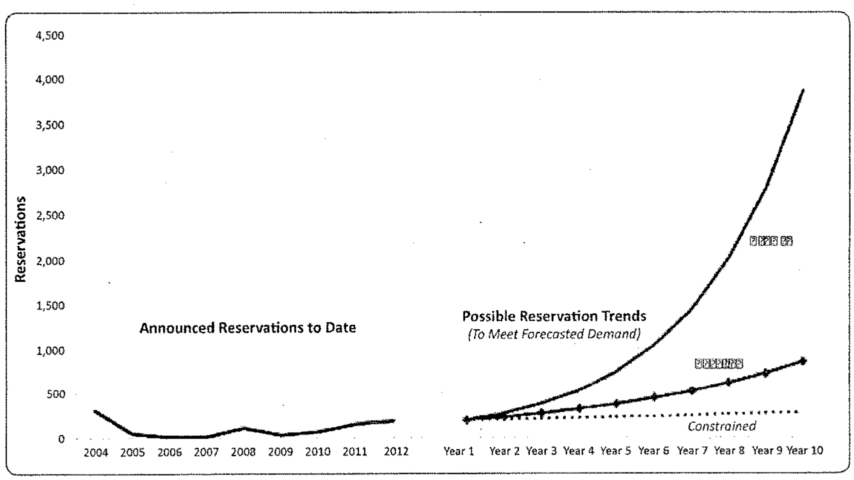


Figure 8: Possible reservations trend to meet forecasted demand

Major Uncertainties

The forecast predicts outcomes related to experiences that, for the most part, do not yet exist. If levels of SRV capability and performance vary from what is expected based on today's information, demand will change from predicted levels.

Forecast results are particularly sensitive to assumptions regarding future consumer behavior. The forecast assumes passengers fly once only, that a potential passenger has a 1/25 probability of flying in a given year (so 40% of interested passengers today will fly within the next 10 years), and that most (95%) passengers have net assets exceeding $5 million. Relaxing or strengthening any of these assumptions changes demand significantly.

Another sensitivity involves research outcomes. Research success and identification of a clear, related commercial application that requires sustained, ongoing SRV use could increase funding beyond the exploratory levels predicted.

The forecast reflects expectations about future government interest in SRVs. If SRV capabilities vary from current expectations, these levels of activity could be either higher or lower. Further, if NASA decision dynamics change, SRVs could be used for astronaut training, to replace sounding rockets to a greater degree, or for microgravity research integrated with ISS activities. The forecast also predicts that more than 50 international governments will begin to fund SRV research. National restrictions on access to SRVs could potentially limit funding from these governments. Alternatively, rapid uptake and greater activity from these nations could result in higher demand than predicted.

As an indicator of the revenue associated with estimated demand, we translated our forecast from seat/cargo equivalents at a rate of $123,000 per seat/cargo equivalent. This estimate reflects announced seat prices across vehicles in active development, extrapolated to all vehicles (including cargo-only vehicles) based on vehicle capacity. It is a rough estimate. No cargo prices (other than satellite deployment costs on an XCOR Lynx Mark III) have been announced, though some providers have stated informally that cargo costs align with seat costs for their vehicles. The mix of vehicles in operation will affect both demand and revenue. Vehicles are priced differently and have different capabilities.

Demand for suborbital flights is sustained and appears sufficient to support multiple providers. Total baseline demand over 10 years exceeds $600 million in SRV flight revenue, supporting daily flight activity. The baseline reflects predictable demand based on current trends and consumer interest. In the growth scenario, reflecting increased marketing, demonstrated research successes, increasing awareness, and greater consumer uptake, multiple flights per day generate $1.6 billion in revenue over 10 years. In a constrained scenario, where consumer and enterprise spending drop relative to today's trends, multiple weekly flights generate about $300 million over 10 years. Further potential could be realized through price reductions and unpredictable achievements such as major research discoveries, the identification of new commercial applications, the emergence of global brand value, and new government (especially military) uses for SRVs. Figure 9 presents a summary of the 10-year SRV demand forecast.

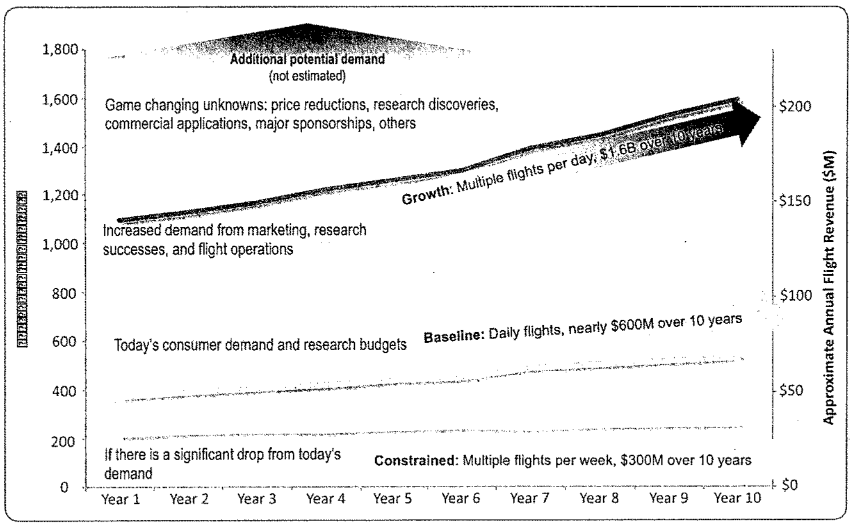


Figure 9: 10-year SRV demand forecast

Chairman PALAZZO. Thank you. I now recognize Dr. Stern for five minutes to present his testimony.

STATEMENT OF DR. ALAN STERN, CHAIRMAN, SUBORBITAL APPLICATIONS RESEARCHERS GROUP

Dr. STERN. Thank you. Chairman Palazzo, Congresswoman Edwards, and Members of the Subcommittee, thank you again for the opportunity to meet with you today.

I am a planetary scientist, and I have used suborbital sounding rockets since the 1980s. I have been a Principle Investigator on numerous NASA missions, and I served, as you said, as Associate Administrator responsible for the Science Mission Directorate at NASA headquarters. I am the current Chairman of the Commercial Spaceflight Federation's SARG or Suborbital Applications Researchers Group.

Mr. Chairman, in 1946 when the U.S. Army formed its rocket research panel to determine how researchers could best exploit the capabilities of captured German V–2 rockets, only a tiny fraction of the Nation's scientists were aware of the powerful impact that suborbital rockets could have on their research. After all, few scientists of that era had ever before had access to space launch capability of any kind.

Yet barely a decade later rocket borne research had become so powerful a tool that it formed the centerpiece of 1957's landmark International Geophysical Year.

In 2012, the space research and education communities and large parts of NASA and other federal research agencies are similarly unaware of the powerful opportunities that the new reusable suborbital vehicles can offer for education and for research. Today's analogies to V–2s in 1946 are strong.

Early adopters like myself see transformational promise in these vehicles, primarily because they offer frequent access to space at low cost. Indeed, within a few years this industry is likely to provide the capability to fly hundreds to perhaps thousands of experiments annually and to do so at typical payload launch costs that are ten times or more lower than the 1 to $2 million present day sounding rocket costs.

These vehicles also offer other important benefits. For example, gentler rides for payloads than on suborbital sounding rockets, reducing design costs, the development of market-driven, simple, rapid payload safety integration processes that lower barriers to entry for scientists and universities and corporations. The opportunity to fly larger payloads than we could normally fly on a sounding rocket, reduced experiment waiting times to flight going to the high-flight rates, and very importantly the opportunity to fly researchers and educators with their payloads.

This capability is another game changer that will reduce experiment development costs and increase experiment reliability by eliminating the need for expensive experiment automation that has for too long been commonplace in space as a substitute for the researcher or the educator being able to be there themselves as in most scientific disciplines.

These new vehicles offer something else that is also both new and revolutionary. That is the routine stepping stone capability to try out and develop research players and experimental techniques at low cost before they are brought up to the International Space Station. Just as in the minor leagues in baseball we try out players and techniques before advancing them to the majors.

As a result of these numerous attractive attributes, I expect broad demand for commercial reusable suborbital vehicles in the following areas. Upper atmospheric research, space life sciences, technology testing for spaceflight, microgravity science, auroral, ionospheric, and space weather research, and an education and public outreach.

As early evidence for the demand for these vehicles and what they are likely to generate in that demand, I point out that the number of scientists attending Next Generation Suborbital Researchers Conferences has doubled in the past two years, from about 200 in 2010, to over 400 this year. Researchers and educators are already voting with their feet.

What these communities could use now are more funding opportunities with NASA and other agencies to exploit the coming capabilities of these vehicles.

And finally, let me say that the primary regulatory uncertainties that I foresee for these new vehicles are those that might limit their ability to achieve high flight rates at low costs and to fly researchers and educators on those flights.

I urge you to minimize these and other regulatory burdens on this new and highly-promising American industry, and I thank you for your time and for inviting my views.

[The prepared statement of Dr. Stern follows:]

Written Testimony
To
The House Subcommittee on Space and Aeronautics
Hearing:

The Emerging Commercial Suborbital Reusable Launch Vehicle Market.

S. Alan Stern
01 August 2012

Chairman Palazzo, Ranking Member Costello, and Members of the Subcommittee, thank you for the opportunity to testify today on *The Emerging Commercial Suborbital Reusable Launch Vehicle Market.*

As you may know, I am a planetary scientist who has used suborbital sounding rockets since the 1980s, a principal investigator on numerous NASA suborbital, orbital, Space Shuttle, and planetary missions, formerly NASA's Associate Administrator for the Science Mission Directorate, and the current chairman of the Commercial Spaceflight Federation's SARG (Suborbital Applications Researchers Group) committee for the scientific and educational applications of commercial reusable suborbital vehicles. These and other relevant experiences have provided particularly relevant experience in executing and managing research in space, including the application and benefits of suborbital flight systems.

In 1946, when the U.S. Army formed its Rocket Research Panel to determine how researchers could best exploit the capabilities of captured German V-2 rockets, only a tiny fraction of the Nation's astronomers, atmospheric scientists, biologists, and solar physicists were aware of the powerful impact that suborbital rockets like the V-2 could have on their research. After all, the V-2s were developed for another purpose—war fighting—and few U.S. scientists had ever had access to any space launch capability to do their research. Yet just a decade later, rocketborne research had become so powerful a tool that it formed the centerpiece of 1957's productive and impactful, and now legendary, International Geophysical Year (IGY).

In 2012, the space research and education communities, and large parts of NASA and other federal research agencies like NSF, NOAA, USGS, DOD, NIH, and the Department of Education, are unaware of the powerful opportunities that reusable suborbital vehicles like Virgin Galactic, XCOR, Armadillo Aerospace, and Masten Space Systems, and Blue Origin offer for research and education/public outreach (EPO) activities in space. After all, these new commercial, reusable suborbital vehicles were developed for another purpose—in this case space tourism—and few U.S. scientists have ever had the scope of access to space launch capabilities to do their research that these vehicles are specifically designed to provide. The analogies in this new commercial, reusable suborbital vehicle era to 1946 and the offering of V-2s to the research community are strong. Similarly, I believe the analogies to the demand growth for sounding rockets by 1957 and the great dividends from—and high demand for—suborbital research using commercial, reusable vehicles, will be similarly strong later in this decade and early in the next.

This hearing asks, "What are the unique benefits that suborbital RLVs offer the scientific community for research? (And) How can these new vehicles be applied to STEM education?"

So let me point out some of the major, unique benefits that these vehicles offer; these include:

✓ Frequent access to space at low cost, a game changing combination. Specifically, within a few years we'll have the capability to fly hundreds to thousands of experiment opportunities annually at typical launch costs of $100,000-$200,000 per seat equivalent payload (depending on the suborbital provider)—that's 10 to 100 times the launch rate of current suborbital payloads, at launch costs 10 times or more lower than today's typical $1M to $2M suborbital payload launch costs on sounding rockets. And most payloads will fly many times—e.g., to study changing phenomenology in atmospheric science or to explore large parameter space problems in microgravity science—something never before feasible or affordable, another game changer.

✓ Much gentler rides for payloads than current suborbital rockets. The new generation of reusable suborbital vehicles have been built for average tourists to fly. As a result, rather than the special, custom designs required today for telescopes, spectrometers, and other sensors to ensure they survive and operate after strenuous launches on sounding rockets, many kinds of standard, off-the-shelf laboratory equipment can be flown on the new generation of reusable suborbital vehicles, creating important savings in terms of payload development.

✓ Far simpler and more rapid payload safety/integration processes, akin to airborne research aircraft than the high Shuttle/Space Station paperwork hurdles that space researchers are familiar with today. I believe this will entice many new entrants into space research.

✓ The opportunity to fly larger payloads than could normally be flown inside a Space Shuttle cabin, e.g., allowing sophisticated medical imagers to study test subjects as they acclimate to microgravity for the first time.

✓ Flexible operations that will include worldwide launch basing, the ability to launch at specific times coincident with natural terrestrial and astrophysical phenomenology, with classroom schedules, and with circadian rhythms, and the accompanying, essentially immediate (minutes scale) access to samples, test subjects post-flight—all things no human flight systems offer today or have in the past.

✓ And, very importantly, the opportunity to fly researchers with their payloads. This capability—another game changer—will further reduce experiment development costs, and increase experiment reliability, by eliminating the need for expensive experiment automation that has for too long been common in space as a substitute for the researcher or educator being able to be there themselves. It will also offer high appeal to many space researchers, just as geological and oceanographic field expeditions do for researchers in those fields.

As a result of these and other benefits offered by commercial, reusable suborbital vehicles, I expect high demand in the following application areas:

- Upper atmospheric research
- The space life sciences
- Technology testing for spaceflight
- Microgravity physics and chemistry
- Auroral and ionospheric research, and
- Education and public outreach.

Finally, I would be remiss if I did not point out two other key benefits I expect the new generation of commercial, reusable suborbital vehicles will provide.

The first is the newfound ability these vehicles offer as stepping stone to try out and develop research players and experimental techniques at low cost before they are brought up to the International Space Station, just as the minor leagues in baseball try out players and techniques before advancing them to the majors.

The second key benefit I foresee is the power of these vehicles to inspire STEM education, by flying large numbers of student experiments at low cost—something otherwise impossible today—and to take teachers and educators to space from and back to the classroom to inspire students to pursue STEM careers. The immediacy of spaceflight access provided by commercial, reusable vehicles is, I believe, going to be another game changer.

The impact of commercial, reusable suborbital vehicles won't be limited to the US. At their low experiment launch cost, virtually every one of the 190+ nations on Earth can afford a human spaceflight program for the first time showcasing the flight of their nationals and their experiments on suborbital spaceflight. The returns—for national pride, for education, for motivating students into STEM careers by seeing their citizens conducting operations in space, and for basic R&D purposes—will be high, and the consequent returns to the US will be as well.

Simply put, next generation suborbital spaceflight offers to make space access frequent, inexpensive, and routine for researchers and their payloads alike—something never before achievable in spaceflight.

The hearing invitation also asked, "what is the current demand for research and development, scientific, and educational payloads on suborbital RLVs? What is the timeframe for flying these payloads?"

The current demand is small, perhaps a few dozen payloads per year. But I expect this demand to grow dramatically when routine flights by commercial, reusable suborbital vehiclers begin in 2013 or 2014, particularly when researchers and educators see early-adopter colleagues beginning to reap the many benefits of these new vehicles that I enumerated above. I fully expect demand by researchers and educators to grow by factors of 10 to 100 by late in this decade. And as evidence for the first sign of that demand growth, I point out that in just the past two years, the number of individuals attending annual Next-Generation Suborbital Researchers Conferences has grown from about 200 in 2010 to over 400 this year.

Finally, the hearing invitation asked, "What are the regulatory uncertainties that have the most impact on the suborbital researchers that intend to fly experiments on future RLVs?"

To this query I would answer that the primary regulatory uncertainties are those associated with the commercial, reusable suborbital industry so that they can achieve high flight rates at low cost, and to be able to fly researchers and educators efficiently, as they will tourists. So I urge you to minimize the regulatory burden on this new and highly promising industry, to the benefit of the research and education communities here in these United States, and to the development of this uniquely American industry which will service many more of the 190+ nations on Earth, so that their education and research communities can also enjoy the many strong benefits these vehicles offer.

Thank you for your time and for inviting me to share my views at this hearing. I very much appreciate the opportunity to provide this testimony and I look forward to working closely with all of you and your staff to nurture and promote the development of this promising new domestic industry for research, for education, and for advancing the importance of spaceflight to this nation's economy.

One Page Written Statement and Testimony Summary for The House Subcommittee on Space and Aeronautics

S. Alan Stern

01 August 2012

- The era of commercially reusable suborbital vehicles is almost upon us.
- These vehicles offer numerous game-changing capabilities for both research and education.
- These include far more frequent and far less expensive access to spaceflight than we have ever known. They also include the further game-changing capability for researchers and educators to routinely operate their own experiments in space.
- Application areas as diverse as atmospheric science, microgravity science, space life sciences, and technology testing are expected to be big beneficiaries of these new vehicles.
- Researchers and educators from countries around the globe are expected to use these vehicles in the coming years.
- NASA and other domestic agencies can also exploit these vehicles to inspire students in STEM education and to serve as proving grounds for experiments and experimental techniques needing to be tested and developed before they are sent to the International Space Station.
- For this industry to be successful, the regulatory environment surrounding them must not stifle their ability to fly frequently and at low cost, and to carry researchers and educators on flights.

Chairman PALAZZO. Thank you. I now recognize our next witness, Mr. Whitesides, for five minutes to present his testimony.

STATEMENT OF MR. GEORGE WHITESIDES, CEO AND PRESIDENT, VIRGIN GALACTIC LLC

Mr. WHITESIDES. Mr. Chairman, Congresswoman Edwards, and Members of the Subcommittee, I am honored to be here today.

Virgin Galactic's goal is to become the world's first commercial space line. We have invested hundreds of millions of dollars into this business and into the American economy. Our prime contractor, Scaled Composites, has constructed our first space vehicles and is currently flight testing them as we prepare for commercial service. Our manufacturing joint venture, the Spaceship Company, is hard at work building our second vehicle set. Overall, this project has directly or indirectly employed over 1,000 people in the United States since its inception.

As I continue my testimony, Mr. Chairman, with your permission I would like to share some video footage of our vehicles in flight, taken over California's Mojave Air and Spaceport and New Mexico's Spaceport America.

Virgin Galactic was founded in 2004, to commercialize the technologies demonstrated by SpaceShipOne, the first privately-built vehicle to safely carry human beings into space. When it landed, it not only earned the $10 million X PRIZE and a spot in the Air and Space Museum, it also served as evidence that private entities are capable of building and operating spaceships that can carry humans both safely and affordably.

To date, Mr. Chairman, we have accepted $70 million in deposits, representing over $100 million in future business. Those financials are important but so is a different measurement. As of last week we have accepted deposits from 536 individuals, which is more than the total number of people who have ever gone to space. We anticipate flying that many people within our first year or two of commercial service.

Our system is proving to be an attractive platform for researchers and educators. Already we have accepted deposits from several customers in these areas, including universities as well as research institutions and from NASA itself. With a spacious cabin, relatively gentle gravity loads, frequent flights, affordable pricing, and a longer period of microgravity than many other platforms, we will offer an important tool to help innovators conduct significant science, advanced technology, and educate and inspire the next generation.

We commend Congress and NASA for creating NASA's Flight Opportunities Program, which is playing a critical role in assuring that experiments are ready to fly as soon as the spaceships themselves are in service. As we prepare for commercial service, staff at both Virgin Galactic and Scaled Composites have been interacting with the FAA and in particular the Office of Commercial Space Transportation, or AST, for many years. We believe that the FAA and specifically AST are responsibly discharging their legislative accountabilities concerning suborbital spaceflight.

Businesses like ours have a clear imperative to do all that we can to responsibly manage the risks associated with operating our vehicles. In our case many of our staff, including myself, will fly on our spaceship before any member of the paying public, and our founder, Richard Branson, will be on our first commercial flight. Our team includes a number of professionals with deep expertise in safely operating aerospace vehicles. This includes our Vice President of Operations, Mike Moses, who was responsible for the preparation and launch of the Space Shuttle's final 12 missions. Mike and other members of our team interact with AST on a regular basis, allowing for frank, two-way exchanges of information.

In 2004, Congress determined that eight years of real flight data was a reasonable amount of time for a regulatory learning period, a value with the suborbital industry supported then and continues to support today. When it passed the most recent FAA Authorization Bill, the House of Representatives renewed the eight-year period. The Conference Bill extended the learning period for the scope of the FAA authorization itself, which runs until late 2015.

We are pleased and appreciative that Congress took this action and look forward to working with both bodies of the legislature on the duration of this period in the next Congress.

Moving forward, the regulatory uncertainty that has the biggest potential impact on our business is the concern that the learning period for our suborbital operations might be reduced. Already we are faced with the prospect that soon after we go into commercial operations, rules and regulations may change substantially, potentially disrupting those operations and our business. A stable regulatory environment is the best way to preserve America's status as the world leader for suborbital spaceflight.

In closing, Mr. Chairman, I thank you for the opportunity to appear before you today. As we all remember Sally Ride this week, an American hero and a pioneer who opened the space frontier to women, Virgin Galactic seeks to build on her legacy by opening the space frontier to all. I look forward to answering any questions you might have.

[The prepared statement of Mr. Whitesides follows:]

George Whitesides

President and CEO, Virgin Galactic

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Before the Committee on Science, Space, and Technology
Subcommittee on Space and Aeronautics
United States House of Representatives

August 1, 2012

Chairman Palazzo, Ranking Member Costello, and members of the Subcommittee, I am honored to be here today on behalf of Virgin Galactic. I have been asked to address the emergence of a strong domestic industry for commercially built reusable launch vehicles, with particular focus on the industry's relationship with the Federal Aviation Administration (FAA) and on the potential impact regulatory uncertainties have on our business and others like ours.

I will begin by providing a brief overview of the company I represent here today and of the markets we serve. I will then discuss our relationship to date with the FAA, and how that relationship might be impacted by recently passed legislation. I will conclude with some thoughts on what regulatory uncertainties still remain, how those uncertainties are impacting our business today, and how they might impact us in the future.

Virgin Galactic was founded in 2004, directly as a result of the historic success of SpaceShipOne, the first privately built spaceship to successfully carry human beings into space and bring them back. As that vehicle rocketed into space, it not only earned the famous $10 million Ansari X PRIZE and a spot in the Smithsonian's National Air and Space Museum, it also served as proof that private entities are capable of building and operating spaceships that can carry humans to space both affordably and safely. That vehicle was also in many ways the impetus behind Congress passing the "Commercial Space Launch Act Amendment of 2004," which was signed into law only a few months after SpaceShipOne claimed the X PRIZE. Among many other accomplishments, that bill directed the US Secretary of Transportation to "encourage, facilitate, and promote the continuous improvement of the safety of launch vehicles designed to carry humans ... [and] to encourage the development of a commercial space flight industry." One way in which Congress charged the Department of Transportation to meet these dual goals was by limiting certain new regulations within eight years after the bill passed. This was done specifically because, as the bill reads, "the regulatory standards governing human space flight must evolve as the industry matures so that regulations neither stifle technology development nor expose crew or space flight participants to avoidable risks."

These two milestone events of 2004—the successful flights of the world's first privately built manned spacecraft and Congress's protection of this critical freedom to learn and grow—helped convince entrepreneurs like our founder, Richard Branson, that commercial human spaceflight was a worthy field for investment, and that the United States of America was the only country on the planet in which this industry could begin. In that spirit, Virgin Galactic was born as the world's first commercial spaceline. Our first step was to hire Scaled Composites—the legendary California-based company that designed and built SpaceShipOne, in addition to numerous vehicles for private, corporate, and US military customers—to build a larger, more customer-friendly version of SpaceShipOne and its mothership. These new designs would come to be known SpaceShipTwo and WhiteKnightTwo.

Since that time, our investors have pumped hundreds of millions of dollars of private funds into this business and into the American economy. Our prime contractor, Scaled Composites, has fully constructed our first space vehicles, and is currently testing them as we prepare for commercial service. Virgin Galactic and Scaled Composites—and now Scaled's parent company, Northrop Grumman—have created a new joint venture called The Spaceship Company (TSC), of which I am also President and CEO. TSC is a manufacturing organization designed to build not just a single spaceship, but a fleet of SpaceShipTwos and WhiteKnightTwos. Overall, this project has directly or indirectly employed more than one thousand people in the United States since its inception, with the majority of those people holding high skill, high wage positions.

As we prepare to enter routine commercial service, demand has been extremely encouraging. Virgin Galactic has accepted $70 million in paid deposits on spaceflights, with $107 million in commitments. The financials are important, but so is a different measurement: we have accepted deposits from more than 535 people. This is more than the number of astronauts who have ever been put in space by NASA, Russia, and China combined. We anticipate flying that many people within our first year or two of commercial service.

Virgin Galactic's current and future revenue is almost entirely derived from private individuals and organizations. Our future astronauts have already paid us between $20,000 and $200,000 (the full ticket price) for their future tickets to space. They come from a wide range of backgrounds and nationalities, but are united in their desire to have the unique experience of floating in weightlessness and looking down on planet Earth from above. These future astronauts are aware that they are pioneers of a new era of exploration, and are excited to play a critical role in maturing this industry as early adopters.

While we are pleased that our service has found such a strong reception with private individuals, we also know that our vehicles will be used for more than personal spaceflight. Indeed, our system is proving to be an extremely attractive platform for researchers and educators. Already, we have accepted deposits from several customers in these areas, including universities as well as research institutions, and from NASA itself as future users of SpaceShipTwo. We have signed a Memorandum of Understanding with the National Oceanic and Atmospheric Administration, who have expressed an interest in both SpaceShipTwo and WhiteKnightTwo as research vessels. With a spacious cabin, relatively gentle gravity loads, frequent flights, affordable pricing, and several minutes more high quality microgravity than researchers are accustomed to getting on successful research platforms like drop towers and parabolic flight aircraft— we offer an important tool to help innovators conduct significant science, advance technology, and educate and inspire the next generation. Ultimately, these research and educational flights are an important part of both our bottom line and our corporate citizenship to the world. We commend Congress and NASA for their work in creating programs like NASA's Flight

Opportunities Program, which is playing a critical role in ensuring that experiments are ready to fly as soon as the spaceships themselves are in service.

These different market areas, to say nothing of the real potential offered by further business segments, give us great confidence that our business plan is solid, and that there is great room for growth. We are adding future astronauts at an increasing rate as we clear each technical milestone in the project, and expect a dramatic uptick of sales associated with some of our major upcoming events, such as our first rocket-powered test flight, SpaceShipTwo's first trip into space, and Richard Branson's flight. We have great confidence in our ability to continue bringing new jobs and new revenue to the United States.

Although outside of the scope of this hearing, it is also worth noting that Virgin Galactic has just announced a new small satellite launch vehicle, which we call LauncherOne. As part of that announcement, we identified four future customers for that service, each of which is a privately funded, entrepreneurial American business. In the words of our founder, "LauncherOne is bringing the price of satellite launch into the realm of affordability for innovators everywhere, from start-ups and schools to established companies and national space agencies. It will be a critical new tool for the global research community, enabling us all to learn about our home planet more quickly and affordably."

LauncherOne is still a few years away from its maiden flight, but SpaceShipTwo gets closer to commercial service with each passing day. As we prepare for that historic milestone, staff at both Virgin Galactic and Scaled Composites have been interacting with the FAA, and in particular the Office of Commercial Space Transportation (FAA/AST), for years. Congress has charged FAA/AST to both "ensure protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch or reentry activities, and to encourage, facilitate, and promote U.S. commercial space transportation," and Dr. Nield and his team are living up to both parts of that charge.

Our own safety team includes a number of experts with invaluable experience in safely operating space vehicles gained through time spent with NASA, the Air Force, and other pioneers of the US space industry. This includes our Vice President of Operations, Mike Moses, who served as the Launch Integration Manager for the Space Shuttle until that program's recent retirement, and our Vice President of Safety, Major Jon Turnipseed, formerly of NASA, the US Air Force, and Rockwell International, among other illustrious organizations. Mike, Jon, and many other members of our highly skilled and professional team interact with FAA/AST on a frequent and regular basis, allowing for frank, two-way exchanges of information.

Additionally, our contractors at Scaled Composites have been working with FAA/AST for many years, first in the context of the SpaceShipOne flights, and now in the context of SpaceShipTwo's Experimental Permit, which was recently granted. Beyond those meetings, there is a further set of interactions between FAA/AST and our spaceports—both the Mojave Air and Spaceport, where we are testing our vehicles, and Spaceport America, from which we will begin our commercial operations.

With all of those parallel conversations, there is a significant amount of information travelling back and forth between our project team and the FAA. I would like to note that it has been very useful to have FAA/AST serve as a single point of contact for our permits and licenses. Our system is relatively unique in combining elements of aviation and space exploration, thanks to our use of the WhiteKnightTwo. Similarly, while we fully anticipate remaining in close contact with the local FAA offices relevant to our centers of operations, it is most beneficial to have those discussions in the context of a broader relationship with FAA/AST.

Over the past several years, we and our contractors have seen firsthand that the "learning period" created in 2004 and extended just recently is critical to both the commercial viability of businesses like ours and to the actual safety of the spacecraft themselves. At this point in time, with a wide variety of space vehicle designs being developed by various companies and only a small amount of operational experience, relative to more mature industries such as commercial aviation, it is particularly important that the technical experts be given the freedom to make full use of their unique knowledge of each specific system in order to achieve a very high level of safety. As stated previously, this was the reason that the 2004 bill included a reasonable period of time in which the industry could grow and build a track record, and the recent extension preserves Congress's stated goals while updating the timeline to reflect the current state of the industry.

In 2004, Congress determined that eight years of real flight data was a reasonable amount of time for this learning period, a value which the industry supported then and continues to support now. However, with companies such as ours electing to come to market with more capable and customer-friendly systems that are still under development, (rather than inserting SpaceShipOne directly into commercial operation,) that flight data has not yet been generated. During the recent discussions about this learning period as part of the most recent FAA Authorization bill, the House of Representatives renewed that eight year period. The final bill renewed that learning period for the scope of the FAA Authorization itself, which runs until late 2015. We are pleased and appreciative that Congress took this action, and look forward to working with both bodies of the legislature on this issue in the next Congress.

Businesses like ours have a clear imperative to do all that we can to responsibly manage the risks associated with operating these vehicles. In our case, many of our staff will fly on our spaceship before any member of the paying public; and our founder, Sir Richard Branson, and members of his family will be our first paying customers. Indeed, before I became CEO of Virgin Galactic, my wife and I became some of the company's earliest customers, and we both eagerly await our flights to space. These are just some examples showing why we have the strongest possible incentives for safe operations.

Virgin Galactic and our partners will enthusiastically continue our dialog with FAA/AST over the coming years of the learning period. We are aware of the appropriate channels through which to deliver information about our technology and our concept of operations to the FAA's experts, and do not foresee that the recently enacted extension of the learning period would cause any difficulty in transferring the relevant information.

Moving forward, the regulatory uncertainty that has the biggest potential impact on our business is the concern that the learning period for our suborbital operations might be reduced or circumvented. The lessons of aviation and orbital flight are of great value to us but do not easily map to frequent reusable suborbital flight. While our team is hard at work to ensure that those lessons are being brought to bear in our own systems wherever appropriate, the regulations that govern a dramatically more mature industry like commercial aviation cannot simply be copied over to govern this brand new enterprise. To do so would eliminate our collective chance to learn, which would have a serious impact on the viability of this business and on the level of safety we can offer. Already, we are faced with the prospect that very shortly after we go into commercial suborbital operations, the rules and regulations may change, potentially disrupting our operations and our business. A stable regulatory environment – which is what we have now, thanks to the recent extension, even if we might wish that the extension had been longer – is the best way for the federal government to accelerate our start of commercial service and to preserve America's status as a world leader for suborbital spaceflight.

Although it is also likely outside of the scope of this hearing, I would be remiss if I did not mention the other regulatory uncertainty that is most significant for our business: export control. Virgin Galactic, like the rest of the aerospace industry, will benefit greatly from sensible policies and prudent application of those policies. Clearly, much of the original language regarding export of aerospace technologies was written at a time when no one foresaw businesses like ours. The time is approaching when updates to those lists could dramatically impact our business and the USA's position at the forefront of this new industry. We believe it is possible to modernize export control in a way that both streamlines business and improves national security, and we encourage the Congress to take the actions necessary to accomplish this goal.

In closing, on behalf of my colleagues at Virgin Galactic and at The Spaceship Company, I thank you for the opportunity to appear before you today. As we remember Sally Ride, an American hero and a pioneer who opened the space frontier to women, Virgin Galactic seeks to build on her legacy by opening the space frontier to all. I hope that this analysis of our business, the growth potential for the commercial suborbital launch vehicle industry, and the most critical regulatory issues impacting us and companies like ours has been useful for your deliberations. I look forward to answering any questions you might have.

Chairman PALAZZO. Thank you. I now recognize our next witness, Mr. Alexander, for five minutes to present his testimony.

STATEMENT OF MR. BRETTON ALEXANDER, DIRECTOR, BUSINESS DEVELOPMENT AND STRATEGY, BLUE ORIGIN

Mr. ALEXANDER. Thank you, Chairman Palazzo, Congresswoman Edwards, Members of the Subcommittee. Thank you for the opportunity to testify this afternoon on behalf of Blue Origin. We appreciate the Committee's longstanding support of the development of space and commercial human spaceflight.

Blue Origin was founded in 2000 by Jeff Bezos, the founder of Amazon.com, with the sole purpose of developing technologies and vehicles to enable human access to space at dramatically lower costs and increased reliability. The ultimate goal is to enable more people to fly in space to be able to do more things, whether for science, exploration, or simply adventure travel.

We believe in incremental development, beginning with suborbital vehicles before moving onto orbital systems. Our New Shepard suborbital system will take three or more astronauts to 100 kilometers altitude where they will experience several minutes of microgravity, be able to see the darkness of space, and view the curvature of the earth. Key elements of this suborbital architecture, a reusable vehicle with vertical takeoff, vertical landing rocket, separable Crew Capsule with a pusher escape system, are also key elements of our orbital architecture designed to take people to low-earth orbit and the International Space Station.

Let me now address the markets for suborbital spaceflight. First, we believe that people are the game-changing element for spaceflight. We can't tell you all the activities that people will do in space, but we are certain the number of people and activities will increase greatly as the cost comes down and safety improves.

Research and science is a valuable secondary market. We are poised to offer the research community flexible, repeated access to space on dramatically-accelerated timelines for a fraction of the cost. Research tools once limited to a few investigators will be within reach of a wide array of federal agencies, industry, and even college and high school students.

These suborbital systems have significant promise for STEM education for our Nation's youth, with routine flights, the ability for schools to tuck small, untended experiments and payloads along for the ride is within reach, giving hands-on space experience previously unimaginable.

Other markets for suborbital spaceflight are likely to be developed that we cannot yet image. Who would have thought that ten years ago there would be over 500,000 apps for something called a smart phone? The barries to entry to develop an app is minimal. There is no need to spent billions on developing the network or the phone itself. Similarly, scientists, school kids, and others can develop apps for suborbital spaceflight at little to no upfront cost compared to traditional spaceflight activities. The sky is truly the limit.

Let me now address the regulatory framework. Commercial spaceflight is in its infancy, and there is no one-size-fits-all approach to regulation. Each company is developing a different system. Blue has a vertical takeoff, vertical landing vehicle with a capsule that returns under parachute. Others have vehicles with wings and wheels. What is appropriate for one type of vehicle may not be appropriate for others.

The current question of how and when the FAA will regulate the safety of spaceflight participants is the greatest uncertainty affecting the development of this industry. I want to take this opportunity to thank you for the passage last year of an extension of the learning period to the full eight years from the date of the first paying passenger flight as per the original intent of the CSOA. While the final bill extended this only until October, 2015, we appreciate Congress's recognition that the learning period serves a valuable purpose and will work with you to extend the learning period to at least eight years or longer.

We believe the best path forward would be to continue the informed consent approach indefinitely, allowing individuals to make their own decisions on how best to manage their own safety and inherent challenges of spaceflight.

Regarding our interaction with the FAA and the development of regulations, there are two primary ways in which we interact with the FAA. The first is through the formal NPRM regulatory process, and the second is through our individual applications for permits and licenses and FAA oversight of our flight activity. We have found that on the whole both have worked well. The FAA has shown itself receptive to real world input as data is being gathered and flight activities continue.

We look forward to the FAA's planned monthly telecoms as an opportunity for dialogue between the FAA and industry, allowing for open and frank discussions about technical design and safety.

In conclusion, we believe suborbital spaceflight offers great promise and opportunity for the Nation's economy, scientific research, and STEM education. As private commercial developers, we are not looking just to government but are investing private funds to enable this bright future. NASA and other government agencies can capitalize on this private investment and take full advantage of these new capabilities.

Thank you for the opportunity to be here today, and I look forward to your questions.

[The prepared statement of Mr. Alexander follows:]

Statement of
Bretton Alexander
Director, Business Development and Strategy
Blue Origin, LLC

before the

Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
U.S. House of Representatives

August 1, 2012

Chairman Palazzo, Ranking Member Costello, and Members of the Committee, thank you for the opportunity to testify this morning on behalf of Blue Origin. We appreciate the Committee's long-standing support of the development of space.

About Blue Origin

Blue Origin was founded in 2000 with the sole purpose of developing technologies and vehicles to enable human access to space at dramatically lower cost and increased reliability. The ultimate goal is to enable more people to fly in space to be able to do more things, whether for science, exploration, or simply making space travel a more *personal* and accessible endeavor, sometimes referred to as tourism.

Blue Origin was founded by Jeff Bezos, the founder of Amazon.com, and has a design, development and manufacturing facility in Kent, Washington, a suburb of Seattle, and a launch and test site in west Texas.

To increase the number of people that can fly into space, we believe we need to dramatically improve safety while also lowering the cost. To do so, we are developing reusable launch vehicles that take off vertically and return to the launch area to conduct a powered vertical landing.

We believe in incremental development, beginning with suborbital vehicles before moving on to orbital systems. In 2006 and 2007, we flew a subscale demonstrator which demonstrated vertical takeoff and landing of a multi-engine vehicle. Last year, we flew a larger experimental vehicle which was developed to demonstrate the full suborbital mission profile. We continue on our development of the *New Shepard* suborbital system, which will take three or more astronauts to 100 kilometers altitude where they will experience several minutes of microgravity, be able to see the darkness of space, and view the curvature of the Earth.

During a *New Shepard* flight, our Crew Capsule will separate from the Propulsion Module for flight through apogee and descent, landing by parachute, while the Propulsion Module returns for a powered vertical landing. The Crew Capsule is equipped with a pusher escape system, which can be activated at any time to accelerate the capsule away from the booster in event of an emergency.

Key elements of our suborbital *New Shepard* system – a reusable vertical takeoff, vertical landing rocket, and a separable Crew Capsule with a pusher escape system – are also key elements of our orbital architecture, which is being designed to enable human access to low Earth orbit and the International Space Station.

Suborbital Markets

Blue Origin is focused on enabling human access to space. We believe that people are the game-changing element for spaceflight. We can't tell you all the activities that people will do in space, but we are certain they will find many useful human endeavors as the cost comes down and safety improves.

One human spaceflight market that is directly relevant to NASA is astronaut training. Suborbital vehicles will offer the ability for astronauts to train in many aspects of the spaceflight environment, including the high G's of launch, the weightlessness of microgravity, and landing and recovery procedures. NASA routinely flies astronauts on dozens of parabolic flights for training and we believe suborbital flights will be able to provide an integrated, realistic experience that will contribute significantly to astronaut training.

Research and science is a valuable secondary market. In addition to tourism, these vehicles open the gates for realizing a vast array of scientific and technical goals, from high altitude observations of the sun and the universe around us to the effects of microgravity in materials, fluids, and biology.

Suborbital flights are nothing new; sounding rockets have been flying for decades. What is changing today is that we are poised to offer the research community flexible, repeated access to space on dramatically accelerated timelines for a fraction of the cost.

The reusable launch vehicles, or "RLVs", Blue Origin is developing offer new and enhanced capabilities, and with it we expect new researchers and other users.

- These vehicles are designed for much lower 'g' loads than a sounding rocket, as the *New Shepard* vehicle's primary mission is human space flight. As a result, the *New Shepard* vehicle can accomodate much more delicate experiments than could be undertaken on a sounding rocket.
- We plan for flights at more frequent intervals, allowing researchers to collect repeated data, and thereby study trends and changes over time.
- We expect the size and reusability of the *New Shepard* vehicle will allow much lower costs than sounding rockets, widening the number and type of researcher who can consider space research.
- Research can be tended by an on-board human technician. Previously, researchers had to create an entirely autonomous experiment, and if the slightest thing went wrong it could amount to a complete loss of the experiment. Tended experiments free researchers from being required to automate everything, and allow for quick trouble shooting while the experiment is in progress.
- Finally, New Shepard will fly to altitudes that are not well serviced by sounding rockets. Scientists sometimes joke about the area in the atmosphere that they call the "Ignorosphere", often ignored not because of its importance but simply because of the difficulty collecting data

from it. The *New Shepard* RLV will facilitate more frequent study of this region of the atmosphere.

As a result, we are entering a new era in space research. Research tools once limited to a few investigators will be within reach of a wide array of federal agencies, industry R&D programs, and even college and high school students. The RLV will also add a few new tools to the tool chest, by providing capabilities that simply are not currently available.

We have already begun preparations to fly three research experiments on our early test launches, allowing researchers from Colorado, Indiana, Florida, Missouri, Louisiana and Germany to study fluid dynamics and astrophysics.

Suborbital activities also have significant promise for science, technology, engineering and mathematics (STEM) education for our nation's youth. With routine flights, the ability for schools to tuck small untended experiments and payloads along for the ride is within reach. One can even envision standard payload kits schools can buy for spaceflight clubs much the way school robotics teams buy standard robot kits and compete against each other.

It's "hands on" and it's about science, technology, engineering and math. But it's the 'magic' of spaceflight that is the draw for kids. Some of you may remember the Shuttle's "Getaway Special" and "Hitchhiker" programs that flew dozens of student experiments in the 1980's and 1990's. Imagine now if we could open up these doors to hundreds of classrooms around the country, as well as extracurricular groups. That would be a powerful catalyst for STEM engagement.

Other markets for suborbital spaceflight are likely to be developed that we cannot yet imagine. Who would have thought 10 years ago that there would be over 500,000 apps for something called a smart phone? The barrier to entry to develop an app is minimal, requiring nothing more than one person with coding skills. No need to spend billions on developing a cellular network or the iPhone platform. Similarly, scientists, school kids, and others can develop "apps" for suborbital spaceflight at little-to-no up-front cost compared to traditional spaceflight. The sky is truly the limit.

Regulatory Interactions

Commercial spaceflight is in its infancy and there is no "one size fits all" approach to regulation at this time. Each company is developing a different system, some of which are radically different from each other and traditional space systems. Blue has a vertical takeoff, vertical landing vehicle with a capsule that returns under parachute. Others have vehicles with wings and wheels that drop from an airplane or takeoff horizontally from a runway. What is appropriate for one type of vehicle may not be appropriate for others. In the development of regulations, industry and the FAA need to have a dialogue on the validity of differing regulatory approaches on the differing technical approaches. Without this, we will be left with an approach that could do considerable harm to the emergence of this new industry.

The 2004 Commercial Space Launch Amendments Act (CSLAA) established a learning period in which commercial space flights could take place based on the informed consent of those flying, with the goal of eight years of flight experience before even considering a more top-down regulatory regime. We thank the House of Representatives for the passage last year of an extension of this learning period to last a full eight years from the date of the first paying passenger flight, as per the original intent of the CSLAA. While the final bill extended this period only until October 2015, we appreciate the Congress's recognition that the learning period serves a valuable purpose. We will work with the Congress to extend the learning period to at least eight years or longer from the date of the first paying passenger flight, as per the original intent of the CSLAA.

The best path forward, however, would be to continue the current path, in which individual passenger astronauts are allowed to make their own decisions on how best to manage their own safety in the inherent challenges of spaceflight. We believe that the informed-consent approach to passenger safety should be extended indefinitely, at least until spaceflight is sufficiently routine that it merits the commitment of regulatory resources and we can be confident that the top-down regulatory approach will prove safer than allowing informed individuals to make their own decisions. The current uncertainty surrounding how and when the FAA will regulate the safety of spaceflight participants is the greatest regulatory uncertainty affecting the development of this industry.

At the present, there are two primary ways in which we as a spaceflight developer interact with the Federal Aviation Administration (FAA) on the development of regulations: The first is through the formal process of promulgating regulations. The second is through our individual applications for experimental permits and licenses and FAA oversight of flight activity. We have found that, on the whole, both work well. In the permitting and licensing process, FAA closely scrutinizes applications and simultaneously has shown itself receptive to input on how to best protect public safety and foster a commercial space industry. As the industry matures and the number of flights increases, real world data is being gathered that can be used to refine the FAA's methodologies to be more realistic while continuing to protect the public.

We look forward to the FAA's planned experiment of monthly telecons with people interested in the space launch regulatory process, to create a more-informed dialogue on the role of regulation in this human endeavor. We hope that this will be an opportunity for dialogue between the FAA and industry that precedes the formal Notice of Proposed Rulemaking (NPRM) process, allowing for open and frank discussions about technical designs and safety.

Conclusion

Suborbital spaceflight offers great promise and opportunity for the nation's economy, scientific research, and STEM education. As private commercial developers, we are not looking just to government, but are investing private funds to enable this bright future. NASA and other government agencies should capitalize on this private investment and take full advantage of these new capabilities.

Blue Origin is working to develop a new market for human spaceflight. Like any new market, no one really knows the size and breadth of this new marketplace. We are confident that new human access to space will be self-expanding, and look forward to serving this new market.

Thank you for the opportunity to be here today and I look forward to your questions.

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Chairman PALAZZO. Thank you. I now recognize our next witness, Mr. Nelson, for five minutes to present his testimony.

STATEMENT OF MR. ANDREW NELSON, CHIEF OPERATING OFFICER, XCOR AEROSPACE

Mr. NELSON. Thank you, Chairman Palazzo, Congresswoman Edwards, and Members of the Subcommittee. Thank you for this opportunity to speak about the reusable suborbital markets and how this industry can be a catalyst for new jobs and economic growth given an efficient government and appropriate regulatory stance. It is my belief that suborbital reusable launch vehicles are critical to America's future innovation-led economy, the education of our children, and our national security because reusability is the transformative step needed for affordable and responsive space access, which is an enabler of these noble objectives.

XCOR's long-term vision of the future space industry starts with the premise that there are robust opportunities for self-sustaining, profitable space businesses in low-earth orbit and near-earth resource exploration. But numerous challenges must be solved to realize this vision, and failures will occur along the way.

But free of regulatory uncertainty and excessive constraints, government can enable industry to once again embrace the risk-taking spirit that built our country. The potential payoff is similar to the railroads, the air transportation system, or the internet. In other words, the next great American-led trillion dollar enterprise, the commercial space enterprise.

The first technical hurdles to overcome are fully reusable propulsion systems and thermal protection systems, and we believe suborbital RLVs are the ideal proving ground for these technologies. This has been XCOR's focus for over 12 years, and it will continue.

XCOR was founded by individuals who dreamt of going to space and pursue their dreams, giving up lucrative jobs in a lot nicer places than Mojave. In 1999, after they were laid off from an entrepreneur rocket adventure, they chose to follow the ethos that Henry David Thoreau expressed when he said, "Go confidently in the direction of your dreams and live the life you have imagined." And in so doing have arguably created one of the most innovative and determined aerospace companies the U.S. has seen in the last 50 years.

We XCORians have pursued the American dream without benefit of great personal wealth but with significant determination and character, and we are now building reusable rocket engines for ourselves and others like United Launch Alliance, and we are building the Lynx for reusable suborbital vehicle that is scheduled to start flight tests in the new year.

In two years XCOR and our partners have sold over 200 flights on the Lynx, and 50 of these sales have come in the last three months, demonstrating increasing sales velocity as we near first flight and the incumbent network effects you see in most markets. Our typical buyers have net investible assets of 1 to $2 million or more but many less wealthy enthusiasts are buying also, and many people are buying multiple flights. Industry and the research community are also buyers, and we project these markets to eventually surpass the personal spaceflight markets.

For over ten years XCOR has played a leading role within the industry by actively collaborating with the FAA. For example, we helped create the definition of suborbital rocket, was instrumental in crafting and leading the campaign to pass the first Commercial Space Launch Amendments Act in 2004, and XCOR has direct and productive contacts with FAA/AST staff in Southern California, Florida, Washington, DC, and elsewhere. We believe that Congress should enable the FAA to move more staff into the field where operations are occurring so we can facilitate the improvement in safety.

In earlier testimony you heard others speak of the eight-year learning period, and we, too, support the restoration of full learning period starting with the first commercial suborbital human spaceflight for revenue. At the same time XCOR strongly supports a new FAA initiative to use its existing authority to engage with industry on safety concerns, experiences, and best practices.

We are greatly concerned with the potential expiration of learning period because this could lead to unfettered regulation based on paper analysis and speculation rather than actual flight data and experience. Recent statements by at least one senior elected official have suggested the current licensing regime may be repealed in the final months of this Congress, and any sudden such changes or reliance on speculative regulations would have a chilling effect on the industry and the thousands of jobs we represent collectively and the jobs we plan on creating in the near future.

So such a change would also cripple our chances to be competitive internationally. The industry and FAA have been successful in persuading foreign governments to consider adopting the U.S. system of regulation, licensing, and informed consent. Suddenly changing from this environment to a speculator regulatory regime will cause countries to forego the adoption of the U.S. system and create local rules, and local rules can create an uneven playing field for us in those foreign markets, impacting jobs in various states represented by the Members of the Committee.

Another impediment to export markets is the U.S.-designed and built manned suborbital RLVs is the ITAR. Their strong international interests and demonstrated demand for suborbital RLVs, however, ITAR causes inherent uncertainty with customers which inhibit U.S. job creation.

We encourage the Subcommittee to take a leadership role to explicitly identify manner suborbital RLVs as a Commerce Control List item and open up the free world to U.S. commercial space products, services, and competitors.

I thank the Committee for the opportunity to present these thoughts for the record, and I look forward to your questions.

[The prepared statement of Mr. Nelson follows:]

Testimony of Andrew Nelson
Chief Operating Officer & Vice President of Business Development
XCOR Aerospace, Inc.

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Before the Committee on Science, Space, and Technology
Subcommittee on Space and Aeronautics
United States House of Representatives

August 1, 2012

Opening Comments

Chairman Palazzo, Ranking Member Costello, and members of the Subcommittee, thank you for the opportunity to meet with you about the reusable suborbital vehicle marketplace. Although small today, this market's successful emergence is critical to America's future economic strength, global scientific leadership, educational supremacy and our national security. It is therefore timely that Congress look at the impact of regulatory uncertainty on these markets, how industry interacts with the FAA, and how this industry contributes to job creation, the health of the aerospace industrial base in the US, and our country's international space competitiveness against strong head winds caused by the current export licensing regime.

The Vision That Drives Us

But before I address these specific questions, I would like to paint a picture for you of the future of space access and development that we at XCOR envision. Our vision starts with the premise of "human settlement" and economic prosperity from space-based businesses and ventures that may drive prosperity for generations. In the not too distant future, we envision humans creating sustainable businesses in space, settling other bodies in our solar system, and in the distant future, even perhaps going beyond our solar system.

A great number of technical, legal, business and economic challenges must be solved before this happens, but the first challenge that must be solved has to be lower cost, safer, and more regular and dependable access to space. But in order to achieve this, industry and government customers must be able and willing to take the risks incumbent with any ground breaking, hard and difficult task, free of regulatory uncertainty and excessive constraints on the fundamental risk taking spirit that built our great country.

As with any mode of transport; rail, air, sea, or even roads, this means full reusability of vehicles with negligible servicing between operation, and for space, this means fully reusable propulsion systems, robust thermal protection systems and safe reentry mechanisms that support near-daily operations. This has been our research and development focus at XCOR for over 12 years, and will remain our focus for another 12 years, and probably more.

In addition to being a viable commercial market in its own right, the suborbital RLV industry is also important today because it is the proving ground for safer, fully reusable, and much more affordable orbital access technologies, concepts, and practices that we believe will create the next multi-trillion dollar global enterprise, the Commercial Space Enterprise, much like the Internet and the global communications networks we have today.

XCOR Introduction

XCOR Aerospace was founded by four individuals who had dreamed of going to space for much of their entire lives and had followed their vision into professional careers in the aerospace industry, sometimes giving up much more lucrative opportunities in other industries. They pursued their American Dream without the benefit of great personal wealth, but with determination, their knowledge, and their wits. And in 1999 when the four were laid off from a previous entrepreneurial rocket company, they did not give up. They chose to follow the ethos that Henry David Thoreau expressed when he said, "Go confidently in the direction of your dreams. Live the life you have imagined." And in so doing, have arguably created one of the most innovative and determined aerospace companies the US has seen in the last fifty years, XCOR Aerospace.

Now on the verge of commencing test flights of the Lynx suborbital reusable launch vehicle, XCOR has spent the past 12 years building a business from scratch, boot strapping themselves in the early days with credit cards, savings and the goodwill of friends and family, with not a billionaire in sight. The company has since designed, built and tested fourteen different rocket engine designs, and has several more in various stages of development. The company has a string of firsts and records that would be the envy of any aerospace company 100 times our size, including:

- In 2001, the first commercially designed, developed and flown rocket-powered vehicle in the world, the XCOR EZ Rocket;
- In 2003-4, proposed, and with partners and supporters in Congress and the Administration, won passage of the Commercial Space Launch Amendments Act of 2004, thereby establishing the regulatory basis of the new Commercial Space Flight Industry;
- In 2005, we delivered the first US Mail by rocket powered aircraft and in the same flight, set the recognized world record for rocket powered point to point flight (it is also the *shortest*, long distance flight in the Fédération Aéronautique Internationale, FAI, record books!)
- In 2007, designed, built and tested the first new liquid oxygen / methane engine in the US in over thirty years;

- In 2008, developed the first piston pump fed rocket aircraft ever built and flown in the world, the XCOR X-Racer;
- In 2008, the first time a rocket powered aircraft flew seven times in one day, and carried eight people in the same day;
- By 2009, had flown 66 manned rocket flights, which at the time was over 50% of the manned rocket flights in the 21st century; and
- In 2010, demonstrated one of the world's first flight-weight liquid hydrogen rocket piston pumps.

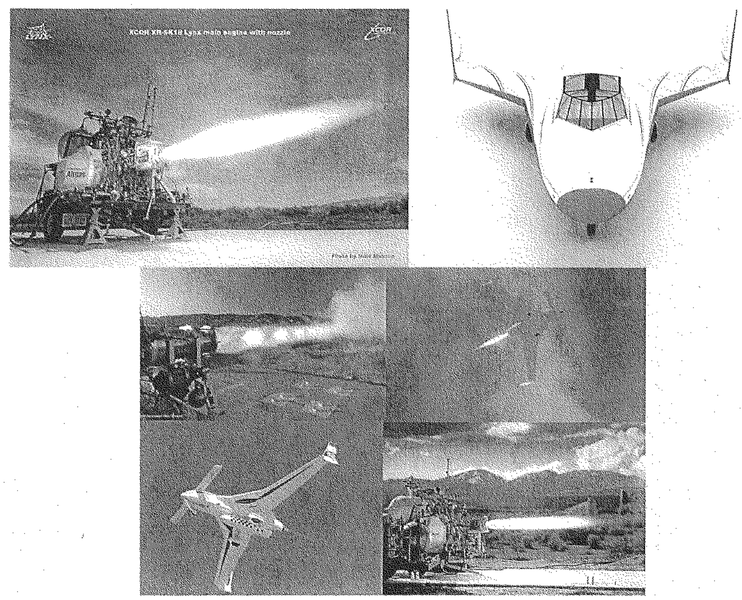
The XCOR Product Lines:

XCOR has two primary product lines: fully reusable rocket engines and related hardware, and suborbital RLV launch services and sales (wet leasing) using those engines. In the future, we expect to develop a fully reusable orbital system and place that vehicle into service at US locations.

We sell non-toxic, liquid rocket engines and related design and testing services to US prime contractors, the government and second tier suppliers.

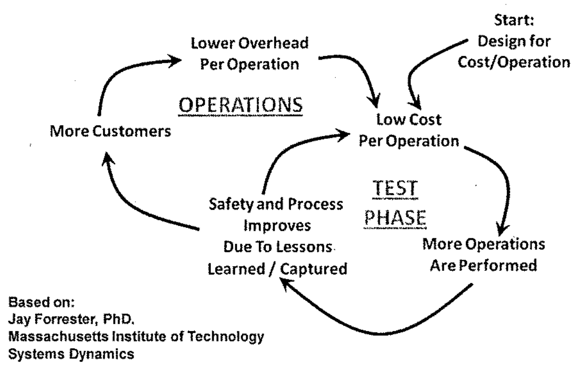
We intend to start operating Lynx vehicles commercially from Mojave, CA and other sites for ourselves, but the longer term plan is to "wet lease" Lynx RLVs to private and government customers in the US and, if allowed to export, around the world. This latter opportunity is key: if law and policy allow us, XCOR and our friendly competitors can return the US to global Space industry preeminence with a dominant position in technology and innovative approaches to customer needs, while helping to rebuild the weakened aerospace supplier base that threatens our national security space enterprise.

XCOR and our commercial sales partners have already sold over 200 flights (seats) for Lynx vehicles and announced wet lease contracts for the establishment of future independent "spacelines", thereby proving the market demand for flights and vehicles. [As in the early days of flight, Boeing became the airframe supplier, and United Airlines became the airline, we see the suborbital RLV market evolving along similar lines.]



What makes XCOR's rocket engines and vehicles unique are their full reusability, non-toxic propellants, environmentally-friendlier exhaust composition, exceedingly low cost of operation, and "designed for safety" philosophy.

To enhance safety, we believe in the Systems Dynamics model of holistic positive feedback originated by the noted MIT professor, Dr. Jay Forrester. As we design-in lower operational costs of our engines and Lynx vehicles, the more we can afford to test the system, thereby allowing us to improve the overall safety of the engine or vehicle at a quicker pace than those who have more costly and/or less operable systems. As systems, processes and safety improves, this should draw additional customers, which improves our unit costs, and thereby allows us to lower prices when the market dictates or we choose to do so. The improved safety and lower prices drive additional demand, and the virtuous cycle reinforces itself. This philosophy is shown in the simple figure below.



Market Success and Market Growth:

To date, XCOR has seen significant market success and we see significant market growth in front of the industry as suborbital RLVs come on line.

The potential emerging markets for suborbital RLVs that XCOR Aerospace is targeting include:

- Vehicle sales and wet leasing (the future "spacelines," "personal and fractional ownership models," government, and "utility operators"),
- Launch services (personal space flight, nanosatellite launch, training, research, education, test / qualification, and others)
- Engine and related equipment sales and service.

Already, in the last 24 months, XCOR and our sales partners have recorded over 200 reservations for Lynx flights. In the last 12 months, there were over 150 sold, with the last three months seeing commitments signed for over 50 flights. I present these nested numbers to demonstrate to the committee that the velocity of sales is increasing as we get closer to commercial flight. We attribute this increased sales velocity to expected and easily estimated "network effects." One of these sales is a firm contract for tens of flights from a single purchaser as part of their commercial business strategy rewarding their customers, employees and partners. This "promotional or media" related sale is 100% of the projected annual market of a recent overly-conservative market demand forecast. Based on our sales to date, XCOR sees a demographic of personal space flight buyers that is quite broad; those with net investable assets of $1-2 Million and above, but many sales to enthusiasts well below that level of wealth. We are also seeing multiple flight purchases on our vehicles and from customers who are buying flights on our competitor's platforms. This bodes well for the future of our industry.

The personal spaceflight demand is separate and distinct from the scientific and industrial uses of Lynx and other suborbital RLVs. The unique benefits that suborbital RLVs offer the scientific community for research, and the industrial base for in-space equipment testing and certification services, are frequent access to space, significantly lower cost of experiment development and vehicle integration, almost instantaneous access to experiments upon completion, an ability to do multiple space flights per day, enhanced readiness levels for launch, and more potential launch sites than today.

XCOR projects these markets to eventually surpass the personal spaceflight markets in four to five years as the research, educational and industrial communities learn of the unique advantages of these platforms versus today's existing options for access to the upper atmosphere and micro-gravity (primarily, sounding rockets and parabolic aircraft flights) and make the appropriate program investments over time.

XCOR's Record of Active Engagement on Safety, Regulation, and Policy

XCOR has played a leading role within industry for over a decade by actively engaging with the FAA's Office of Commercial Space Transportation to work through many legal and regulatory issues facing reusable launch vehicles and commercial human spaceflight. For example:

- XCOR personnel helped FAA create a definition of "suborbital rocket" that allows airplane-like spaceships to fly under commercial space launch licensing, rather than commercial aviation certification rules.
- XCOR filed the first "substantially complete" license application for a piloted reusable launch vehicle, largely as a regulatory pathfinder.
- XCOR's Chief Executive Officer, Jeff Greason (and other staff) have actively participated for many years as a Member of the FAA's Commercial Space Transportation Advisory Committee, and as Co-Chair and long-time participant in its Reusable Launch Vehicle Working Group. Furthermore, XCOR has actively responded or otherwise participated in several draft rulemakings and guidance development efforts, as well as industry standards efforts.
- Finally, Greason has testified twice before Congressional committees, and led or participated in many briefings to Senators, Representatives, Executive Branch officials, and their respective staff on broad industry initiatives to promote ever-increasing levels of safety and related policy and regulatory issues.

With regards to specific regulatory issues, XCOR has a full time Director of Federal Relations who also serves as XCOR's safety officer and maintains direct contact with FAA staff in Southern California and Washington, D.C., about XCOR's vehicle design, development, and test plans. XCOR is very appreciative of AST Associate Administrator Dr. George Nield's efforts to move AST staff out into the field where they can directly observe and even participate in industry development and test efforts. We would request that Congress provide AST with greater funding flexibility and encouragement to move more staff out of Washington and into the field.

Evolution of Industry Safety

As XCOR officials have stated consistently since the earliest days of consideration of the CSLAA, reusable launch vehicles – particularly those which are piloted and/or designed to carry spaceflight participants into space – are a new class of transportation vehicle, neither aircraft nor expendable launch vehicles, and they should not be regulated the same way as these century- or half-century-old technologies. Commercial human spaceflight in particular is a new industry, and neither industry nor government knows the absolutely safest way to design, build, and test these systems. Except of course not to try at all.

Our challenge is to learn what works and what doesn't work as quickly as possible, which ultimately requires flying hundreds and even thousands of flights. This in term implies flying for revenue, while fully disclosing the risks involved to our customers. That was the purpose of Congress' creation of a "learning period" in the original CSLAA, during which limited regulation of participant safety based on actual events was allowed, but not speculative regulation: it would allow both industry and, frankly, the government, to learn together how to best achieve continuously-improving safety as the industry grows and innovates.

Of course, in 2004 many people believed that commercial flights might start the very next year, and therefore an eight year restriction would grant us eight years of learning. This did not happen, primarily because industry did not try to rush an early capability into commercial operation and we've seen an unprecedented economic slowdown that has impacted many companies's ability to maintain investor in flows to support more rapid development. Given that the learning period would have expired in December of this year, we applaud Congress' extension of that for the duration of the FAA reauthorization bill enacted earlier this year. In particular we appreciate this Committee's forbearance to allow that extension to become law as part of another Committee's legislation.

That said, next year we will come back to Congress to seek restoration of the entire eight-year learning period. Ideally, the eight year clock should not begin with the passage of legislation, but with the first licensed flight of a spaceflight participant for revenue, so that all parties gain from a full eight years of data-gathering before unfettered regulation may begin.

At the same time, XCOR has strongly advocated that AST use its existing authority to engage with industry – and vice versa – to discuss regulatory approaches, technical issues, and other safety concerns now. While no licensed or permitted flights have occurred that could lead to a formal rulemaking, there was never any statutory or policy limitation on discussing safety, indeed the CSLAA encouraged such efforts. It simply restricted AST's ability to promulgate rules in the absence of data, and even then the so-called "moratorium" was only for eight years.

XCOR is therefore enthusiastic about AST's recent initiative, as reported in *Space News* on July 23rd, to begin actively discussing safety issues and potential "guidance" that AST might promulgate today. Indeed, an XCOR consultant was largely responsible for securing greater policy flexibility within FAA to allow AST to pursue these discussions. XCOR staff have already met with Pam Melroy who is leading the effort for the FAA/AST and followed up on those conversations to demonstrate our commitment to supporting her efforts.

Regulatory Uncertainties and Their Potential Impact on the Industry

When XCOR was formed in 1999, the greatest risk we faced was that a commercial spaceflight vehicle with wings might be regulated as a commercial airplane, using the 75+ years of regulations that FAA and its predecessor agencies have built up to police commercial aviation. Congress solved that with passage of the CSLAA in 2004. Most recently, our concern was that the expiration of the regulatory learning period for human spaceflight could lead to unfettered regulation based on analysis and speculation, rather than actual flight data, or on reliance on inappropriate aircraft technical standards. Congress has partially addressed our concern by extending the learning period until October 1st of 2015, but this remains of great concern to industry and XCOR.

Recent statements by at least one elected official have suggested that even this short extension may be diluted in the final months of this Congress, a very negative outcome that we would request this Committee to oppose on a bipartisan basis. Any sudden changes or inconsistency in rules and regulations would have a chilling effect on the industry, and the thousands of jobs we represent, and the even more jobs we plan on creating in the next few years.

It is important for Congress to realize that the industry and FAA have been active in discussions with other regulatory agencies around the world, and we have been successful in persuading them to commence the process of adopt similar regulatory regimes to our own (the "licensing/informed consent" regime). This has resulted in a critical market opportunity for the companies at this table and others, pending export licensing, to potentially operate U.S.-designed and built suborbital vehicles at many locations around the world. Suddenly changing the US regulatory regime from a "licensing / informed consent regime" to a "certification" regime will cause other countries to stop their adoption of the "US System" and encourage the creation of local space vehicle certification regimes. Such activities would create the real potential of an uneven playing field for US competitors in foreign markets due to home grown regulatory and certification standards and also slow down the market introduction of US products and services in those foreign markets, thereby hurting high tech / high paying job creation at home.

The industry's and FAA's regulatory evangelism means that the same designs and operating practices that we refine and mature here in the U.S. will be able to satisfy other nations' regulatory requirements, gaining us not only revenue but additional flight experience and accelerated learning towards even greater safety, not to mention the job creation from the export opportunities.

Another impact (or probable unintended consequence) of not extending the learning period to the original eight year period, or eliminating the learning period in its entirety, is the real potential to actually decrease safety levels or at least inhibit continual safety improvement that is the characteristic of the *licensing* environment currently in place. This is seen when an item is "certified" there is great hesitancy to change it. In the aviation industry, that is justified, since the standards are based on over 100 years of experience and billions of hours of flight time.

In the fledgling commercial space industry, this is the exact opposite of what a responsible safety officer would desire. The rapid insertion of safety enhancements into rapidly maturing systems and processes is vastly preferential to the cautious "don't change it" approach characteristic of a certification regime. This latter approach would be especially counterproductive since spaceflight certification standards written in 2012 or even 2015 would be based on very limited flight experience, or worse still on human supposition about the meaning of this limited experience. At the same time, they would likely increase costs to manufacturers and operators, and therefore customers, all without any real increase in safety.

Another critical concern is that the FAA may be persuaded to rely on a specific government customer's unique requirements as the basis for safety standards. NASA's unique system requirements should not be turned into FAA regulatory certification requirements, now or in the future. NASA's "internal standards" are typically uniquely tailored to NASA's unique needs or culture, and therefore are inappropriate for commercial operations. NASA, as a customer, has the right and the obligation to set their own requirements to meet their mission needs, and has the right and the ability to waive those standards when appropriate. However, if a NASA standard is automatically adopted as a FAA regulation, then the commercial industry is stuck with the NASA customer requirement as a de facto standard. And it is perceived that the FAA and industry cannot "waive it" without extensive and costly deliberations. NASA should not be in the business of establishing or recommending standards to the FAA for commercial space flight.

A consensus industry-led body should be tasked with such efforts, much like the industry led body, RTCA, is tasked with developing technical standards for the aviation community, that then get promulgated into FAA airplane certification rules. As with the RTCA, government customer input can be welcomed and even actively sought when eventually establishing commercial space standards, but the government customer should not be the originator of draft standards nor set these requirements by fiat.

Export Licensing for Manned Winged Suborbital RLVs

A primary issue that is inhibiting a more robust international marketplace for US-designed and built manned winged suborbital RLVs is the export licensing regime. Currently, there is strong interest, and demonstrated demand, for these vehicles; however, such demand is severely dampened by the inherent uncertainty caused by the export licensing regime for these vehicles. Recent rulings have defined any manned suborbital reusable vehicle that crosses the 100 kilometers (62 miles) Karman line (an imaginary line that is the unofficial boundary of space and the atmosphere) as being a "satellite" and hence on the US Munitions List (USML). This was, to our belief, never the intent of the original Thurman Act that placed unmanned satellites on the USML but explicitly excluded the only manned rocket craft of the day, the Space Shuttle, and the manned International Space Station.

Significant market opportunity, US technical leadership, and the related US-based manufacturing and operational jobs that will come with such sales, is not being capitalized upon due to the US export licensing regime. XCOR, nor the industry is asking for unfettered permission to sell winged, manned suborbital vehicles and systems to just anyone, but certainly, areas of the world that are allies to the United States should be considered "open for business." We encourage this subcommittee to take the leadership to explicitly identify "manned suborbital reusable launch vehicles" as a Commerce Control List (CCL) item, and open up the free world to US products, service and competitors.

Summary

I thank the committee for the opportunity to present these thoughts on the record for your consideration when considering future policies for our emerging industry.

The reusable suborbital launch vehicle industry is the proving ground, the initial step, to the necessary and required future systems and technologies that will enable a future Trillion Dollar Commercial Space Enterprise.

By serving as the pathfinders for fully reusable systems, the suborbital RLVs are also viable economic and innovation engines in their own right, with the promise of: creating tens of thousands of jobs over the next five to ten years; inspiring a new generation students to pursue the sciences, mathematics, engineering and technology professions; and reinvigorating the moribund tier two and tier three aerospace industrial base that threatens to impact our national security space apparatus.

An inconsistent and/or "certification" based regulatory environment at this stage of the industry's maturity would have a chilling effect on systems implementation, commencement of service, job creation, and the promulgation of a the "US System" of space-licensing that will promote the expansion of US exports and influence around the globe. We encourage Congress to pass the originally established "eight year learning period" after the first commercial suborbital RLV flight.

The export licensing regime currently in place is being interpreted aggressively by officials resulting in manned suborbital RLVs being placed on the USML and inhibiting the growth of these markets in countries friendly to the US, and negatively impacting the job market at home. We encourage the subcommittee to recommend legislation to move manned Suborbital RLVs to the CCL and enable US companies to meet pent up demand for these US designed and manufactured products and related services.

Chairman PALAZZO. Thank you. I now recognize our final witness, Dr. McCandliss, for five minutes to present his testimony.

STATEMENT OF DR. STEPHAN R. MCCANDLISS, RESEARCH PROFESSOR, THE JOHNS HOPKINS UNIVERSITY

Dr. MCCANDLISS. Mr. Chairman, Congresswoman Edwards, and Members of the Committee, thank you for inviting me to answer your questions on suborbital research investigations regarding decision metrics, infrastructure, and capability requirements, student involvement, and future directions for suborbital research.

Regarding the questions on decision metrics, I would like to point out that scientific peer review panels are for NASA are assembled by each of the four science divisions; geospace, heliophysics, planetary, and astrophysics to conduct research from suborbital platforms.

Panels look for some way cool advancement of their scientific capabilities that is enabled by some new technology, and they seek to build a technically-adept workforce. Relevance to overall NASA strategic plan is a requirement. For heliophysics investigation that might be a new high resolution imager or for astrophysics it might be a device that can image planets about nearby stars.

My own work, we are building a new high-efficiency far ultraviolet spectrograph that is six times more sensitive than anything we have flown before, and it can observe more than 40 targets at once in the area of the size of the moon.

To pass the muster of the highly-oversubscribed peer review there has to be some capability of the chosen vehicle, usually the altitude, which provides the only way to do the research. If you can do it from the ground, you are not going to fly.

Regarding suborbital infrastructure and capabilities, the commercially-operated launch provider, NSROC, run by orbital sciences, with oversight from the NASA Sounding Rocket Project Office, provides a staple of 11 different launch vehicles to experimenters picked by peer review, and they also provide a host of very mature modular subsystems to fly, to provide missile flight safety, de-spin and separation, high-speed telemetry, altitude control, recovery, fine point and command uplink for real time control of the payload.

Experimenters have access to full integration and test facilities at Wallops in Virginia, including ground station, shaker table, spin balance, and moments of inertia measurements. In addition, the NSROC Sounding Rocket Project Office holds project management reviews, and all these things are necessary to ensure that things will be carried out safely.

The message is one-size-doesn't-fit-it, as we heard earlier. Some experimenters want to fly as high and as long as they can. Some want to fly tailored trajectories at specific altitudes. It all depends on the science. For our observations I require a vehicle that will provide 400 seconds of time above 100 kilometers with a precision real-time pointing system so the student can make target adjustments during flight.

Student participation in sounding rocket research is a longstanding hallmark of the program. Some would argue it is the most important product. Students become an integral part of the science and technology they develop. They work in an apprentice mentor relationship with senior researchers, where much know-how is passed on in oral form from one generation to the next much like a guild of old spaceship builders. And there is the slide example.

In our astrophysics program we emphasize hands-on experience with optics, mechanics, electricity, magnetism, vacuum systems, computer programming, data acquisition, design, testing, calibration, integration, trouble shooting, mission planning, communication, and publication of results. Within the short tenure of a graduate student, they become scientists with a fundamental regard for systems engineering and are highly prized by the aerospace community.

Many of the Ph.D. and undergraduate students go on to fill key roles in the development of instrumentation for a host of space-based missions. However, as of late, excuse me. The number of sounding rocket students receiving Ph.D.'s has fallen as the displayed example shows. It is directly correlated with the decreasing number of lost opportunities over the past 40 years and symptomatic of a reduced production of technically-adept leadership.

Regarding future challenges and opportunities, the challenge for developing reusable suborbital vehicles as meaningful research platforms will be to identify those appropriate niche markets, both commercial and scientific, where human-in-the-loop or an in-situ access module provides some unique capability that will pass the muster of the peer review. From my perspective the current crop of reusable vehicles on the books falls well short of our requirements.

My astrophysics sounding rocket colleagues and I agree that generally new funding opportunities to advance the core capabilities of the expendable sounding rocket community are more likely to generate meaningful scientific, technical, and programmatic impact for future space-based missions run by NASA, DOD, and even private concerns.

There is a logarithmic gap in the launch portfolio between the $3 million it costs to develop a sounding rocket and $200 million it costs to launch an Explorer mission. The missing piece is a commercial launch capability in the $10 million range that is capable of placing 250 to 500 kilograms into low-earth orbit, Virgin Galactic Launcher-1, or the Falcon-1 from SpaceX.

Establishing this capability can reduce risk and cost for future Explorer missions, Flagship missions, to reduce development times for increasing technology readiness levels, and most importantly, by expanding the technically-adept workforce. There is no substitute for experiment, experience. Expanding the suborbital program and filling the logarithmic gap in the launch portfolio is key to maintaining our leadership in space science.

Thank you.

[The prepared statement of Dr. McCandliss follows:]

Written Testimony of Stephan R. McCandliss

Research Professor in the Department of Physics and Astronomy
The Johns Hopkins University

Given before the Subcommittee on Space and Aeronautics,
House of Representatives
Hearing on -
The Emerging Commercial Suborbital Reusable Launch Vehicle Market

August 01, 2012

Mr. Chairman and Members of the Subcommittee, thank you for inviting me to address the following questions on suborbital research platforms. For the past 24 years I have conducted sounding rocket and laboratory experiments in astronomy using the launch services provided by the NASA Sounding Rocket Project Office. I have also Chaired and served on a number of NASA and NSF review panels for the purpose of ranking the scientific and technical merits of proposed research, including that conducted from suborbital platforms. In addition, I am a member of the NASA Astrophysics Sounding Rocket Assessment Team (ASRAT) charged with assessing how to reinvigorate the Astrophysics Sounding Rocket Program. The opinions expressed herein are my own and do not necessarily reflect the views of the Johns Hopkins University.

Questions from and answers for the committee:

1. What are the types of issues that need to be addressed when deciding on the merits of proposed research and the appropriate platform for that research (e.g. balloon, sounding rocket, ISS, commercial reusable launch vehicle)?

The NASA Science Mission Directorate provides guidance to each of its four Science Divisions in the form of its Strategic Plan. Each division then solicits proposals for basic research that will advance their own science and technical readiness in accordance with the Strategic Plan. These proposals then undergo peer review, where a panel of experts ranks them in order of intrinsic merit. In the case of suborbital research, panels are quite keen on proposals that seek to develop new science, as enabled by new technology, while training the next generation of space scientists. Each of these criteria, science, technology and training, are given roughly equal weight in determining the overall intrinsic merit of a proposal, depending somewhat on the instructions given by the Science Division to the panels.

The proposal solicitation often lists a number of suborbital launch services. For example the recent Astrophysics Research and Analysis Program (APRA) element of the NASA Research Announcement for Research Opportunities in Space and Earth Sciences

(ROSES) – 2012, offers opportunities to propose for science investigations to be carried out from sounding rockets - both expendable and reusable, balloons, CubeSats and ISS payloads. It is the charge of each review panel to decide how the proposed investigations, utilizing these various platforms, stack up against each other and whether they should be recommended for funding by NASA.

2. What particular capabilities and infrastructure (e.g. telemetry, guidance and navigation, payload processing, etc.) are needed to enable suborbital research, including your particular area of research?

For the past twenty-four years I have enjoyed the formidable support of the NASA Sounding Rocket Project Office (SRPO) for launching the fine-pointing experimental spectrographs that we build at Johns Hopkins University. (In fact, as we speak, my team is traveling from Baltimore to the NASA Wallops Island Flight Facility in Virginia to commence integration and testing of our latest experiment called FORTIS. Its goal is to explore the mysteries of escaping of ultraviolet radiation from the dusty confines of galaxies, using a new type of spectro/telescope that has more than six times the sensitivity of our previous experiments and can acquire spectra from forty-three individual targets simultaneously, within a region as large as the moon - 1/2 a degree = 1800 arcseconds. We expect to launch FORTIS this fall.)

The SRPO provides oversight to the operations of the NASA Sounding Rocket Operations Contract (NSROC), currently run by Orbital Sciences. This team supplies complete launch support for peer review selected experiments. They maintain a variety of mature standardized subsystems, including: a bevy of launch vehicle configurations, payload separation and de-spin modules, missile flight safety command destruct systems, recovery systems, shutter doors, payload skins, guidance and navigation modules of various precision, telemetry links at a variety of rates, and command uplink modules for specialized real-time payload interaction during flight – which includes the capability for steering the payload. NSROC also provides ground support in the form ground-station interface, environmental testing (shake, spin balance and moment-of-inertia measurement), and full experiment to subsystem integration services for the payload.

In addition to the launch infrastructure, the SRPO and NSROC will convene a series of project meetings, which include: a Mission Initiation Conference, a Requirements Definition Meeting, various Design Reviews, a Mission Readiness Review, and a Pre-Shoot Meeting. It is in these meetings that the experimenter outlines their mission goals and success criteria, chooses those systems that are necessary to meet their particular requirements, tracks the compatibility of the experiment with that of the subsystems, and establishes protocols to ensure the safety of all involved personnel.

For my own ultraviolet spectroscopic experiments, the vehicle of choice is a Black-Brant IX. It can throw 1000 lbs of payload to an apogee of approximately 300 kilometers. This vehicle provides approximately 400 seconds of time above 100 kilometers, which we require for unattenuated viewing of ultraviolet emissions from astronomical objects. We also require 3-axis (pitch, roll and yaw) fine-pointing acquisition and control system for tracking our targets with sub-arcsecond precision. A command uplink system is also used to make real-time fine pointing corrections. Students are usually chosen to "drive" the payload as they tend to have superior reaction time.

Recovery of the payload is also essential as it allows opportunity for reflight with improved technology and a means to learn from and correct mistakes. NASA expendable sounding rockets provide low cost, risk tolerant platforms from which experimenters can test technology to its limits. We seek to find "the edge of the envelope" without going over it. But failing that, as inevitably happens in experimental programs, we gain invaluable experience in learning how to recover once we do.

3. Please describe the end-to-end process in which students participate in suborbital research and the skills and benefits students acquire from that end-to-end approach.

Most suborbital research programs involve graduate and or undergraduate students in every aspect of an experiment. They learn to define science goals and measurement objectives and how they flow down into the instrument requirements that inform the systems engineering of the design, fabrication and testing phases of the experiment.

Students become an integral part of the science and technology they develop as they work in an apprentice-mentor relationship with a more senior researcher. Much of the knowhow is passed on in oral form, from one generation of experimenter to the next, much like a guild of old shipbuilders. In my own work, developing novel astronomy experiments in ultraviolet spectroscopy, we emphasize, in addition to the astrophysics, hands-on experience with optics, mechanics, electricity, magnetism, vacuum systems, computer programing, data acquisition, design, testing, calibration, integration, troubleshooting, mission planning, communication and publication of results. Within the short tenure of a graduate student, they become scientists with a fundamental regard for systems engineering and are highly prized by the aerospace community.

I have had the good fortune to work in productive collaborative relationships with nine graduate students in my past 24 years at Johns Hopkins and I can say without a doubt that I've learned as much from them as they have from me. Student participation in sounding rocket research is a longstanding hallmark of the program. Some would argue the most important product.

Many of the 40 Ph.D. students that have come out of Johns Hopkins University sounding rocket programs over the last 50+ years have gone on to fill key roles in the development of instrumentation for a host of NASA space mission, such as, the Advanced Camera for Surveys and the Cosmic Origins Spectrograph on Hubble, the James Webb Space Telescope, the Hopkins Ultraviolet Telescope, the Far-Ultraviolet Spectroscopic Explorer, the Galaxy Explorer, and the Mercury Messenger Mission to name a few. Some have even gone on to become Principal Investigators, leading exciting new science missions. Every academic, industrial and government research institution engaged in suborbital research has a similar story to tell. As of late the number of students receiving Ph.D.'s based on data from astrophysics experiments has fallen, as the attached Figure shows. It is symptomatic of a decrease in technically adept leadership.

4. What are the opportunities and challenges for suborbital research going forward?

There are many possible scientific research opportunities emerging for the commercial reusable suborbital sector. For example, in-situ research of upper atmospheric phenomena would be a logical fit for a vehicle with an apogee of 100 km. Understanding the effects of suborbital flight on normal human physiology would also appear to be a necessary prelude to the establishment of a routine commercial suborbital transportation capability.

I view the emerging stable of reusable suborbital vehicles with a mix of excitement and uncertainty. I am excited by the possibility of routine suborbital flight. I would love to fly across the Pacific Ocean in under an hour. However, I am uncertain as to whether the systems required to place a human-in-the-loop will lead to an increased experimental capability beyond that which we enjoy with the current stable of expendable NSROC vehicles. But then again, stories abound about how the student used the real-time command uplink system to save an expendable NASA sounding rocket mission from certain failure.

The challenge for developing reusable suborbital vehicles as meaningful research platforms will be to identify the appropriate niche markets, both commercial and scientific, where either human-in-the-loop or an in-situ access module provides some essential new scientific opportunity or technical capability that will pass the muster of Geospace, Heliophysics, Planetary and Astrophysics peer review panels.

It is important to note that most of the cost of carrying out a suborbital investigation goes well beyond the mere cost of the launch. The launch vehicle is the easy part. It will be necessary to develop a whole set of instrumentation infrastructures for collecting and recording data, along with integration and testing facilities. Moreover, review processes must be established to keep the launch providers and the experimenters on the same page and their workforce safe.

From my perspective as an astrophysics experimenter, the near term capabilities of reusable vehicles falls well short of the 300 km apogee we require to place our payloads above 100 km for approximately 400 seconds. In my view, generating new funding opportunities to advance the core capabilities of the expendable sounding rocket community are more likely to generate meaningful scientific, technical and programmatic impact for future national space based missions run by NASA, DOD and even private concerns.

For example, the recent Astro2010 decadal survey recommended expanded development of low cost missions operating in low earth orbit (LEO) and the upper atmosphere, as a means to rapidly respond to pressing scientific, technological, and workforce development needs. Currently, there exists a logarithmic gap in the funding profile between the approximately $2M to $4M that its costs to develop a sounding rocket mission and the approximately $200M plus cost of an Explorer mission; the lowest level of orbital flight opportunity offered by NASA.

The NASA Astrophysics Sounding Rocket Assessment Team (ASRAT - of which I am a member), convened by former Astrophysics Division Director Jon Morse during the tenure of then Science Mission Directorate Associate Administrator Alan Stern, outlined how a sounding rocket to orbit program could be implemented to fill this gap in the NASA launch portfolio. The purpose of this program would be to launch to LEO, for periods of up to a month, highly meritorious payloads that have been successfully flown as a sounding rocket.

Such a program would provide for the further maturation of sounding rocket initiated science and technology thrusts, but in an orbital environment more closely matched to the developmental needs of Explorer and Flagship missions. The ASRAT argued that establishing a sounding rocket to orbit line would ultimately reduce the costs for Explorers and Flagships because instrument development risk could be retired early. The ASRAT Astro2010 decadal survey White Papers that describe the core capability of the astrophysics sounding rocket program and benefits and envisioned methodology for establishing the sounding rocket to orbit program maybe downloaded from ASRAT Wiki page (http://www.galex.caltech.edu/ASRAT/).

The ASRAT identified two crucial components for enabling a sounding rocket to orbit program. One of those is the availability of low cost commercial launch systems capable of delivering payloads of modest mass to LEO, such as SpaceX's Falcon-1 or the recently announced Virgin Galactic Launcher-1. The other component is the development of standardized support subsystems for power, pointing, thermal control, and command and data handling, which are required to support these payloads in an orbital environment.

The SRPO, with its history of maintaining low costs through the use of standardized modular systems, in combination with the commercial interests of the NSROC, makes for an ideal partnership to migrate their formidable low cost and modular support system from the suborbital to the orbital regime. They would require only a modest amount of funding, not much more than the cost of a sounding rocket mission, to begin development of such systems. The expenditure would payback a hundred fold by increasing science return from the suborbitals and lowering development cost, and thereby risk, for instrumentation destined for Explorers and ultimately Flagships missions.

Research from suborbital platforms provides the nation with a vital base of core competency for advancing cutting edge science through the development of new technologies for future flagship missions while nurturing the next generation of technically adept leadership for the aerospace industry. I strongly recommend that the committee, on both sides of the aisle, become advocates for expansion of the workforce and capabilities of the NASA suborbital programs, and invite you to further investigate the benefits that establishing a sounding rocket to orbit line would have on reducing costs for future Explorer and Flagship missions. Expansion of these programs is a strategic investment towards accelerating the scientific and technical advancement required to maintain the future competitiveness of our aerospace sector. Now more than ever we need low cost access to space.

Chairman PALAZZO. Thank you, and I thank the panel for their testimony.

I now recognize myself for five minutes for questions.

My first question is pretty much a two-part question. It is going to be directed to Mr. Whitesides, Mr. Alexander, and Mr. Nelson.

How does the SRV industry currently collaborate with the Federal Aviation Administration in developing draft guidance for test flights and current operations? And what is the proper role for industry in developing future regulations?

Mr. NELSON. George and I have talked on so many panels together, I think we could probably finish our sentences a lot of times. So we collaborate with FAA on draft test flight processes and procedures much as the rest of the industry. It is important for us to have the integration of local staff so they can understand what we are planning to do. There is regular meetings and especially through the licensing process, they want to understand how our vehicle was built and designed, as well as how we are intent on testing it.

Mr. ALEXANDER. I think I would like to add that we have got a very good working relationship with the FAA. Their staff are knowledgeable, but what they need is access to our plans and procedures, and that comes through that regulatory interaction through the process of applying for experimental permits and licenses and through the oversight of the activities that are regulated by the FAA.

That interaction is the most important piece in terms of both understanding from industry's side how things are operated but for the FAA to understand what is going on in the industry such that the industry provides a real education opportunity for them to see what is really going on.

So the back and forth, in order to develop regulations later, to develop draft guidance, to develop test procedures and things like that, they need to see what is actually going on in industry, and it is through that application process that they get that back and forth.

We do think that the FAA is setting up a monthly telecom to have a dialogue with industry. That is going to be another opportunity for industry collectively to interact with the FAA to talk about technical details. We think that that is going to be very valuable as well.

Mr. WHITESIDES. Mr. Chairman, in the interest of time, I will leave it with them.

Chairman PALAZZO. Nothing to add? Thank you, and this is pretty much for all you all again, so maybe you all decide who is going to go first.

When will the companies begin commercial operations, and what type of flights will be the first to produce revenue for your company?

Mr. WHITESIDES. Why don't I start? Mr. Chairman, our goal is to start powered flight by roughly the end of the year and to go into commercial operation by the end of 2013. So we are looking at roughly an 18-month timeframe for the start of commercial operations.

We have always base lined starting flying with commercial customers with our customers who in some cases have been waiting to fly for several years. We have recently talked about inserting some of the NASA payloads that we have been contracted to fly earlier on. So that is in discussion, but our baseline is to start with our commercial customers.

Mr. ALEXANDER. We are still in the development phase for our new Shepard suborbital flight system, and as we get deeper into our flight test program we will start accepting reservations and then having plans for when we first fly. We do think that passengers and scientific research will be the first revenue-generating activities.

Mr. NELSON. We hope to commence our flight test program the end of this year, early next year with a flight test program that would end late 2013, and if things go as planned, so we will be at the end of 2013, flying paying participants.

We do expect that there will be some science missions that are unmanned, that are automated that could be flown potentially earlier than that as well.

Chairman PALAZZO. Ms. Christensen, your forecast paints a rosy picture for the future of this industry. Can you tell the Committee why we should believe there is a real market out there for these vehicles, and what is your level of confidence in the demand forecast?

Ms. CHRISTENSEN. Mr. Chairman, my objective in characterizing the industry, my team's objective has been to be as data driven and accurate as possible. We are an independent firm. Our business model is to provide rigorous analysis. We have released a 100-page report that identifies the many, many dynamics of the market that we identified, the uncertainties, the assumptions that we have made, and where those assumptions might vary.

I will note that our findings are very much aligned with a broad dataset derived from interviews and research, and we have laid that out as fully as possible.

Chairman PALAZZO. Thank you. I am out of time.

I now recognize Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman.

As you know, I have been both a healthy skeptic of the industry and the potential but also quite curious, and I haven't made it any great secret that I would want to be one of those, I want to be number 537 if there is room. It does seem to me that on a Congressional salary it is highly unlikely that I could afford the deposit.

But it raises a question, Ms. Christensen, about the profile of the individuals who want to leave those deposits and fill out this industry because they are clearly high net-worth individuals because they have the financial capacity for that, but it seems to me that we are so accustomed to getting on boats and planes and our automobiles, and there is a comfort level attached to that, and this is somewhat different and experimental, and so what happens with those individuals that you think will fill out the industry if the flight itself doesn't kind of meet that comfort zone for people who are not necessarily scientists and researchers but they just want to experiment a little bit?

Ms. CHRISTENSEN. We identified that question of how consumers, how spaceflight participants will actually respond to the experience as one of the major uncertainties that we are looking at. I can tell you that based on the survey that we did, and we focused on high net-worth individuals, most of those individuals viewed spaceflight as either extremely or somewhat inherently risky, and many of the individuals that were interested in taking suborbital flights had that view as well.

So to the extent that that speaks to that question, that population does appear to have a sense that that is part of the—and we also in our survey articulated to them elements of the experience, such as what it might be like, both the positive and the, you know, you might feel ill, and so that was part of the process of informing survey respondents in getting their answers.

Ms. EDWARDS. And Mr. Whitesides, if you could help me understand, in any of these sort of risky behaviors, there is a potential that there is a mishap that is going to happen. I mean, that happens with cars, and I wonder if your company or others have established any plan as to how you will conduct investigations or determine root causes should there be a mishap, and what do you think the relative role of the Federal Government should be in the event of such an occurrence? And I think, for example, of an agency like the National Transportation Safety Board. Is that something in terms of the Federal Government that we have to stand up to have some capacity for investigation that it doesn't now have with respect to spaceflight?

And I know that there is, there clearly is an expression of concern about a regulatory environment that might constrain development, but what is the right level of regulation that the Federal Government has to engage itself in, in order to oversee what is in essence a consumer-driven market?

Mr. WHITESIDES. To start with the first question, Congresswoman, I think it is a great question, and the answer I think is that in terms of mishaps it depends on the type of mishap. So for very serious mishaps, the NTSB, I believe, will work with AST, and NTSB has assigned an investigator who is becoming proficient in essentially our sector. He has come out to Mojave, he has met with many of our companies, and I think I speak only for myself but I view him as really a very highly-skilled individual who seems to understand the issue.

So that engagement has begun. I think AST also has its own set of plans and for a serious mishap we, I think, would obviously defer to the NTSB's leadership of that investigation.

For other mishaps, which frankly occur, lesser mishaps, you learn things continually through the flight test program, some of those I think the flight test team can handle themselves. They will just learn something. It is a minor issue, and that is the point of flight test is to improve the vehicles to the point that we are comfortable flying customers.

Part of the reason that we have certainly taken many years to prepare these vehicles is because we have been in flight test for years, and we will not fly people on these vehicles until we feel comfortable that it is the time to do so.

I think in terms of your last question, I think the government and in particular the Science Committee, who essentially crafted the 2004 amendment to the CSLAA, developed the right posture for this moment of time, and I think we obviously support that at this time.

Ms. EDWARDS. Mr. Chairman, if I could just ask a final question of Dr. McCandliss, and it actually has to do with the scientific environment. It is tough for me to imagine how you balance having a sort of sterile, more laboratory environment with also commercial passengers that satisfies the needs that scientists have to do research. Is that a concern of yours?

Dr. MCCANDLISS. Yes. For our own purposes we require to be outside the cabin. So being inside the cabin would not be where I would want to be, I mean, we conduct research essentially in-situ. So it is incompatible really with the human spaceflight aspect.

Chairman PALAZZO. Before moving on if I could just ask Ms. Christensen, again, on part two of my question, on your industry forecast, what is your level of confidence in the demand forecast?

Ms. CHRISTENSEN. My level of confidence is strong in our baseline forecast. We built that up using a very substantial array of data through critical lens. There are certainly uncertainties embedded within that ranging from consumer response to research outcomes and so on, but just as a calibration note, I will say that our baseline of about 4,500 seat equivalents, you can look at that in light of the number of sold reservations to date, which is about 925.

So that as a calibration point I think is indicative of that it is a realistic forecast.

Chairman PALAZZO. Thank you.

I now recognize the gentleman from Texas, Mr. Smith.

Mr. SMITH. Thank you, Mr. Chairman.

Let me direct a couple of questions to Mr. Whitesides, Mr. Alexander, and Mr. Nelson. You all mentioned a while ago, Mr. Whitesides for Virgin Galactic, that you expect to be in commercial operations in about a year and a half. Mr. Nelson, you said the same things about XCOR. Mr. Alexander, you didn't give a specific time, but I gather you are about a year behind that or 2–1/2, three years away from commercial operations?

Mr. ALEXANDER. I would say we are later than what you heard from the others. Yes.

Mr. SMITH. Okay, and Mr. Whitesides, you had over 500 deposits, I think, Mr. Nelson, over 200, and Mr. Alexander, you were on the cusp of getting them.

I guess my first question is this. In regard to your revenues, what percentage of your revenues do you think or expect or project to come from paid passengers versus scientific research? Mr. Whitesides?

Mr. WHITESIDES. Congressman, I believe that certainly the initial bulk of the market, I think, is in the individuals.

Mr. SMITH. Paid passengers. Okay.

Mr. WHITESIDES. Yeah. For us at least.

Mr. SMITH. Mr. Alexander?

Mr. ALEXANDER. I would agree with that, that people is the real market. We believe that the research market is secondary, but we are likely to fly research, you know, activities before we fly people.

Mr. SMITH. Okay. Mr. Nelson?

Mr. NELSON. Initially we see the participant market being the driver, however, we do see the research market, especially industrial research, surpassing that market, we feel 4 or five years in, as the value proposition is known and becomes known to industrial players outside the government market.

Mr. SMITH. Okay. Now, you have two passengers, I think, Mr. Alexander has three, Mr. Whitesides, eight, two are pilots, I think, and of the two, Mr. Nelson, with XCOR, one is a pilot. I guess on a scale it looks like that Virgin Galactic is going to have more revenue just on the basis of more passengers, but when do you project to make a profit, Mr. Whitesides?

Mr. WHITESIDES. We expect to be cash flow positive within about a year of the start of commercial operations.

Mr. SMITH. Okay. Good, and Mr. Nelson?

Mr. NELSON. On a GAP basis as well as regular accounting, we are profitable last year. We have additional revenue streams from other parts of our business. We hope that occurs again this year.

Mr. SMITH. But as far as commercial space.

Mr. NELSON. Commercial space, we expect in the first 12 months to be profitable.

Mr. SMITH. Good. I hope you are right and wish you well in that regard.

Let me go to the FAA for a minute. You asked—answered a question a while ago about your relationship with the FAA, but my question is this. What FAA regulations are of most concern to you?

Now, Mr. Whitesides, you sounded like a while ago that you were okay with the current regulations. You were worried about the future new changes in regulations, but in general, what regulations, present or future, are of most concern to you?

Mr. Whitesides?

Mr. WHITESIDES. Congressman, you captured it exactly, in fact. We believe that the current regulatory posture of AST is a good one, and our preference would be to maintain the original eight-year intention of Congress.

Mr. SMITH. Okay. Great. Mr. Alexander?

Mr. ALEXANDER. We completely agree. We believe that the informed consent approach that this committee originated in 2004, really allows the individual to make the choice as to what level of safety or what level of risk they want to accept. Just as someone who climbs a mountain has a choice of whether to do that or not.

Mr. SMITH. Okay. Mr. Nelson?

Mr. NELSON. I have nothing more to add. They said it perfectly.

Mr. SMITH. Last quick question is this. Oh, is my time up? It is not up. Last quick question is this. How do you view yourselves, the three of you all who are about to engage in commercial operations, do you see yourself as competitors, as rivals, and if you see yourself as rivals, do you also see that each of you in your own way is adding sort of a value added to the enterprise and to the overall commercial operations in space?

Just in reverse order. Mr. Nelson first.

Mr. NELSON. I have been asked this question before, Congressman, and the current stage we are in is coopetition. We are competitors, but we also have to cooperate. It is a very early stage of the industry, and so things like regulatory frameworks and this sort of thing we are in dialogue with through the Commercial Spaceflight Federation and the FAA.

But, yeah, certainly this is a competition, but we have very different value propositions, very different experiences. Just like going to Disney or someplace where you have six roller coasters you want to ride all six roller coasters, and we are seeing that with our customer base.

Mr. SMITH. And that is the value added strength in numbers maybe?

Mr. NELSON. Absolutely, and certainly we have—I have said many times that we are very happy that Sir Richard Branson stepped into this marketplace because to the public face that was a wonderful thing. It made it acceptable to say I want to fly to space.

Mr. SMITH. Okay. My time is up, but, Mr. Whitesides, real briefly if you can give your view of that.

Mr. WHITESIDES. I think on a personal basis we view each other as brothers in arms doing historic work and obviously once we go into commercial operation, then we will compete like any good capitalists.

Mr. SMITH. Okay. Good. Thank you, Mr. Chairman.

Chairman PALAZZO. Thank you. I now recognize the gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very, very much, Mr. Chairman. Yes. That last question was really pretty interesting, Lamar. Nobody said robber baron or bureaucrat so I am glad to hear that those two mindsets has not dominated your industry. I think it is fascinating that we do, your industry now is being heralded as a potential trillion dollar, new trillion dollar enterprise for the future. It wasn't that way back in 2004, when we were working on the Commercial Space Act, and let me note that informed consent was just mentioned. Getting that principle established for this industry was a horrendous task. I mean, this Congress went—that was an issue that almost prevented the development of this new trillion dollar commercial industry, and it took a lot to get our colleagues to accept that. There were people who were skeptical about it as—and by the way, I don't think you are skeptical. I think that you are going to be the first one on that rocket. I know I am not skeptical, but I wouldn't go up there on one of those rockets. I will stay on my surfboard, thank you.

About your industry, how much of your industry is based on technology that was developed for the American Space Program, and how much of it is new that you are putting into this program yourself? How much new technology is coming from your enterprise? How much of it was based on things that the government developed for NASA over the years?

Mr. NELSON. From an XCOR perspective the key parts of our technology we developed ourselves, and in fact, we have relied much more on the automotive industrial base to make the engines fully reusable and to be able to last thousands and thousands of rocket flights.

Mr. ROHRABACHER. Uh-huh.

Mr. NELSON. Now, granted, we all stand on the shoulders of great individuals in people and the organization of NASA, and but some of the core key technological developments were done internally or——

Mr. ROHRABACHER. And the real things that makes this, that makes your industry possible had actually been developed without a direct federal subsidy. Is that correct? Or I am not saying running the business but in terms of developing the shape of your craft and the design and the whole concept, or am I wrong there?

Mr. WHITESIDES. You are correct, sir. Certainly in our case our technology is primarily based off the SpaceShipOne Program, which was financed by Paul Allen and, you know, to date our entire program has been privately funded.

Mr. ROHRABACHER. So we have a tremendous new industry that basically has emerged based on the enterprise and the creativity of a group of profit-seeking entrepreneurs as compared to, for example, I understand there was very little government involvement in your enterprise, but there was a lot of government involvement in the Volt. Wasn't—the recent car and so we are lucky we didn't have the government having the same kind of influence on you industry that it had on the development of that type of automobile.

Let me ask you a little bit about suborbital space and some of the challenges that you face. I see there is technical challenges, which you are moving forward on. We are trying to handle the regulatory channels, challenges now, and this is just as big a hurdle as the technology challenges, and then the financial and the market challenges are the things that you are going to have to face as entrepreneurs as any other businessmen.

But right now if we don't have the right type of regulatory and don't continue with some of the leeway that we gave you in the Commercial Space Act of 2004, would you say that that would be a death blow to your industry, or would this just a setback, or might it be positive?

Mr. ALEXANDER. I appreciate the question. I think if we were to have imposed today's aviation regulatory environment on the Wright Brothers, they never would have gotten off the ground, and that is the big fear, that we will take all the lessons learned but take them in the wrong way and impose strict regulations that don't take into account the changing way of doing human spaceflight that this industry represents.

Mr. ROHRABACHER. That was a very good answer. I have got a couple seconds left, and I would just like to note that in two hours if your industry is successful, in about two hours we can be on the opposite side of the world. Eventually we are going to have a system which can deliver passengers to the other side of the world in two hours or packages. That seems to me to be something that has tremendous potential for benefit. It also would lead to cheaper, it may lead us to a cheaper, as you have already mentioned, way of delivering satellites into orbit, and I wonder if we all remember that Lindberg got a contract for delivering the mail and eventually it helped him then as a private operation to show, to build a plane that went across the Atlantic.

And so there is just a great deal of exciting things that lie ahead for your industry, and we are counting on you, but we need you back here to make sure that we know what we need to do so we are not in the way.

So thank you very much, Mr. Chairman.

Chairman PALAZZO. You are welcome, and for the panel's information we are going to go into a second round of questions. Everybody is agreeable to that?

Okay. Dr. Stern, I know you have been quiet over there, so we have got one just for you. What is the necessary price point at which K through 12 STEM educators could begin to use SRVs in their curriculum?

Dr. STERN. Well, that is a great question. As you know, the primary barrier to schools using spaceflight have been the long time it takes to fly things. A lot of things that happen in the Shuttle Program, for example, a sixth grade class would start it, and they would be in college by the time some other sixth grader was carrying it out, and then the prices were so high that it just wasn't within reach of the normal school system.

In these vehicles, however, the price points are quite low. If you take, for example, George's company's cost of $200,000 to fly an individual. You say I want to fly a shoebox-sized experiment, say it weighs a pound, for a class, then that ratio of $200,000 to one pound would cost, it is about $1,000, which is quite affordable. The school could have a car wash, a bake sale, what have you, and afford to have the students fly something in space, and that is really revolutionary in terms of the access, and that is one of the reasons that educators are so excited about this industry is because they are going to get access to space on rapid time scales and at costs they can afford.

Chairman PALAZZO. How soon do you think we will actually see secondary students engaging in these types of scientific projects?

Dr. STERN. I think you will see that very shortly after the commencement of commercial activities, but it is really up to the individual companies to make their case to the school systems around the country that they are open for business.

Chairman PALAZZO. I mean, because it is just so important, yes, especially kids at that age to get them excited about science, technology, engineering, math. So hopefully they will just embrace that dream and carry it out and make a career out of it, which will also help us become more competitive with some of our global competitors.

My next question is for Dr. Stern and Dr. McCandliss. How will research universities benefit from these new vehicles, and could we see the number of undergraduate students that fly their own experiments grow as a result of cheaper options for suborbital flights?

Dr. MCCANDLISS. Yeah. The more flights you have, the more opportunities you have. The question will become where will the funds come from to build the instrumentation. The cost of launch is really a small part of what it costs to develop the scientific instrument and fly it on a launch vehicle. There are costs associated with engineering, design, development, testing, and then ultimately integration with payload.

So who is going to bear those costs? That is the question.

Dr. STERN. Mr. Chairman, if I might add, I think we have to wrap our heads around a different way of doing business when we think about suborbital. Just like mainframe computing, spaceflight has been very rare since its inception, and just like PC computing, it is about to become routine.

So when Steve and his colleagues and individuals in my community typically think about spaceflight, we think about inventing a new experiment. Well, that is not the way to think about it in suborbital. You want to think about an individual experiment that in an educational sense does a good job, flying again and again and again, being handed from school to school to school every day of the year so that you divide that cost by 365 days in the year or by many school systems all performing the same experiment the way that we all used to do classic physics experiments as undergraduates, and we didn't invent new experiments. We carried out the cookbook, and in that mold where private industry develops or universities develop curriculum experiments that get handed from student to student so that you don't have to reinvent the wheel, and you can take advantage of these low price points for the launch, then we can really see this kind of space access revolution, which I think is upon us.

Dr. MCCANDLISS. I think most educators would say that cookbook experiments have their place in an educational environment, but it is not going to advance the science.

Chairman PALAZZO. I now recognize Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman.

Mr. Nelson, in your written testimony you advocate for a full eight years of data gathering before, and I quote, "Unfettered regulation may begin." Does that mean also that space participants would continue in this period to fly under informed consent? Some say that is "fly at your own risk." You said it. And I recognize the need for the industry to kind of get its sea legs, and we are not anywhere near yet the level of experience achieved in aviation, but it seems that this is a pretty lengthy time.

What do you hope to gain and what experience do you hope to gain over the eight years of licensed flights, and why would a lesser time period not provide similar results?

Mr. NELSON. Thank you, Congresswoman. It is a very good question. Between the Wright Brothers' first flight and the introduction of the DC–3, which is recognized as the sort of breakthrough safety vehicle, there was approximately 30 years of experience gained with hundreds of different types of aircraft, systems, engines, flight environments, customer types, and businesses. We see that when you, even though technology now expands and develops quicker, we still need a period of time to operate and to practice and to learn. And as we better understand how we will make these vehicles as safe as we can and still remain economically viable, we need to take that time.

To answer your question about after the eight-year learning period and we start to have the beginning of a regulatory environment and certification standards, we still want to fly with informed, under informed consent, meaning it should continue indefinitely as my colleague to my right mentioned.

The reason for that is is because in order to have a statistically-significant database to go through the assured safety ten to the minus six safety levels that are normally associated with even general aviation, you need thousands and thousands and thousands of flights, and it is important for us to have that experience.

Thank you.

Ms. EDWARDS. Thanks. I just want to remind us all that nobody paid to go on the Wright Brothers flights. I don't recall that as part of the history books, and I wonder, Dr. McCandliss, I want to go back to something that you mentioned earlier, which is this question of whether you really do need for, real science, and I am not talking about, not that the high school scientists for an education purpose aren't really great, but I am talking about our Ph.D. scientists at Johns Hopkins and our other research institutions. The kind of environment that you need in order to perform the science that you could then have peer reviewed. The environment that has been described on the vehicles that we are talking about, do you think that that is at a, projected to be at a capacity where you would be able to do that kind of experimentation, developing instrumentation that is really sensitive in an environment that also contain human payloads or human people?

Dr. MCCANDLISS. Yeah. It will depend upon the type of science that you are talking about. Now, for things like physiological research to see whether or not people will be able to keep their lunch down——

Ms. EDWARDS. I am talking about high, you know, sort of really high technology instrumentation.

Dr. MCCANDLISS. Right. For our own purposes for say NASA science programs where we have strategic plans that we are trying to advance and discover secrets of the universe for lack of a better term, we require a good strong base of researchers who are savvy and can carry out a lot of the tasks that are associated with building instruments, which as everybody down the line here knows is a very painful process to get everything to work all at once. There are a lot of Frankenstein moments, you know, where you finally have breathed life into the instrument, and it lives, and everyone is very happy. But there is a lot of sweat and pain that goes up to that.

Ms. EDWARDS. I only call our attention to it because I do think it raises a question about how we are going to be able to carry the passengers that want to fly and have left deposits with what we need to do scientifically.

Dr. MCCANDLISS. Ms. Edwards——

Ms. EDWARDS. And before you get there, I just wonder also if you could clarify for the record that even though you work with an NTSB partner who is on your site, NTSB does not currently have any legislative, statutory authority in commercial spaceflight. Isn't that correct?

Mr. WHITESIDES. To be honest, I am not an expert on this subject, but my impression is that if there was a mess up, I believe it has been represented to us that the NTSB would work with AST on that investigation.

Ms. EDWARDS. I feel certain that the NTSB doesn't have any current legislative authority.

Mr. ALEXANDER. The FAA, AST and the NTSB have an MOU jointly signed by the two parties. Whether they have statutory authority or not, I can't speak to.

Mr. NELSON. And just a couple weeks ago they actually did sort of an accident practice out in Mojave with NTSB local first responders and participants from the industry as well as the airport and fire and rescue. So I know that they are actively engaged in the subject matter of which you speak.

Ms. EDWARDS. Thank you. Mr. Chairman, maybe there is some point at which we could actually bring the NTSB in and FAA and ask some of these questions. I mean, our witnesses, you know, they are terrific, but they aren't in a position to answer those questions.

Thank you.

Chairman PALAZZO. I now recognize the gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. Let me just note that by eliminating the burden of informed consent, what we actually did is we eliminated the weight, the unnecessary weight of having extra lawyers on every flight, and that I think has made a major difference and would have made a major difference in the Wright Brothers as well. It isn't so much as a subsidy as it is the elimination of an unnecessary factor, especially if you consider people should be free to decide for their own selves if they would take risks in their lives.

As my father was a Marine fighter pilot and guess what? When he signed up, he knew exactly what the risks were, and he was willing to do it, we put lawyers into the whole system of the military because was he able to make that informed consent? Well, of course, he was.

When we should put the regulatory regime onto your industry as compared to other industries in the past. I would suggest that eight years more experience in finding out what your industry is going to be all about, we don't know right now whether the suborbital space is going to lead to satellites being launched or how far you are going to be able to take passengers, whether it is going to be a ride up and a ride down or whether it is going to be a ride to the other side of the world. We don't know those things yet, and this is a softball question for the panel, but wouldn't it be more dangerous to put regulations in place right now before we have gathered all of the statistics on the differential type of flights that you are going to be making over this next 8 years?

That is a softball question. I am sure somebody can answer it there.

Dr. STERN. Well, I will speak from the standpoint of the research community, and the power of these vehicles to transform our ability to do frontline research and to do education, two very different things, is in the frequency of flight. It is not that they are going somewhere new. It is that they are going there every day. So we can go to the upper atmosphere every day or we can, for example, look at physiological changes and how people adapt to zero gravity with much larger groups of people than a few select astronauts to fly hundreds of thousands of people.

It is the frequency of flight that is key, and if the regulatory environment hampers, impedes, or stifles that, then we won't get the research benefits, and we probably won't have the tourism benefits either.

Mr. ROHRABACHER. Anybody else want to answer that?

Mr. NELSON. In the past I have used a hypothetical example, and I guess I should do the research on it, but, you know, we have wiring that runs by cryogenic tanks. In aircraft you don't have wires that run by cryogenic tanks. If they were going to regulate aircraft wiring on our vehicle, that could potentially create a safety hazard.

So we would have to go through a various process to get it waived, get it changed, et cetera, but by creating regulations that we don't have experience around, then you perhaps create an environment of just I just described.

Mr. ROHRABACHER. I think that we should have faith in our entrepreneurs and our frontiersmen and our explorers, at least for a limited period of time so that they can push back the frontier, and then we can come in when—and reach our compromises and reach our argreements as to how much regulation is needed to make sure our society functions as a whole.

One last question for Mr. Stern. What type of training is necessary for researchers to fly along with their payloads into suborbital space, and are there companies that offer this type of training, or is it provided by the government or provided by these companies themselves that are providing the transportation?

Dr. STERN. Yes, sir. That is a very good question, and I will speak from the standpoint that my firm, the Southwest Research Institute, has already invested our own money to purchase nine spaceflight tickets on XCOR and Virgin Galactic for the purpose of research missions, early research missions not paid for by the government but from our own funds. So we are already in the process of doing that. I am the principle investigator of that program and therefore, going through our training process.

The training falls into three categories. The first is to understand how to operate your own scientific gear, just as you would on a sounding rocket flight, which I did many times after peer review. The second is the same kind of training that the space tourists take just to be familiar with the environments and the cabin and the vehicles themselves, and the third kind, which I think is unique to the research community, is really to make sure that you are going to be effective in a short period of time. Time management, distraction management, et cetera.

Earlier, Ms. Johnson asked a question, excuse me, Ms. Edwards asked a question about the efficacy of research flights, of research being done on tourist flights, and I am sure that is going to happen in the early days, but I think that we are going to see a real market differentiation. In fact, we already worked with Virgin Galactic to buy the first charter flight, which is all researchers, and I think that that is where you will see, just like cargo doesn't fly in the cabins with people, there are cargo flights, and there are passenger flights. You will see the development of research birds and specific research flights where everybody is down to business, and that will be separate from honeymooners or what have you and the tourist line that are going for a peak experience.

Mr. ROHRABACHER. Mr. Chairman, I would like to thank you for holding this hearing. This issue and this new industry is key to prosperity, it is key to national—and I would suggest that while they are working to make a buck and develop this new type of enterprise, it will have tremendous applications that will make our country safer. We will see a technology transfer from a private company into the defense arena rather than the other way around, and so we wish then Godspeed and lots of success.

Thank you, Mr. Chair.

Chairman PALAZZO. Yes. Thank you, Mr. Rohrabacher, and I guess we need to start talking about how soon we have to put our Kodell request in for the most successful company with the best safety record.

I do want to thank today's witnesses for their valuable testimony and the Members for their questions. The Members of the Subcommittee may have additional questions for the witnesses, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments and statements from Members.

The witnesses are excused, and this hearing is adjourned.

[Whereupon, at 3:47 p.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Carissa Christensen

Enclosure 1

Questions from Chairman Steven Palazzo:

1. In your prepared testimony you identified currently funded research areas that are better served by SRVs than by existing alternatives. For each area listed in the testimony, i.e., Atmospheric Research, Suborbital Astronomy, Longitudinal Human Research, and Microgravity Research, please elaborate on which SRV attributes in your opinion make them better alternatives than existing launch platforms.

SRVs are well suited to some niche applications. These include experiments that can use the one- to five-minute microgravity window and cannot be modeled with computer simulation, do not have adequate terrestrial research alternatives, or require human tending. SRVs also provide frequent research opportunities at a lower cost and with more accessibility than most other space platforms, albeit for a shorter microgravity duration. For the basic and applied research areas of Atmospheric Research, Suborbital Astronomy, Longitudinal Human Research, and Microgravity Research, SRVs provide unique capabilities, or unique combinations of capabilities, that better serve specific research activities than existing platforms. Specifically:

- Atmospheric Research: With repetitive, frequent flights through a region of the atmosphere that is rarely measured, SRVs can gather atmospheric data cheaper and more consistently than sounding rockets.
- Suborbital Astronomy: SRVs allow astronomers to place instruments at altitudes that provide access to ultraviolet and infrared spectra. Ground-based telescopes do not provide access to these spectra. Telescopes on SRVs have the potential to be much cheaper than orbital observatories like Hubble for short-duration observations. SRVs are also potentially less expensive than sounding rockets.
- Human Longitudinal Research: Researchers can study SRV passengers and crew to understand physiological responses to microgravity and acceleration transitions that occur over a few seconds to minutes. SRV providers intend to fly numerous passengers with frequent re-flights of pilots. Currently, no other platform provides an opportunity to study gravity transitions on a large population for more than a few seconds, or the effect of frequent flights on the same individual.
- Microgravity Research: SRVs provide a combination of capabilities (low cost, quick access to payloads, multiple minutes of microgravity, human tending, and re-flight) that are well suited for some niche microgravity research applications. Currently, this combination of capabilities does not exist on any other platform.

2. *In your testimony you conclude that, "this will be a commercial marketplace heavily influenced by individual consumers, with, based on our estimate, government at less than 10 percent of total demand." In your opinion what is the price elasticity of the non-governmental demand for these services? How would doubling the current price assumptions change your demand forecast?*

Commercial human spaceflight is the largest non-governmental market sector. For that market, we used our survey of individuals with at least $5 million in investable assets to show the effect of changing prices on demand. We found that among these ultra high net worth individuals decreases in price had a significant and positive impact on demand while increases in price decreased demand at a much slower rate.

For other non-governmental markets outside commercial human spaceflight (including education and media and P.R.), we did not specifically measure price elasticity, but expect these markets to be more sensitive to increases in prices.

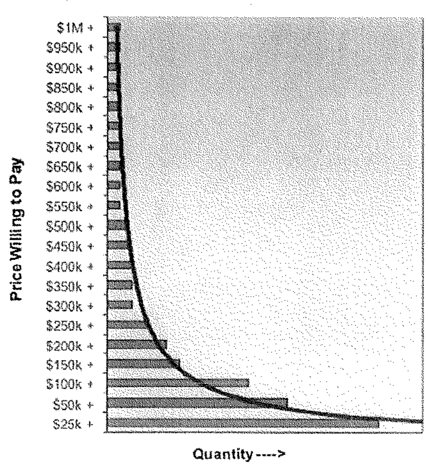


Figure 4: Price elasticity of suborbital tickets for individuals with $5M in investable assets

Questions from Congresswoman Donna Edwards:

1. In your prepared statement, you say that "Student-built projects can fly to space and return, frequent launches allow alignment with academic calendars, and schools can afford likely SRV prices."

- *What are the prices that you estimate would be charged and what evidence do you have that schools can afford those prices?*
- *Why would schools choose to pay for flights when they can engage in STEM flight projects with NASA that do not involve transportation costs?*

What are the prices that you estimate would be charged and what evidence do you have that schools can afford those prices?

SRV developers have not announced prices for educational payloads. Based on interviews and historical data, viable prices would likely be $2,000 to $5,000 for K-12 (cube-sized payload) and typically $10,000 to $20,000 for universities (locker-sized payload), which appears to be consistent with expected prices based on announced plans.

To determine affordability of education payloads, we looked at comparable on going science, technology, engineering, and mathematics (STEM) build programs. One of the largest and widest known non-space STEM programs is the FIRST Robotics Competition. The non-profit FIRST (For Inspiration and Recognition of Science and Technology) organizes the annual 9-12 FIRST Robotics Competition, where students work as teams to build robots that compete in specific tasks, such as stacking bins or basketball. In its first 10 years, FIRST Robotics grew from 28 teams to 600 teams.

In 2012, 2,343 teams competed in FIRST robotics; teams are typically 25 students. Costs per team vary from $6,000 to up to $30,000, depending on the number of competitions in which teams participate.

Why would schools choose to pay for flights when they can engage in STEM flight projects with NASA that do not involve transportation costs?

Based on the success of FIRST Robotics and other STEM build projects, we believe schools will be able to afford these estimated prices for SRV payloads. In addition, based on interviews we conducted, these estimated prices were affordable for some schools.

SRVs do have some advantages over other NASA STEM flight projects, although, as you note, these NASA programs offer free launches, such as NASA's CubeSat Launch initiative and Educational Launch of Nanosatellite programs.

SRVs can potentially enable novel and unprecedented levels of participation by students in space. The frequent launches could enable schools to align projects predictably with academic calendars, an important demand consideration for schools. Furthermore, unlike what is typically the case with ISS payloads, student experiments can be returned to the students. Costs to schools may be lower than orbital alternatives, depending on who is paying for the activity. Space agencies often subsidize orbital education programs.

Developing awareness of the possibilities of SRV education potential among science teachers and developing programs that align with existing curricula will be important for SRV providers to be successful in realizing the potential of the education market.

2. *Your views on the magnitude of the human space flight market differ markedly from that of XCOR. While you view human space flight as the predominant market and other markets such as basic and applied research and aerospace technology and test demonstration as much smaller markets, XCOR sees research and testing markets as eventually surpassing personal spaceflight in four to five years. Can you explain how such different conclusions could have been reached?*

Our baseline forecast reflects predictable demand based on current trends and consumer interest. Uncertainty is embedded in the forecast, as it predicts outcomes related to experiences that, for the most part, do not yet exist. Human spaceflight on SRVs and demonstrated research capabilities of new SRVs will shape attitudes and behavior and change outcomes, as will other factors such as general awareness, perceptions of safety, and media posture.

Within the applied research and aerospace technology test and demonstration markets, our forecast reflects expectations about future government interest in SRVs. In the United States, the forecast predicts modest funding will be transferred from current existing research programs to research on SRVs. Internationally the forecast predicts significant interest in SRV research, with approximately three to six years to implement large, standing SRV programs. The forecast predicts exploratory "what if" research by commercial companies globally. The forecast reflects that no clear commercial application has been identified. Game-changing unknowns such as price reductions, research discoveries, faster uptake by international customers, and commercial applications were not estimated, but could significantly increase demand.

3. *To what extent can the requirements for NASA-supported microgravity research, including altitude be met by commercial RLVs? What is the basis for your assessment that there is a market for microgravity research on commercial RLVs?*

Current NASA-supported microgravity research is conducted on the ISS and primarily consists of human research to support future exploration activities and some long duration physical experiments to support future technologies. These activities are not well aligned with SRV capabilities and were not included in our forecast. (We do forecast research through the independent National Space Biomedical Research Institute, which receives NASA funding; and aerospace technology tests and demonstrations sponsored by NASA's

Flight Opportunities Program.) CASIS, a nonprofit organization that evaluates research aboard the ISS, is evaluating the use of SRVs as a precursor to ISS research.

In the commercial microgravity research market, we concluded there is interest by research companies and organizations to sponsor small, low cost, exploratory experiments. (Typical budgets for exploratory projects are likely to be from $10,000 to $30,000 per experiment.) We predict exploratory commercial research will start slowly and increase to a total of about $5 million annually. We based this conclusion on numerous interviews with individuals from research-intensive industries, including biotech, pharmaceutical companies, and technology-focused venture capital firms, which indicated companies are unlikely to spend more than $100,000 on research without a clear economic outcome, but many companies are willing to conduct "what if" experiments to find an economic application while training and energizing their workforce.

4. *What is the basis for your statement that longitudinal human research would be better served by suborbital research vehicles than by existing alternatives, given the very short duration of microgravity exposure?*

Longitudinal human research uses many research subjects to determine how humans across a variety of demographics respond. Only about 500 people have traveled to space, and few have traveled to space commercially. The vast majority were professional astronauts and cosmonauts on government missions. Although SRVs provide a much smaller duration of microgravity compared to orbital systems, there are interesting physiological changes, such as vascular responses, that occur in the first few minutes of gravity transitions. SRVs will allow researchers to probe these responses with a broad sample pool composed of men and women across all age groups and a range of physical conditions.

Responses by Dr. Alan Stern

Questions for the Record
Chairman Steven Palazzo

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Space and Aeronautics Subcommittee Hearing
August 1, 2012

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1. Please elaborate on the differences and similarities between the internal and external payload markets for commercial suborbital vehicles, and explain which you expect will be larger, and why.

The primary applications I foresee for external payloads aboard commercial suborbital vehicles (CSVs) will be atmospheric sampling, atmospheric sonde release, passive and active atmospheric remote sensing in the UV and IR portions of the spectrum, certain types of radiation monitoring, UV and IR astronomy and solar physics payloads, and technology testing of sensors of the types just described. This market segment is presently retarded because few of the CSV manufacturers have made the vehicle modifications needed to carry significant external payloads.

While there are many external payloads and research investigations that can be envisioned from CSVs in the longer term, all of the CSV vehicle manufacturers are now preparing their vehicles to conduct internal research activities inside their cabins from the beginning of commercial operations forward. The primary applications of internal payloads are much broader than the applications for external payloads, with a likely much broader number of experiments to be performed on a regular basis. These include studies of human and animal model adaptation to microgravity, studies of human and animal model response to the near-space radiation environment, visible and near-UV/near-IR astronomy and solar physics applications, microgravity fluids, microgravity fundamental physics and chemistry research, microgravity flammability and materials processing research, atmospheric/ionospheric imaging at visible and near-UV/near-IR wavelengths, space operations research, the development of zero-G techniques and procedures for application on the ISS, technology testing of payloads, and education and public outreach payloads. Some of these applications, such as the ability to study the "ignorosphere" in situ, is unique to the CSV platform's altitude range, while others benefit from the 10-to50 times increased flight frequency that CSVs offer over conventional sounding rockets.

Questions for the Record
Congresswoman Donna Edwards

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Space and Aeronautics Subcommittee Hearing
August 1, 2012

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1. Your prepared statement notes that the ability to fly researchers with their payloads *"will further reduce experiment development costs, and increase experiment reliability, by eliminating the need for expensive experiment automation that has for too long been common in space as a substitute for the researcher or educator being able to be there themselves."* What do researchers hope to do in the short time that the experiment will be operating in suborbital space?

There are numerous answers to this question; I will limit my response to some of the major activities researchers will be involved in aboard these vehicles. These include: Controlling their experiments (thus avoiding the cost and complex testing required to automate the experiments, e.g., providing pointing toward targets out the window, manipulating controls in response to data being taken as one does in the laboratory environment); serving as human test subjects in experiments studying human adaptation to microgravity; manipulating samples in fluid and furnace experiments as is done on the ISS; and conducting educational demos for classrooms. Concerning the "short" timeframes involved, that these timescales are no different than researchers are used to for many kinds of science, such as most solar eclipses and stellar occultations observed by groundbased telescopes, many kinds of auroral science, and studies of tornados and lightening; in fact, the suborbital research period available is an order of magnitude longer than any microgravity drop tower experiment comparable to almost all NASA sounding rocket flights.

2. What are NASA researchers' requirements for microgravity research, including altitude, and to what extent can these requirements be met by commercial RLVs? What is the basis for your assessment that there is a market for microgravity research on commercial RLVs?

The requirements for microgravity research are the length of time in microgravity and the quality of the microgravity. Every suborbital flight is expected to provide 5-10x the amount of microgravity time currently available in a single parabola aboard a "zero-G" aircraft, with consequent microgravity quality that is also 10 to 100 times cleaner. The reason for the longer experiment times is the higher altitude these vehicles can reach, which creates longer "hang times." The reason for the better quality of microgravity is the absence of aerodynamic disturbance forces that buffet zero-G aircraft but will not affect suborbital vehicles because of their high altitudes. The basis for this assessment that there is a market is two fold: first, the high but unaffordable demand we already see for microgravity research on the ISS, and second, the voices of the hundreds of researchers who are attending NSRC suborbital meetings to explore the applications of the new generation suborbital vehicles.

3. What issues need to be addressed when deciding on the merits of proposed research and the appropriate platform for that research [e.g., balloon, sounding rocket, ISS, commercial RLV]?

Researchers will make these assessments themselves, choosing the most appropriate vehicles for their particular research, so that their proposals will fare well in peer review panels. Researchers who make bad choices of platforms will likely not see their proposals accepted. The research community has been successfully practicing this kind of thinking for decades already, e.g., choosing which groundbased or spacebased assets to use for a given astronomical experiment, choosing zero-G aircraft vs. various ISS experiment facilities for microgravity science; this is entirely within the present state of practice.

4. A 2010 National Academies report on NASA's suborbital program included discussion on the use of commercial RLVs for scientific research and educational training. With respect to commercial suborbital platforms, the report stated that: "*the environment is so benign that many of the challenges of spaceflight do not apply (e.g., autonomous execution, thermal stress, radiation, high-g launch environments, high reliability, and so on) and the process for gaining access to space could become so straightforward that the applicability of the educational experience to the NASA way of doing business will be diffused.*" What is your response to this statement in the National Academies report?

I agree with this endorsement, commercial RLVs will likely revolutionize our ability to frequently access the space and microgravity environments, allowing many more research experiments than are currently feasible and opening up new kinds of research that were not previously feasible (e.g., studying dozens to 100s of test subjects each year as they adapt to microgravity; performing 100s to 1000s of microgravity experiments per year; sampling and otherwise studying the upper atmosphere on a daily basis, and routinely testing payloads in the space environment before they are committed to flight on the ISS or expensive satellite missions, to name just a few examples.

Responses by Mr. George Whitesides

Responses of Virgin Galactic to the Written Questions of Chairman Steven Palazzo

1. **Please elaborate on the concerns expressed in your prepared testimony about the effects of uncertainty of export control regulations.**

Virgin Galactic recognizes and fully supports the need for export control regulations and practices, which help ensure the security of the nation and the preeminence of America's innovation economy. However, as noted in our prepared testimony, the authors of the relevant regulations and practices could never have foreseen businesses such as Virgin Galactic. The longstanding U.S. Non-proliferation export control policy and the Missile Technology Control Regime are a case in point. As such, when export control laws and policies are applied to us, the situation often resembles that of the proverbial square peg and round hole.

These circumstances are suboptimal for our company in two respects. The first is in slowing our progress, particularly as our company first started. Virgin Galactic and our contractors are proudly using and developing American technology, but many of our earliest employees were British experts in train and airline operation, who possessed unique and highly relevant expertise to benefit our American enterprise. Ensuring our full compliance with all relevant laws meant keeping this staff at arm's length during the critical early days of the company.

More importantly, current regulations and the enforcement thereof have limited our ability to generate revenue, and will continue to do so, potentially to a dramatic extent. On a regular basis, we receive inquiries from customers interested in purchasing large amounts of future spaceflights if those spaceflights could be conducted abroad, even if only on brief "sortie" missions conducted by a US-based crew on a US-based vehicle. Virgin Galactic has denied these requests, sacrificing revenue, due to concerns about the large expense and uncertainty associated with the relevant export control processes.

As our vehicles transition from flight test into commercial service, such requests and the revenue streams they represent are likely to become larger and more frequent. Ultimately, restrictions that only allow us to operate our vehicles within the United States, or which render attempts to do so untenably expensive due to bureaucratic requirements, will cap our companies growth and prevent us from generating revenue for our American workforce. Such restrictions would have an even greater impact on our potential future products, such as a suborbital point-to-point transportation system.

Responses of Virgin Galactic to the Written Questions of Congresswoman Donna Edwards

1. **Is the slower than expected progress by the commercial suborbital reusable launch vehicle industry and delay in meeting estimated initial operational dates a result of financial (investment), technical, or regulatory challenges?**

Although we cannot speak for other companies, the timelines for Virgin Galactic stem mainly from deliberate choices made to value safety and quality of our spaceflight experience over the expediency of an early first flight.

Although no one could be more eager to see SpaceShipTwo enter into commercial service than we are, our team recognized from an early date that cutting corners in a way that would sacrifice safety or detract from the life-changing experience our future astronauts expect was simply not an option. For that reason, at many junctures between the original 2004 establishment of the eight year learning period and now, we have elected to conduct extra design cycles, conduct more test flights, and build in extra precautions into our system, even if this meant accepting a slip in the schedules that we anticipated in the earliest days of this industry. In addition, the team chose to build a bigger spaceflight system that permitted more customers per flight and a greater volume in which to experience weightlessness.

We are fortunate to have had the support of our customers and our investors in those decisions, and have made them in confidence that Congress would react favorably to our safety-oriented decisions.

2. **What do your commercial business plans assume as to the frequency of flights and flight operations? To what extent do you believe the estimated market demand can support and sustain those assumed flight frequencies and what is the basis for your belief?**

Our business plan incorporates a number of scenarios for how our frequency of flights may change over time, depending both on market demand and on our available supply.

It is clear from both the design of our space flight system and from the strong level of demand demonstrated by the more than $70 million in deposits we have already collected that even in the earliest days of our commercial operations, our flight rate will exceed the highest flight rate ever demonstrated by any human spaceflight system. As future SpaceShipTwos and WhiteKnightTwos enter into service, we will be able to increase that flight rate until we are flying much more frequently than any vehicle ever has to date. Our large backlog of customer orders gives us high confidence that demand will match that supply, even under conservative assumptions.

3. **How are issues being handled regarding liability associated with research payloads operating on suborbital flight that may carry humans, spaceflight participant liability, and third-party liability? To what extent will advertised ticket prices reflect the cost to the company of liability insurance?**

At present, Virgin Galactic does not plan to fly "mixed flights" of astronauts and research payloads (although, pending regulatory approval, exceptions may be made for certain minimal experiments such as bio-monitoring vests worn by spaceflight participants for research purposes). It is anticipated that at some point, researchers will fly alongside their payloads, but it is not expected that experiments and uninvolved spaceflight participants would have share a flight.

For all flights, regardless of whether payloads or spaceflight participants are on board, Virgin Galactic will comply with the insurance requirements levied by the Federal Aviation Administration as part of our launch license(s). Spaceflight participants will be required to sign Waivers of Claims, as required by Part 440.

Our prices have been set based on our understanding of the likely cost to the company of meeting all regulatory requirements. If regulations were to change, or if other circumstances rendered our past understanding inaccurate, it is possible that our pricing would change in the future.

Responses by Mr. Bretton Alexander

Blue Origin Response to
Questions for the Record

The Emerging Commercial Suborbital Reusable Launch Vehicle Market
Committee on Science, Space, and Technology, Subcommittee on Space and Aeronautics

Held August 1, 2012

Response to Questions for the Record (QFRs) submitted by Congresswoman Donna Edwards:

1. **Is the slower than expected progress by the commercial suborbital reusable launch vehicle industry and delay in meeting estimated initial operational dates a result of financial (investment), technical, or regulatory challenges?**

   The current regulatory environment, including informed consent of those planning to ride onboard, does not substantially limit the development of the commercial human spaceflight industry. Blue Origin communicates often with the Office of Commercial Space Transportation (AST) within the Federal Aviation Administration (FAA) to maintain a solid working relationship. Blue Origin was the first company to receive an experimental permit for rocket launches, under which we flew our *Goddard* vehicle in 2006. As mentioned in my testimony, we believe the informed consent regulatory framework is appropriate for commercial human spaceflight for the foreseeable future as we gather actual flight data on the various vehicle designs being developed. The informed consent regulatory regime does not present a substantial barrier to spaceflight development, but another regulatory regime might be of concern to others considering entering the field of commercial spaceflight.

   Spaceflight is a difficult undertaking which demands careful attention to all aspects of development in order to ensure the safety of those on board the vehicles, as well as the uninvolved public. When the first privately developed spacecraft flew into space in 2004, many within the industry expected commercial flights to quickly follow using the same vehicle. Indeed, that was the expectation with the passing of the Commercial Space Launch Amendments Act (CSLAA) in December 2004, establishing the statutory framework for regulation of this emerging commercial spaceflight sector.

   For Blue Origin, development of our *New Shepard* suborbital vehicle is underway and is similarly paced by our technical approach and attention to safety. We believe in an incremental development approach, increasing capability with subsequent vehicle developments. To date, we have flown several demonstration vehicles, including the *Goddard* low-altitude vehicle in 2006-07 and a larger suborbital demonstration vehicle last year in 2011. We are currently developing our next suborbital vehicle.

   While the pace of technical development can be accelerated with greater funding, much of the commercial spaceflight development effort is and should be done at private expense, at the pace that the private investment community can sustain. Public investment to accelerate the commercial space effort should be limited to programs that are able to attract substantial private investment (at least 80% private investment), to make good use of public funds.

2. **What do your commercial business plans assume as to the frequency of flights and flight operations? To what extent do you believe the estimated market demand can support and sustain those assumed flight frequencies and what is the basis for your belief?**

Blue Origin is currently in the development phase of its operations, and has not established flight schedules, pricing, and other operational details.

Blue Origin believes that suborbital spaceflight offers a new capability that provides opportunities for human spaceflight, research and development, and education. As I testified, we believe that people are the game-changing element for spaceflight, with research and science as a viable secondary market. In both cases, safety, reliability, and cost are keys to success. Different vehicles developed by different companies will address these markets, and potentially others, in different ways.

Since the commercial spaceflight market has not yet come into existence, it is difficult to project its potential size. A recent market assessment, *Suborbital Reusable Vehicles: A 10-Year Forecast of Market Demand*, conducted by The Tauri Group, found that the market for a variety of suborbital spaceflight applications is real, sustainable, and sufficient to support more than one provider. Additionally, the study found that human spaceflight, or so-called space tourism, is the larger market. These projections match our internal estimates, but we also recognize the inherent difficulty of attempting to characterize the size of an immature marketplace.

3. **How are issues being handled regarding liability associated with research payloads operating on suborbital flights that may carry humans, spaceflight participant liability, and third-party liability? To what extent will advertised ticket prices reflect the cost to the companies of liability insurance?**

Blue Origin is in the vehicle-development phase, and has not yet established its policies for flights of research activities alongside space flight participants.

As mentioned in my testimony, Blue Origin believes that human spaceflight will be the primary activity for our suborbital vehicles, with science and research activities comprising a secondary market. Blue Origin has begun a pathfinding program to fly select research experiments that do not require humans to be aboard. With respect to these pathfinding experiments, Blue Origin's current policy requires that the proposed science and research payload undergo a safety review process, working with the payload provider to determine if the payload poses undue risk to the spacecraft. These pathfinding research institutions have also assumed the risk that their experiment hardware may be damaged during a flight.

A separate review is made to mitigate any possible harm to third parties (also sometimes referred to as the uninvolved public). Blue Origin closely cooperates with FAA in this review. Under the permitting and launch licensing process, the FAA assesses the impact on planned operations of the vehicle, both nominal and off-nominal operations.

In past launches, Blue Origin has obtained insurance policies from an underwriter with respect to potential third-party liability. Blue Origin has not yet entered into substantive discussions with insurance underwriters concerning potential coverage of space flight participants or research experiments. Blue Origin intends to work with the insurance community to obtain the appropriate level of liability insurance for planned suborbital flight activities.

4. **You advocate in your prepared statement for extending the informed consent approach to passenger safety indefinitely, or at least until spaceflight is sufficiently routine. While some enthusiasts may be willing to take on risks, does this not force researchers to fly under the informed consent rules? Having been on NASA's Advisory Council, has the Council addressed this issue and provided input to NASA? What key points were brought up?**

As I mentioned in my testimony, Blue Origin believes that the informed consent approach to passenger safety is appropriate during the development phase for the new commercial human spaceflight industry. Under this approach, individual spaceflight participants are allowed to make their own decisions on how best to assess their own safety in the inherent challenges of spaceflight. We believe the informed consent approach should be extended indefinitely, at least until spaceflight is sufficiently routine that it merits the commitment of regulatory resources and we can be confident that the top-down regulatory approach will prove safer than allowing informed individuals to make their own decisions.

The early imposition of a top-down regulatory approach could do great harm to development of a commercial human spaceflight industry. A top-down approach implies a guarantee by the government of an expected level of safety sufficient to protect the uninformed passenger, as it does in aviation, highways, and other forms of public transportation. Aviation, highway transportation, and other forms of public transportation reached a high level of technical maturity and standardization before the government imposed the current regulatory regime. However, commercial space flight has not yet reached a similar level of technical maturity, nor is there a clear projected date when it will reach such a level. As a result, the government does not yet have, nor is there a projected date when it will have, sufficient information to undertake comprehensive regulation of 'passenger' safety. For the government to attempt such a regulation in the foreseeable future would require adopting a regulatory regime which is more likely to limit safety improvements, rather than further them.

The informed consent regime, however, allows individuals to understand the inherent risks of spaceflight, the design of the vehicle on which they choose to fly, and the performance history of that vehicle and operator, and then to make an informed choice whether to take the flight themselves. The informed individual flyer is best able to manage his or her own risk tolerance in the inherent challenges of spaceflight.

Researchers who choose to fly with their research payloads during the early years of the commercial spaceflight industry would fly under the same informed consent framework as other spaceflight participants. We plan to inform researchers of the risks of flying into space to conduct research, so that they may also make a voluntary, personal decision about the level of risk they are willing to assume in the hostile environment of space.

Hazardous research environments are nothing new. Despite the inherent risks, notable scientific research is currently being conducted in many hostile environments, including underwater submersibles, mountain tops, underwater caves, Antarctica, hurricanes, and animal habitats (see pictures below). Researchers expose themselves to personal risk inherent in these hostile environments and make an informed decision about how best to gather scientific data. Similarly, for studies that might benefit from the unique environment of spaceflight, the decision of how best to collect science data, and whether to accompany an experiment into space, would rest with the individual researcher.

With respect to my time on the NASA Advisory Council (NAC), I do not recall any discussion of researcher risk for suborbital or orbital spaceflight. Discussions of the risk to occupants participating in spaceflight activities were typically confined to assessments of NASA's proposed certification of Commercial Crew vehicles for transport of NASA astronauts to and from the International Space Station.

Attachment: Photos of Scientific Research in Hostile Environments

Figure 1 – Human Occupied Vehicle *Alvin*. The Woods Hole Oceanographic Institution notes *Alvin* has transported over 2,500 researchers on more than 4,400 dives to depths of 14,764 feet (over 2 ½ miles deep).
Source: Woods Hole Oceanographic Institution website http://www.whoi.edu/alvin/, accessed 29 August 2012

Figure 2 – Researchers collecting ice cores on Mt. Everest as part of the study of paleoclimate conditions
Source: Climate Change Institute website http://climatechange.umaine.edu/Research/projects/paleoclimate.html, accessed 29 August 2012

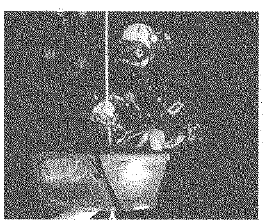


Figure 3 – Cave Diving to collect unique species for scientific study. "It's about cutting-edge science that gives us important data about our climate and reveals a lot about the Eden of now-extinct animals that once lived on the islands of the Bahamas. But blue holes are immense, flooded caves, and the only way to explore them is through the dangerous sport of cave diving."
Source: PBS Nova, *Risking It All For Science*, available at: http://www.pbs.org/wgbh/nova/earth/risky-science.html, accessed 29 August 2012

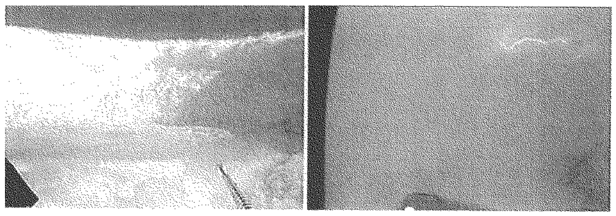


Figure 4 – Left: Research aircraft in the eye of Hurricane Katrina; Right: Research aircraft in Hurricane Felix
Source: *NOAA Aircraft Operations Center Science Section "Hurricane Hunters"* available at:
http://flightscience.noaa.gov/hurricanes.html and http://flightscience.noaa.gov/virtual_hunt.html, accessed 31 August 2012

Responses by Mr. Andrew Nelson

Q&A Pertaining to "The Emerging Commercial Suborbital Reusable Launch Vehicle Market"

Questions for the Record
Chairman Steven Palazzo

Answers For the Record
Andrew Nelson,
Chief Operating Officer, XCOR Aerospace, Inc.

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Space and Aeronautics Subcommittee Hearing
August 1, 2012

1. Your testimony explains that your company's "...vision starts with the premise of human settlement and economic prosperity from space-based businesses and ventures that may drive prosperity for generations. In the not too distant future, we envision humans creating sustainable businesses in space, settling other bodies in our solar system, and in the distant future, even perhaps going beyond our solar system." What are some examples of the sustainable space-based businesses you envision?

   XCOR Response: With a significant decrease (1.5 to 2 orders of magnitude) in cost to launch mass to low Earth orbit (LEO), enabled by fully reusable systems, and the ability to launch that mass on a daily or weekly basis safely and reliably, I believe there are numerous businesses that will flourish in LEO, or will serve the LEO market, and then eventually expand outward to further locations in our solar system. These businesses will either be extensions of existing terrestrial or space industry sectors or in some cases entirely new businesses that are specific to LEO. Below are five examples of potential multi-billion dollar market opportunities that could emerge fairly soon (5-15 years) after launch cost to orbit drops substantially. There are probably more, but these are good examples of what the future could hold given fully reusable launch systems.

   Taking Existing Businesses to LEO:

   (a) Communications -- There are currently significant resources spent on providing communications from space based platforms. However, the satellites are characterized by great size, weight and surprisingly old technology. There are several factors which have caused this dysfunctional market to not follow or mirror the traditional pattern of technology maturation (Moore's Law or its various facsimiles). But with dramatically cheaper and more plentiful launch, the underlying economics of satellites should start to follow a math like other communications markets have enjoyed – i.e., a steady progress towards smaller, faster, more powerful, and more capable systems. In the very near term this may be embodied by global corporations or entities owning and operating their own secure voice and data constellations of micro or nanosatellites for less money and higher reliability than they currently lease transponder time..

(b) On-Orbit Manufacturing / Research Laboratories – Robert Bigelow has already launched two subscale inflatable habitats that are circling the world. He has also reported that he has six or seven sovereign clients who wish to utilize his planned full-sized stations for research. In another application of on orbit facilities, it has been proven by NASAand other research organizations that certain protein crystals used in oncology research and drug discovery appear to grow larger, more purely, faster and with higher yield than similar protein growth processes on Earth. These proteomic processes are currently multi-billion dollar industries on Earth, and dramatically improved access to space could ensure a higher quality product for similar if not lower total cost. A Texas company is doing research on the ISS right now to manufacture stronger antibiotic compounds. I believe these on orbit applications could represent multi-billion dollar opportunities, but they require much easier, cheaper, and plentiful access to space.

(c) Space Based Solar Power – Renewable, clean power generation at the same price or less than today's fossil or nuclear sources is an admirable objective. Further, space based solar power was recognized by the US DoD in 2007 in a report from the National Security Space Office as having the potential to "lessen the chances of conflict due to energy scarcity by providing access to a strategically secure energy supply" among other tactical, strategic and humanitarian benefits. NASA has further performed several studies, and as late as 2012 has awarded new NASA Innovative Advanced Concept (NIAC) contracts to investigate the practical application of space solar power. Assuming significantly lower launch costs from fully reusable systems, more frequent access to space, and self assembling structures (already proven by NASA at a smaller scale), space-based solar power could become multi-tens-of-billions of dollars reality, and secure our energy independence for the imaginable future.

Future New Businesses --

(d) In-space fuel depots – A key architecture pre-requisite for sustainable deep space exploration and industrialization of cis-lunar space is moving towards semi-reusable in-space transportation, enabled by orbital or other in-space fuel depots. This market could be one of the early anchor tenant applications that would justify significant private sector investment in fully reusable orbital vehicles.

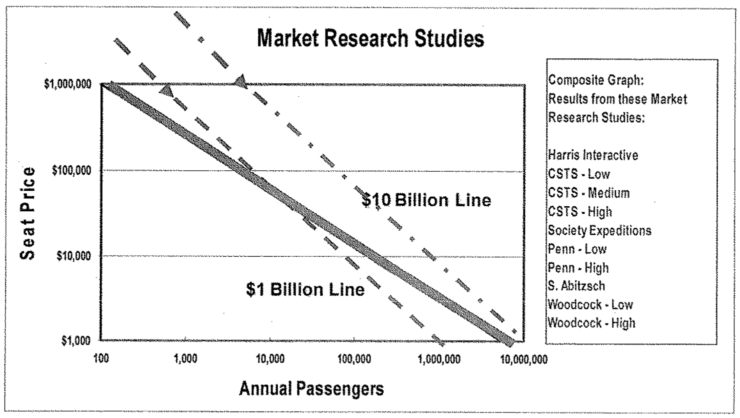
(e) Debris Mitigation companies – as we utilize LEO and MEO for more and more applications, the expansive challenge of debris mitigation will drive new and innovative approaches to cleaning up 50 years of dumping hardware in orbit.

2. Until routine flights can be accomplished actual costs may be difficult to predict. In your opinion what is the price elasticity of the non-governmental demand for SRV services?

How would doubling the current price assumptions change your demand forecasts?

XCOR Response – This question presupposes that actual costs may not be accurately predicted, and hence demand forecasts must be suspect because of uncertain pricing metrics (i.e., prices may double over initial estimates). XCOR does not share this assumption based upon our significant hands-on experience building and flying two previous generations of fully reusable rocket-powered piloted vehicles. XCOR has a well-founded understanding of the primary cost drivers of our business: fuels, labor, support equipment, insurance, and amortization / depreciation.

With respect to the core of the question, what is the price elasticity of demand for non-governmental sRLV services, we note the exhibit below that was created, we believe, by members of the marketing team at Rocketplane, Inc.. It is an amalgamation of several studies performed over the years that addresses the question of market demand and price. As may be seen, there is an expectation of a relatively elastic market below $100,000 per seat. While actual data for space tourism is limited, we believe that XCOR's relative success at selling flights and smaller science payload slots (at $95,000 seat prices) over just the past several months demonstrates that competitive prices and service convenience will stimulate demand.



3. In your testimony you expect that scientific and industrial markets will surpass the personal spaceflight markets in four or five years. What is the basis for this estimate? Who do you anticipate will fund the instrument development for those payloads?

XCOR Response: Our optimistic assessment of this market segment is based on: (a) actual customer sales to date, (b) insights into customer markets and planned budgets of customers that we speak to regularly, and (c) projections based on established methods to determine network effects in technology and technology based service markets. With respect to who will fund instrument development, it depends on the customer. We are seeing private sector funding of experiments and flights, without government inducement. We are also seeing a large number of government or government funded researchers seeking information on the XCOR platform, and how they may access the platform through pre-negotiated government contract vehicles. In general, we believe SRVs will initially attract existing or modified instruments and experiments that would either fly on other airborne or rocket platforms, just more expensively and less often, or would not get to fly at all. But once scientists and other researchers see that they can rely on frequent, affordable, and repeatable access to the space environment, they will start to migrate some of their data collection (or at least technology-maturation for in-space data collection) to SRVs.

Questions for the Record
Congresswoman Donna Edwards

Answers For the Record
Andrew Nelson,
Chief Operating Officer, XCOR Aerospace, Inc.

The Emerging Commercial Suborbital Reusable Launch Vehicle Market

Space and Aeronautics Subcommittee Hearing
August 1, 2012

1. Is the slower than expected progress by the commercial suborbital reusable launch vehicle industry and delay in meeting estimated initial operational dates a result of financial (investment), technical, or regulatory challenges?

XCOR Response:

At XCOR we believe a combination of several factors have slowed progress on the introduction of commercial sRLV services, but the majority of them are finance-related. However, we do believe that those services are now 12-18 months away based on reported developments from other industry actors and our own internal progress. There is one caveat, however: services may be further delayed (and their ramp-up dramatically slowed) should the regulatory regime suddenly change to one predicated on conjecture and subjective rule-making versus standards based on actual experience.

The Economy: A primary reason XCOR believes suborbital services have been slower to progress than originally predicted is the severe global economic downturn C=which began in late 2007 and accelerated greatly in 2008 and 2009. This economic crisis included several challenges which caused programmatic delays for XCOR and others in the industry, including: the freezing of capital markets, a drastically reduced risk appetite among customers and investors, and a shrinking of the supply chain for critical components and subcomponents, due to the failure of businesses caught in such dramatic circumstances. Many of these problems, while improved from 2008-2011, still linger today due to significant uncertainty in global capital markets.

Non-Traditional Investment Sector: Another contributing factor to the slower than expected progress is the fact that the traditional sources of capital for entrepreneurial ventures are not (yet) conducive to the space community. The space market, let alone the suborbital space market, is not a typical investment area of the venture capital (VC) community. It is quite rare when a space company such as XCOR, which is not backed by billionaires or centi-millionaires, can find a venture partner with aerospace experience, who has a fund that allows aerospace investments in the fund's mandate (prospectus), and who is willing to take the risk to invest their limited resources in an aerospace venture. If a company like XCOR does find such a person at a VC fund, the company must obtain a meeting, proceed through due diligence, and then face most funds' requirement that investments be made by consensus of all of the partners. Given the VC industry's traditional focus away from aerospace ventures, and the described industry hurdles, the probability of an aerospace company making it through all of these gates and being funded by a traditional VC is quite remote, particularly in the current environment.

VC Environment Changing For The Good: XCOR does believe that this constrained VC investment environment is changing due to the fundamental shift in government policy towards space transportation (suborbital flight purchases, commercial cargo to ISS and commercial crew), the success of companies like Space Exploration Corporation (SpaceX) and Virgin Galactic in the commercial markets, and the successes XCOR is having with our own development and commercial programs. Should SpaceX or Virgin Galactic file their S-1's and be successful in their initial public offerings (IPOs), then it could signal the beginning of a new era in investing by institutional venture firms, much like the Netscape IPO started the rush to invest in internet businesses. But this breakthrough has not yet happened.

Technology Maturation Took Longer Than Expected: Technology development and maturation has been an issue in the introduction of new suborbital reusable launch vehicle (sRLV) operations since the passing of the CSLAA of 2004. It has been widely reported that several well-funded, and not so well funded, companies in the field have had schedule setbacks in their technology maturation programs. This should be an expected outcome when new entities are trying to do new, leading edge projects, especially when the activities involve human safety. Accidents will, do and have happened that cause loss of vehicles, loss of lives, and setbacks to programs. It is an expected outcome in the maturation process that is part of the American DNA of risk taking for the greater good, and should be embraced and enabled for the betterment of our society.

Regulatory Environment Has Been Very Supportive to Date: The one area mentioned in the question above that has not been a detriment to development thus far has been the regulatory environment put in place in 2004 by Congress. In fact, the presence of the "Informed Consent" and "Learning Period" environment has actually promoted the industry, and XCOR believes that it has been an enabling influence on what investment there has been made to date. Further, the environment has promoted the rapid evolution of experience and technology development not seen in other, more highly regulated industries, thereby enabling faster safety innovation. The continuation of this environment is necessary to continue to improve safety and the economic impacts on our society that have been projected by many independent studies.

Negative Regulatory Change Now Would Severely Curtail sRLV Markets: Should there be a significant change in the sRLV regulatory regime, for example if the learning period is not extended to last for at least eight years after the first commercial sRLV flights, there could be significant negative impact on the introduction and evolution of suborbital flight services. No one in industry opposes regulation based on real world data showing that a problem exists. What industry leaders, and the investors standing behind them, are afraid of is regulation based on speculation or theoretical analysis of potential problems. This fear of unpredictable and unjustified regulation is what could slow or stop new investment and therefore innovation by this industry, which would dampen or reverse the creation of new jobs, more plentiful and affordable access to space for scientists, educators, and even students, and the strategic scientific, economic, and national security benefits of a revolution in space transportation.

2. What do your commercial business plans assume as to the frequency of flights and flight operations? To what extent do you believe the estimated market demand can support and sustain those assumed flight frequencies and what is the basis for your belief?

XCOR Response: XCOR has designed the Lynx suborbital vehicles to fly up to four times per day, six days per week. In a 52 week year, this would imply a maximum flight rate of 1248 flights per year. However, such a maximum rate ignores various weather and wind delays, public holidays, and a variety of other factors. Taking those into account, we believe the realistic maximum flight rate per year of a Lynx vehicle is between 600-1000 flights, with the bulk of the dependencies on weather related phenomenon.

That said, demand does not need to match (or even approach) maximum flight rate for a Lynx operation to be economically viable and a good business. The critical determination of economic viability lies in the complex interaction between pricing, cost, and elasticity of demand. XCOR believes, based on our sales to date, past experiences operating rocket powered winged vehicles, our established supply chains, and extensive customer interactions, that a Lynx vehicle will be the most profitable sRLV in the marketplace on a per participant basis, and the breakeven point for a Lynx vehicle wet lease investment is substantially less than the maximum flight rate of the vehicle.

3. How are issues being handled regarding liability associated with research payloads operating on suborbital flights that may carry humans, spaceflight participant liability, and third-party liability? To what extent will advertised ticket prices reflect the cost to the companies of liability insurance?

XCOR Response: There are a number of insurance carriers that will cover all flights on Lynx at a reasonable cost. The ticket prices published for personal spaceflight and research missions factor in actual price quotes XCOR has received from our insurers, based on existing legal requirements as promulgated into the Code of Federal Regulations after the original enactment of the CSLAA in 2004. Should these insurers drastically change their pricing, XCOR reserves the right to change our prices.

4. Your views on the magnitude of the human space flight market differ markedly from those in The Tauri Group Forecast of Market Demand. While the Tauri assessment views human space flight as the predominant market and other markets such as basic and applied research and aerospace technology test and demonstration as much smaller markets, XCOR sees research and testing markets as eventually surpassing personal spaceflight in four to five years. Can you explain how such different conclusions could have been reached?

   XCOR Response: Our assessments are based on: (a) actual customer sales to date, (b) insights into customer markets and planned budgets of customers that we speak to regularly, but which the Tauri Group did not survey, and (c) projections based on established market analysis methods to determine "network effects" in how technology and technology-based service markets adapt to and adopt new approaches/tools, methods that were not used by the Tauri Group.

Responses by Dr. Stephan R. McCandliss

Follow-up Testimony of Stephan R. McCandliss
Research Professor in the Department of Physics and Astronomy
The Johns Hopkins University

Given in Response to Additional Questions from the Subcommittee on Space and Aeronautics, House of Representatives
Following the Hearing on -
The Emerging Commercial Suborbital Reusable Launch Vehicle Market

September 05, 2012

Mr. Chairman and Members of the Subcommittee, thank you for allowing me to respond to your insightful questions. I note, the opinions expressed herein are my own and do not necessarily reflect the views of the Johns Hopkins University.

I have been asked to respond to the following six questions: two from Chariman Palazzo and four from Congresswoman Edwards.

Questions from Chairman Palazzo:

1. In your response to a question from Rep. Edwards you briefly mentioned that your research is incompatible with human suborbital missions. Would you please elaborate and also explain the altitude requirements with respect to proposed SRVs?
2. Ms. Christensen's testimony suggests that suborbital astronomy would be better served by SRV's than by existing alternatives to access infrared and ultraviolet observations from above the atmosphere. From your experience would you please elaborate on the unique requirements for IR and UV experiments, and the usefulness or lack thereof of proposed SRVs?

Answers for Chairman Palazzo:

1. My research is incompatible with human suborbital missions for a number of reasons:
   1.1. The current crop of proposed SRVs don't fly above 100 km. We don't even open our payload until we reach 120 km. Our flights typically reach 300 km and even then we only get approximately 400 seconds of exoatmospheric time for our observations. We would like even more. Simply put, the proposed SRVs touch space but don't really go into it for any useful length of time.
   1.2. We require a vacuum environment for operation. Being inside a cabin full of breathable atmosphere defeats the purpose.
   1.3. My experiment, without the NASA contractor supplied support, has a mass of approximately 200 kg and is more than 2 meters long and ½ a meter in diameter. It is difficult to envision how such mass and volume could be accommodated,

along with a human attendant and life support system, with the envisioned SRVs.

1.4. We require a fine pointing system capable of staying on target to within 1 arcsecond (the width of my thumb at 3.25 miles) as we fly along a parabolic arc. I doubt the SRV developers have such a device, even on the drawing board, capable of handling the mass and volume we require.

2. UV experiments require the vacuum of space that can only be found above 120 km to avoid absorption of UV light by oxygen molecules. IR experiments require similar altitudes, not to avoid atmospheric absorption, but rather to get above atmospheric emission by OH molecules. X-ray experiments, another common type of payload, require altitudes in excess of 150 km. The current envisioned crop of SRV's cannot provide the altitudes required for operation of these payloads. In Figure 1, I provide a simple graphic to illustrate this point.

Questions from Congresswoman Edwards:

1. Your testimony references the benefits of NASA's suborbital research program for training the next generation of scientists and engineers and for helping to develop the systems engineering skills so critical for leading space missions.
    - To what extend do you think you will be able to provide that same level of training and skill development with commercial reusable suborbital systems?
    - What do you consider to be the major differences?
2. Dr. Stern said in his statement that the ability to fly researchers with their payloads *"will further reduce experiment development costs, and increase experiment reliability, by eliminating the need for expensive experiment automation that has for too long been common in space as a substitute for the researcher or educator being able to be there themselves."*
    - Do you agree that experiment automation is expensive?
    - Would flying with your payload provide advantages to your research or not?
    - What impact would the limited flight time and the time required for physiological adjustment to microgravity have on the ability of researchers to have meaningful interactions with their payloads?
3. At the hearing, Ms. Christensen identified suborbital astronomy, including access to infrared and ultraviolet observations, as an area that will be *"better served by SRVs than by existing alternatives"*. If not, why not?
4. During the hearing, several of the panel's responses alluded to the merits of different platforms for performing research. You indicated that the ability to reach certain altitudes is critical. Could you provide the Subcommittee with a graphical representation of apogees fro the various vehicles so that relative capabilities are better understood?

Answers for Congresswoman Edwards:

1.

1.1. The training level and skill development that our students receive in preparing and launching an experimental payload on an expendable suborbital vehicle (a sounding rocket), utilizing the unique facilities provided by the NASA Sounding Rocket Project Office through its commercial contractor, NSROC, is simply not unavailable anywhere in the world. It provides a unique avenue for new science, enabled by new technology and training for the next generation leadership for space science.

1.2. Considering that the SRV providers have yet to launch a vehicle with any sort of extra-vehicular experimental capability, a comparison of expected educational benefits simply cannot be made.

2.

2.1. Automation is used as required by the experiment. These days, it is relatively easy to incorporate cost effective, automated data acquisition methods into an experiment to ease the data-recording burden and increase accuracy. Automation is not the driver of experiment cost, but rather is the innovation we often seek.

2.2. The ability to fly with our payloads would provide no benefit. It would be detrimental, as the mass of the experimenter would have to be subtracted from the available mass for the payload. We already have the means to interact with our payloads remotely, in real-time, from the ground, via a mature command uplink system.

2.3. The SRV flight time is so limited as to be completely inadequate for carrying out any research, never mind the hindrance of physiological adjustment to microgravity.

3. This is a hyperbolic statement. Without significant access to altitudes above 100 km the commercial SRVs cannot even begin to compete with the capabilities of the existing stable of suborbital vehicles maintained by the NASA Sounding Rocket Project Office to carryout state-of-the-art UV and IR experiments in astronomy. Moreover, if experimenters had to rely solely on the current planned crop of SRVs to advance the NASA Strategic Plans for the individual Science Mission Directorates, then we would capitulate our leadership in scientific, technical and workforce development for space based research to the rest of the world. The SRV community needs time to mature and develop their capabilities, but at present their capabilities fall short of those required by the various experimental communities.

4. The graphic supplied below shows the relative altitudes of typical NASA sounding rockets with respect to the proposed SRVs in the context of various atmospheric parameters. "Space" starts at the thermosphere where atmospheric pressures are eight orders of magnitude lower than at the surface of the earth. The graphic does show that IR and some mid-UV radiation penetrates below 100 km. However, the observation of astronomical objects in these bands from altitudes below 100 km would be severely contaminated by "airglow" emissions. The observation time to acquire meaningful signal would be significantly longer that the duration of the flight.

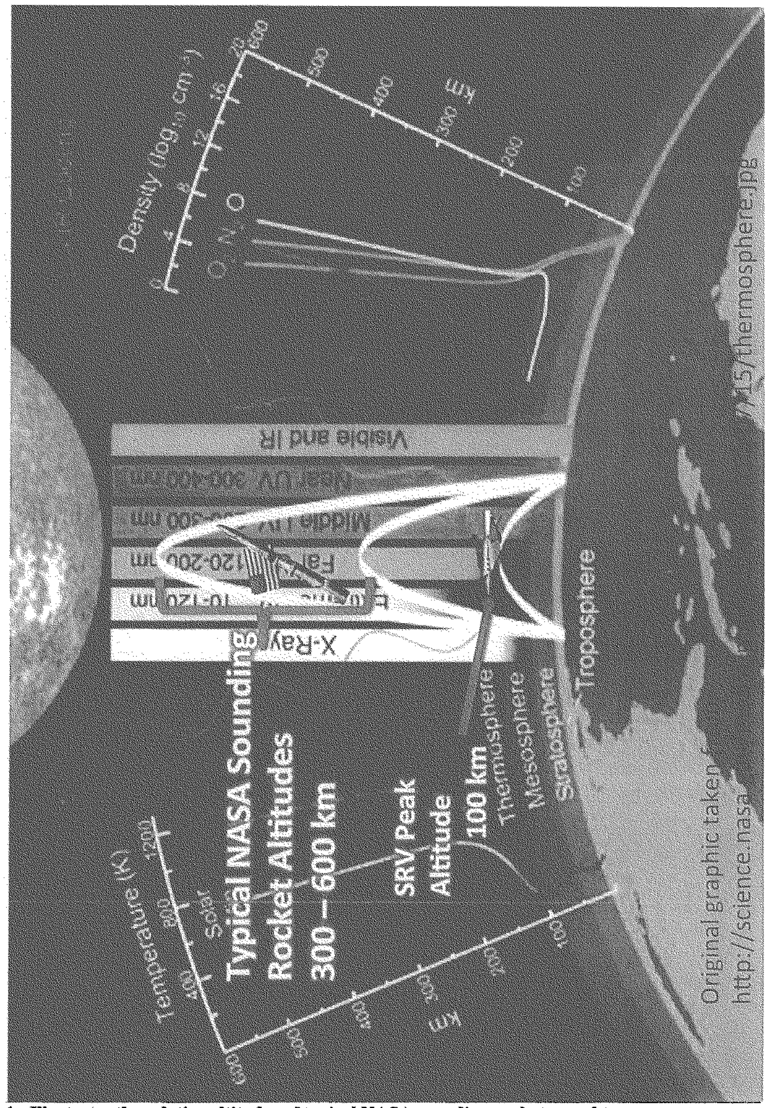


Figure 1: Illustrates the relative altitudes of typical NASA sounding rockets, used to carryout various thermospheric and astronomical research programs, with respect to the peak altitudes planned for the suborbital reusable vehicles (SRVs) that are currently under active development. In particular, IR, UV and X-ray astronomy requires altitudes above 100 km to allow observations that are unattenuated by atmospheric absorption or contaminated by airglow emission.