Supporting Commercial Space Development

Part 1: Support Alternatives versus Investor Risk Perceptions & Tolerances

November 2010

This report, "**Supporting Commercial Space Development Part 1: Support Alternatives versus Investor Risk Perceptions & Tolerances"** was developed with government funding under Contract Order Number NNH11CD08D awarded by the National Aeronautics and Space Administration and may be released by NASA in whole or in part. The views expressed in this report are those of Near Earth LLC and may not reflect the views of the National Aeronautics and Space Administration or the United States Government.

"When a new frontier is opened, the new territory always looks vast, empty, hostile, and unrewarding. It is always dangerous to go there, and almost impossible to live there in loneliness and peril. The technological capacities of the time are always taxed to the utmost in dealing with the new environment. The explorations require huge investments of both public and private funds, and the returns are always hazardous at first…The organization, capital, and equipment required for the first exploratory efforts are so large that people tend at first to think only in terms of governmental and military actions; and only later do they conceive the new territory as simply an extension of their present territory and their present economy….an effort of prophetic imagination is what is required of us as citizens, so that we will not…leave the making of the future to others."

- Ralph J. Cordiner, Chairman of General Electric Company, 1961

CONTACT INFORMATION

For parties wishing to learn more about the report described herein, additional information can be made available.

Near Earth LLC
380 Lexington Avenue, 17th Floor
New York, NY 10016
www.nearearthllc.com

Hoyt Davidson
Managing Partner
(212) 551-7960
hoyt@nearearthllc.com

John Stone
Partner
(646) 290-7796
john@nearearthllc.com

Ian Fichtenbaum
Associate
(646) 290-7794
ian@nearearthllc.com

Table of Contents

1 INTRODUCTION 7

1.1 AUTHORS' QUALIFICATIONS 9
1.2 METHOD AND APPROACH 10
1.3 DEFINITION OF "COMMERCIAL SPACE" 13
1.4 SUMMARY OF NASA OBJECTIVES 15
1.5 SUMMARY OF REPORT SECTIONS 15

2 FINDINGS, CONCLUSIONS & OPTIONS 18

2.1 FINDINGS 18
2.1.1 INVESTOR RISK PERCEPTION 18
2.1.2 INVESTOR INTEREST IN SPACE 19
2.1.3 LESSONS LEARNED FROM PRIOR INVESTMENTS 20
2.1.4 NASA'S COMMERCIAL SPACE SUPPORT PROGRAMS 23
2.2 CONCLUSIONS & OPTIONS 24
2.2.1 IMPROVING PERCEPTIONS 25
2.2.2 FOSTERING INNOVATION 27
2.2.3 SUPPORTING TECHNOLOGY DEVELOPMENT 28
2.2.4 DEMONSTRATING NEW CAPABILITIES 29
2.2.5 VALIDATING MARKETS 30
2.2.6 ENHANCING CAPITAL FORMATION 31

3 RISKS 33

3.1 TECHNICAL RISKS 34
3.1.1 DEVELOPING NEW TECHNOLOGIES 34
3.1.2 DIFFICULTY OF MANUFACTURING AND INTEGRATING SPACE SYSTEMS 35
3.1.3 TECHNICAL OBSOLESCENCE RISK 35
3.1.4 LAUNCH, OPERATIONAL, AND RE-ENTRY RISKS 36
3.2 MARKET RISKS 37
3.2.1 MARKET SIZE 38
3.2.2 MARKET QUALITY AND RELIABILITY 39
3.2.3 MARKET DEVELOPMENT TIMING 41
3.2.4 MARKET LONGEVITY 41
3.2.5 MARKET UNCERTAINTY 42
3.3 FINANCIAL RISKS 42
3.3.1 MAGNITUDE OF CAPITAL REQUIRED 43

3.3.2 TIMING OF CAPITAL REQUIREMENTS 44
3.3.3 INVESTMENT HORIZON AND LIQUIDITY 46
3.3.4 FINANCIAL PROJECTION UNCERTAINTY 48
3.3.5 RETURN ON INVESTMENT 49
3.4 COMPETITIVE RISKS 49
3.4.1 AMOUNT OF COMPETITION 50
3.4.2 NATURE OF COMPETITION 51
3.4.3 BARRIERS TO ENTRY 52
3.5 POLITICAL AND REGULATORY RISKS 53
3.5.1 GOVERNMENT POLICY & SPACE BUDGETS 54
3.5.2 REGULATORY REQUIREMENTS AND COMPLIANCE COSTS 55
3.6 PERCEPTION RISKS 57
3.7 EXECUTION AND OPERATING RISKS 59
3.7.1 MANAGEMENT QUALITY 59
3.7.2 AVAILABILITY OF QUALIFIED EMPLOYEES 60
3.8 RISKS INHERENT IN OPERATING IN SPACE 60

4 INVESTORS 62

4.1 FOUNDERS, FRIENDS & FAMILY 63
4.1.1 DESCRIPTION 63
4.1.2 TYPICAL INVESTMENTS 64
4.1.3 HOW NASA CAN HELP 64
4.1.4 RISK MAPPING 65
4.2 ANGELS AND ANGEL GROUPS 66
4.2.1 DESCRIPTION 66
4.2.2 TYPICAL INVESTMENTS 66
4.2.3 HOW NASA CAN HELP 67
4.2.4 RISK MAPPING 68
4.3 SPACE CAPITALISTS: HIGH NET WORTH SPACE ENTHUSIASTS 69
4.3.1 DESCRIPTION 69
4.3.2 TYPICAL INVESTMENTS 70
4.3.3 HOW CAN NASA HELP 70
4.3.4 RISK MAPPING 71
4.4 VENTURE CAPITAL INVESTORS 72
4.4.1 DESCRIPTION 72
4.4.2 TYPICAL INVESTMENTS 72
4.4.3 HOW CAN NASA HELP 75
4.4.4 RISK MAPPING 76
4.5 PRIVATE EQUITY INVESTORS 77
4.5.1 DESCRIPTION 77

4.5.2 Typical investments 78
4.5.3 How can NASA help 81
4.5.4 Risk mapping 83
4.6 Strategic corporate investors 84
4.6.1 Description 84
4.6.2 Typical investments 84
4.6.3 How can NASA help 86
4.6.4 Risk mapping 86
4.7 Investor risks compared 87

5 INVESTMENTS 88

5.1 Select commercial space and satellite deals 88
5.1.1 Significant Commercial Satellite Financings 88
5.1.2 Significant Commercial Space Financings 89
5.2 Case Studies 91
5.2.1 Rotary Rocket 91
5.2.2 Orbital Recovery 93
5.2.3 BlastOff! 97
5.2.4 NEAP (a project of SpaceDev) 100
5.2.5 Orbital Sciences 102
5.2.6 IOSTAR 105
5.2.7 Beal Aerospace 107
5.2.8 X-33/VentureStar 109
5.2.9 SpaceX 112
5.2.10 Kistler Aerospace (also Rocketplane Kistler) 114
5.2.11 DC-X 120
5.2.12 SPACEHAB 123
5.2.13 XM Satellite Radio (now Sirius XM Radio, Inc.) 130
5.2.14 GeoEye (formerly ORBIMAGE & Space Imaging) 136

6 CURRENT SUPPORT ACTIVITIES 142

6.1 NASA Contracts 142
6.2 Cooperative Agreement Grants 147
6.3 Funded studies 149
6.4 NASA technology demo missions 150
6.5 Space Act Agreements 153
6.6 Patent License 157
6.7 Enhanced Use Lease 159
6.8 CRADAs 161
6.9 SBIR/STTR 162

6.10 IPP SEED FUND 165
6.11 CENTENNIAL CHALLENGES 167
6.12 FAST 171
6.13 COMMERCIAL CREW AND CARGO PROGRAM OFFICE (C3PO) 173

7 NEW INITIATIVES 180

7.1 TAX INCENTIVES 180
7.1.1 ZERO-G / ZERO TAX, TAX HOLIDAYS & TAX DEFERRALS 181
7.1.2 TAX CREDITS 182
7.1.3 FLOW-THROUGH SHARES 183
7.2 CREDIT PROGRAMS 185
7.2.1 LOAN GUARANTEES 186
7.2.2 SUBSIDIZED LOANS 188
7.2.3 FEDERAL FINANCING BANK 189
7.3 ALTERNATIVE CONTRACTING 190
7.3.1 ADVANCED PURCHASE COMMITMENTS (APC) 190
7.3.2 LEASE TO PURCHASE 192
7.3.3 TERMINATION LIABILITY 193
7.3.4 OPEN IDIQ ADVANCE PURCHASE AGREEMENTS 194
7.4 VENTURE CAPITAL / DIRECT EQUITY FUNDING 196
7.4.1 RED PLANET CAPITAL MODEL 197
7.4.2 IN-Q-TEL MODEL 198
7.4.3 ONPOINT TECHNOLOGIES MODEL 200
7.4.4 ESA OPEN SKY TECHNOLOGIES FUND MODEL 201
7.5 GOVERNMENT GUARANTEED COMPLETION BONDS 202
7.6 SPACE AUTHORITY 203
7.7 GOVERNMENT TRUST FUND / SPIC (LIKE OPIC) 207
7.8 SUPER SBIR (E.G. ARMY'S FAST TRACK PHASE II SBIR) 211
7.9 SUPER CHALLENGES 212
7.10 CUSTOMER #1 PROCUREMENT PROGRAM 214
7.11 STIMULUS GRANTS 216
7.12 NEW COTS STYLE PROGRAMS 217
7.13 FREE FLIGHT CHALLENGE 218
7.14 NON-MONETARY GOVERNMENT CONSIDERATIONS 220
7.15 REGULATORY HOLIDAY 222
7.16 ALTERNATIVE BUDGETING 224
7.17 SPACE ACCESS LOTTERIES 225
7.18 BOUNTIES ON ORBITAL DEBRIS 227

1 Introduction

The purpose of this report is to provide NASA with information and options concerning its current efforts to address barriers and challenges to the United States achieving a higher degree of private capital investment in the commercial space industry. Its coverage is meant to be broad so as to serve as a more general resource regardless of how NASA's space commercialization priorities may change over time. A subsequent report will follow this one focused on an evaluation of the numerous initiatives, programs and strategies NASA could pursue to more effectively lower these private investment barriers for each of the currently selected NASA commercialization priority areas. Our efforts in preparing these reports were chartered by the Partnerships, Innovation, and Commercial Space division of the Office of Chief Technologist.

The underlying premise for both of our reports is twofold: first, by fostering and supporting the growth of a vibrant commercial space industry, NASA and the U.S. will gain longer term benefits greatly exceeding their near term investments. These benefits could include, among others:

- A significant increase in the rate of innovation, providing more effective or lower cost solutions for NASA and U.S. objectives in space;
- Levering of NASA and U.S. government space budgets with private capital to accelerate the availability of new space capabilities and infrastructure;
- Reducing the costs to NASA and the U.S. government of achieving its space objectives by outsourcing some of the less challenging activities and missions to commercial operators;
- Strengthening the competitiveness and growth of the existing U.S. aerospace and commercial satellite industries;
- Supporting the emergence of new space-related businesses and commercial aerospace projects focused on creating new commercial markets in space for the economic and social benefit of U.S. citizens on Earth;
- Fostering the growth of new commercial markets in Earth orbit and near Earth to sustain ongoing human and robotic activity near Earth once NASA's space exploration initiatives have moved on to other goals;
- National security enhancement;
- Using our space activities as a means to improve international relations through peaceful collaboration and access to space; and
- Inspiring U.S. students to study science, technology, engineering and math (STEM) to enhance U.S. competitiveness in the global marketplace.

Our second premise is that market based solutions are superior to centralized, top-down planning. The main advantage of market based solutions is that by having private capital at risk financial discipline is brought to the process. Consequently, a bottom-up

approach, where entrepreneurs with a variety of solutions compete for capital and customers, can more efficiently benefit the development of space.

The ultimate goal of our two reports is to assist NASA in being a better partner with industry – and attracting more private capital in the process. We believe the key will be to find the best blend of NASA support mechanisms to optimally match each commercial space application at its then current stage of development.

We should also note up front that this desire to support commercial development of space is nothing new at NASA and there have been serious efforts conducted at various times over the previous decades. In our research and interviews with industry participants we have become aware of many good ideas and programs from the past. Those lessons learned have been incorporated into this report. A couple of examples from the past are illustrative of the rich legacy NASA has to draw on as it plans this most recent commercialization effort.

(1) Joel S. Greenberg, of Princeton Synergistics, Inc., noted in 1992 in a chapter titled "Commercial Development of Space: Government/Industry Relationship"[1] that the large capital investment required, long payback periods involved, and high risk levels resulted in a clear need for government assistance to attract necessary capital. He studied the likely impact of many existing and potential government programs to lower uncertainties in performance (technology), market, schedule, cost and investor exposure (investment size). Ultimately, he determined that the proper role of government was to assist in four ways:
    - Creating new opportunities for private investment
    - Reducing initial capital burden
    - Reducing private sector perceived risk
    - Creating an awareness of the opportunities, technology and policies favorable to private sector investment.

(2) Ralph J. Cordiner, Chairman of General Electric Company, wrote a chapter in 1961 titled "Competitive Private Enterprise in Space"[2] where he discussed how the U.S. should eventually transition from a largely nationalized space industry to a truly competitive market-based model. He envisioned three phases for each layer of exploration (e.g. Earth orbit, Moon and nearby planets, outer solar system):
    - Space Exploration: government directed
    - Economic Development: government phasing out and commercial industry phasing in (e.g. Intelsat as an Inter-governmental organization and Comsat as the U.S. signatory)
    - Economic Operation: private ownership and operation under government regulation (e.g. PanAmSat, GE Americom and the privatization of Intelsat)

[1] Space Economics, Volume 144 of Progress in Astronautics and Aeronautics, 1992
[2] Peacetime Uses of Outer Space, McGraw-Hill Book Company, 1961.

1.1 Authors' Qualifications

The authors are members or employees of Near Earth LLC, a small FINRA licensed broker-dealer focused on providing investment banking and consulting services to the commercial space and satellite sectors. The professionals at Near Earth have both science and finance academic backgrounds as well as both aerospace engineering and Wall Street work experience. Because of this unique blend of financial and technical expertise, Near Earth is frequently engaged by companies, private equity firms, and hedge funds to advise them on their space/satellite related activities, including strategic advisory work, industry sector analyses, valuations of companies, assets and securities and due diligence support for transactions. Near Earth has also been engaged by law firms for expert witness testimony. In addition to advisory work, Near Earth assists early stage companies in raising private equity capital. Clients of Near Earth have included larger industry participants such as General Electric, Hughes Network Systems, Intelsat, SES Americom and XM Satellite Radio and smaller participants such as ATCi, Barret Xplore, Canadian Satellite Radio, Globecomm Systems, International Datacasting, Odyssey Moon, Pro Brand International, Telaurus and Wegener Corp.

Near Earth was founded in 2002 by Hoyt Davidson who acts as its Managing Partner. A summary of Mr. Davidson's qualifications include:

- 23 years of investment banking experience:
  - Managing Director, Co-founder Space Finance Group - Donaldson, Lufkin & Jenrette (1987-2000), the first such industry coverage group on Wall Street
  - Managing Director Telecom Group - Credit Suisse First Boston (2000-2002)
  - Founder, Managing Partner - Near Earth LLC (2002-present)
- Raised over $15 billion for clients, including: PanAmSat, American Mobile Satellite Corp., Loral Space & Communications, Globalstar, ICO, XM Satellite Radio and Universal Space Network. Prior to Near Earth, involved in advisory work for Boeing (Connexion), Comsat, DirecTV, ORBCOMM, Space Imaging, and WildBlue.
- Senior Research Engineer, Space Systems Division of Lockheed (1979-1985)
- S.M. (MBA) – MIT Sloan School of Management, S.B. (B.S.) Physics - MIT

The other partner of Near Earth is John Stone. A summary of Mr. Stones qualifications include:

- 8 years of investment banking experience at Ladenburg Thalmann, National Securities and Near Earth
  - Senior equity and debt research analyst at Ladenburg for satellite & cable
  - Corporate finance unit of National Securities, involved in sourcing, banking and distribution of private placements for early stage technology companies.
- 16 years of project management, software development and design roles at Boeing, Hughes, General Dynamics, Computer Sciences Corporation

  - Was also an Astronomer at U.S. Naval Observatory
- MBA – UCLA, B.S. M.S. Astronomy – Univ. of Maryland, B.S. Physics – Univ. Rochester

Near Earth's Associate, Ian Fichtenbaum, is a graduate of the International Space University, has a Masters in Management degree in Operations Research from the University of British Columbia (Sauder School of Business), and received his Bachelor in Engineering (electrical engineering, minor in physics) from McGill University.

1.2 Method and Approach

To gather background information and perspectives and to canvas a wide range of opinions on NASA and its past and current space commercialization efforts, we conducted 45 phone and/or in-person interviews with experienced and senior level NASA professionals, space entrepreneurs, aerospace companies, satellite operators, investors of various types, space insurance professionals, and others. The interviews with Satellite Operators, Space Insurers and the two named aerospace companies were conducted jointly with NASA personnel.

NASA:

Charles Miller	IPP
Dennis Stone	COTS, C3PO
Brant Sponberg	Small Spacecraft OCT
Andy Petro	Centennial Challenges, FAST, Innovation Fund
Mike Battaglia	IPP seed fund
Lisa Lockyer	Red Planet Capital

Space Entrepreneurs:

Andy Beal	Beal Aerospace
Bob Citron	SPACEHAB, Kistler Aerospace
Gregory Emsellem	Elwing (a development stage ion propulsion company)
Bill Gaubatz	XPRIZE, DC-X
Bruce Holmes	DC-X
Gary Hudson	t/Space, AirLaunch, HMX, Rotary Rocket, Pacific American Launch
John Langford	Aurora Flight Sciences
Jerry Pournelle	DC-X, SciFi writer
Rex Ridenoure	SpaceDev, BlastOff!, Ecliptic Enterprises
Burt Rutan	Scaled Composites
Tom Taylor	SPACEHAB
Henry Vanderbilt	Space Access
Dennis Wingo	Orbital Recovery, Skycorp

Aerospace Firms:

David Thompson, David Steffy	Orbital Sciences
Arnold Friedman, Kathy Shockey, Al Tadros	Space Systems/Loral
[name withheld by agreement]	[name withheld by agreement]

Satellite Operators:

David Bair and others	Eutelsat
Dr. Benedict and others	Intelsat
Paul Bush and others	Telesat
Michele Franci and others	SES

Investors:

Andy Africk	Apollo
Richard David	Investor in land situated adjacent to Spaceport America (NM)
Esther Dyson	Angel: Constellation Services International, XCOR, and Space Adventures
John Higginbotham	SpaceVest
Matt McCoe	Chart Venture Partners
Aneel Pandey	Angel: XCOR
Stirling Philips	FirstMark Capital
Joshua Raffaeli	Draper Fisher Jurvetson
Pete Ricketts	Angel: XCOR and Orbital Outfitters
David Rose	New York Angels
Andy Rush	Diamond Castle
Joel Scotkin	Angel: Masten Space Systems
Ed Tuck	Angel: Magellan, Teledesic, Benson Space, Constellation Services International, IOSTAR

Space Insurance:

John Cozzi and others	AON
John Horner and others	Marsh
Chris Kunstadter	XL Group
Mark Quinn and others	Willis InSpace

Others:

Tom Gillespie, Will Radosevich, Lisbeth Poulos	In-Q-Tel
Jim Muncy	Polispace

The information gained in these interviews was then augmented by our independent research using the Internet and other sources, especially in regard to investment statistics, past space related investments, case studies and current and past NASA programs and initiatives for private industry and space commercialization. The findings, conclusions and options presented in this report are heavily influenced by these interviews and research and represent a consensus view in our opinion. The thoughts presented herein were also based on our considerable experience raising capital and advising commercial space and satellite companies and our understanding of the risk sensitivities and investment strategies of various classes of investors gained over more than two decades, especially as they relate to space ventures. Ultimately the material presented in this report is the product of Near Earth LLC. No endorsement by NASA personnel is implied.

Our approach and objective was to provide NASA with a clear understanding of private industries perspectives and opinions on space commercialization related issues regardless of whether or not such perspectives and opinions were likely to be popular or broadly supported within NASA. We believe much of the value of this report to NASA lies in its presentation of unreserved commentary from sources external to NASA.

This is Near Earth's first engagement contract involving NASA or any government agency. We do not believe there are any conflicts of interest affecting our performance under this NASA contract, however, our perspective is clearly that of an advocate for private industry and a believer in the benefits of space commercialization. We are not unbiased in that respect, but we are also not seeking nor in a position to direct NASA support to any particular business. Our objective is to present NASA with a summary of our understanding of private industry's views on space commercialization and to offer options for NASA's consideration. As we intend to advise, raise capital for and perhaps even invest in companies engaged in various commercial space activities there could arise conflicts of interest in the future were our involvement with NASA to continue and one of our clients was seeking funding or other support from NASA. At present, our only commercial space client with any connection to NASA is Odyssey Moon Limited, an Isle of Man company and Google Lunar X-PRIZE contender. Odyssey Moon has a reimbursable Space Act Agreement with NASA Ames Research Center which we understand to be inactive. Odyssey Moon did not respond to the recent Broad Agency Announcement relating to Innovative Lunar Demonstration Data (ILDD), but may seek to provide services to NASA in the future. As part of our provision of advisory services to Odyssey Moon we have received a small equity stake (1% or so on a fully diluted basis). We also have a roughly 11,000 share indirect stake in ORBCOMM received as partial compensation from a private equity firm we advised years ago.

1.3 Definition of "Commercial Space"

For the purposes of this report, we will use the term "commercial space" to mean something very different from either the commercial satellite operators or the typical cost plus government contracting world of the existing aerospace/defense industry. Our definition aligns with the definition of "commercial" included in the White House National Space Policy of June, 2010 (see below):

> "The term "commercial," for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers."

However, whereas the commercial satellite industry is certainly commercial in every sense of the word and as defined in the National Space Policy, we distinguish it from commercial space due to the terrestrial focus of its applications (e.g. broadcasting, telecommunications, remote sensing) as opposed to in-space services and exploration. We would, however, include in commercial space corporate entities that engage in manufacturing, launching or operating satellites for mostly non-governmental customers. These businesses are funded privately, typically contract on a competitive fixed-price basis, and seek to provide a recurring product or service (e.g. common spacecraft bus, launch vehicle, TT&C network). Examples would include Space Systems/Loral and Arianespace. There are many business units of larger aerospace firms and numerous small aerospace companies that also fit these parameters. We would expect to see them all participate in the development of commercial space.

We also believe that what is often referred to as "OldSpace" will be a major participant and contributor in the development of the commercial space industry, but using different business models and structures than in their core "cost plus" government contracting businesses. A perfect example would be Orbital Sciences through its participation in COTS and its sale of commercial satellites.

We do not, therefore, equate in this report the term "commercial space" with what is being called "NewSpace", although we believe NewSpace companies will play a very important role. This is especially true as NASA's desire to foster commercial space implicitly includes the significant additional goal of increasing the breadth of

participation beyond just the incumbent aerospace companies. We believe broadening participation to include newer and smaller companies will better foster competition, accelerate innovation and attract new sources of capital. This is not just a hypothetical hope. Between 1980 and 2005, companies less than five years old accounted for all net job growth in the U.S. If a new commercial space industry is to be created, energetic participation by entrepreneurs and their investors will be one key factor of success. Finding ways for "NewSpace" and "OldSpace" to work together to build a vibrant and competitive commercial space industry could be equally important.

The commercial satellite industry is a good example of an industry that was created by a combination of:

a) a critical amount of early government research and development, purchasing of technology and contracting for services, and creation of enabling policies and regulations, that reduced private investment risk and supported the creation of the industry's underlying knowledge base, standards and operating procedures,
b) startup initiatives founded within large incumbent firms (e.g. GE – GE Americom, Hughes - DIRECTV, Motorola - Iridium, Loral - Globalstar, Orbital Sciences - Orbcomm),
c) international governmental organizations (e.g. Intelsat, Inmarsat),
d) entrepreneurial start-ups (e.g. EchoStar, Sirius, WildBlue, DigitalGlobe), and
e) large companies acting as strategic partners to back new commercial satellite companies (e.g. Hughes, GM & ClearChannel - XM Radio, Hughes - AMSC).

So in summary, what we believe separates commercial space companies from the existing aerospace/defense industry is not their size, but their relationships to their customers and the government, the business models they employ and the diversity of markets targeted for their products and services. Here are the defining differences as we see them:

- Increased risk sharing: Larger amounts of private capital exposed to the risks of fixed-price, fixed-schedule.
- Focus on standardization v. customization: Commercial space company business models will tend to involve, or at least evolve toward, standardized designs capable of serving diverse customers versus single mission customized solutions.
- Focus on value v. performance: Cost will become a larger factor in design tradeoffs in relation to performance such that "value" becomes the key driver.
- Focus on sustainability v. single missions: The goal will move from conducting a successful mission to designing and building for a sustainable presence serving an ongoing market opportunity. Sustainability will tend to be driven by design for repeatability and higher usage rates which will also push for increased standardization.

- Serving a diversity of markets: Companies will seek to serve a mix of government, enterprise, consumer and not-for-profit customers, both domestically and internationally, with a shift over time emphasizing non-government customers.

1.4 Summary of NASA objectives

An understanding of NASA's broader objectives and priorities is important to choosing the best strategies and programs to foster commercial space industry development. Our report is based on an understanding of NASA's agency-wide objectives as falling into three main phases:

- Phase 1: Build the Foundation: Foster commercial sector to increase pace of innovation and development of game-changing technologies.
- Phase 2: New Systems Development: Foster and then leverage commercial solutions to improve affordability, reliability and availability of access to space and development of new in-space capabilities to support NASA's space exploration and scientific objectives.
- Phase 3: Sustainable Exploration of the Solar System: Commercial support of NASA led human exploration missions to solar system destinations with an ultimate set of goals to:
    - Make space part of our routine environment
    - Manage space as a natural resource
    - Support quests of the future
    - Conduct commerce with human outposts & settlements

1.5 Summary of report sections

This report is organized as follows:

Section 2.0 summarizes our key findings regarding risks, investors and lessons learned from past investments and shares general conclusions from our interviews, research and experiences. We then lay out a set of specific options for NASA to consider regarding support programs and activities NASA could pursue to achieve its goals in the most efficacious and cost effective manner.

The beginning of our background analysis starts in section 3.0 with a detailed description of the various types of risks investors evaluate in making investment decisions and how these risks can often be heightened due to the unique requirements of operating a space-related business. Without understanding the risks and investors'

perspectives of such risks, it is hard to optimally design support activities and programs to mitigate the risks and lower the barriers to investment.

In Section 4.0, we describe the major types of investors that can play a role in financing commercial space companies with an emphasis on their typical investment criteria and key areas of risk avoidance. Different types of investors will accept different levels of risk and invest at different stages of a company's development. Understanding these differences increases the chances of designing support activities and programs better suited to addressing real investor concerns for each type of commercial space activity (e.g. LCRATS, in-orbit services) and stage of development (e.g. start-up, demonstration stage, commercial operation). As part of Section 4.0, we will map our understanding of the risk sensitivities of the various types of investors onto the risks described in Section 3.0.

We then use Section 5.0 to summarize what investments have been made in space in the recent past and to present a series of space investment case studies to highlight past successes and failures and draw lessons learned for the future. It is important in designing new support activities and programs to understand the investment history of the industry, so the perspective of the investment community can be appreciated. It is also very helpful to see what has and has not worked in the past and to explore why.

In Section 6.0, we look at the various support programs and activities currently going on at NASA. We summarize what we understand to be the goals, functioning and over all levels of success of these activities and programs. We then use our best judgment to map the probable effectiveness of these programs against the risks described in Section 3.0 and identify the NASA priorities we believe they most support.

In Section 7.0 we look at several additional programs and activities NASA could pursue to enhance its ability to support the development of commercial space. Some of these are primarily larger or expanded versions of things already being pursued by NASA, others have been used or proposed in the past and a few are entirely new and untried. As with the current programs and activities, we then use our best judgment to map the probable effectiveness of these new programs and activities against the risks described in Section 3.0 and identify the NASA priorities we believe they most support.

In our second report, we will use the findings of this first report to focus on the top five emerging commercial space priority categories and their sub-categories as selected by NASA. We will compare the key risks associated with each such category and sub-category to the risk sensitivities of the most probable sources of private capital. Data for the category risk mapping will be a combination of insights gained from NASA in its industry interviews and workshops, our experience raising capital in the industry and

our recent interviews with space industry participants. We will then show the barriers to investment graphically with the best support activities and programs to overcome these barriers overlaid on the risk mapping to show achievable risk mitigation. The end result should be an effective tool and risk mitigation road map to matching support programs and activities to both investors and the unique risk profiles of specific NASA support categories and sub-categories.

2 Findings, Conclusions & Options

2.1 Findings

2.1.1 Investor Risk Perception

In regards to how investment risk is perceived by private and strategic investors and how these risks represent substantial barriers to private investment, our main finding is that investment in the commercial space industry entails a substantially high degree of risk. These risks are broad in nature and include special risks not typically experienced by most terrestrially focused industries such as launch or in-orbit failure and the political risk of changes in government policy. While technology risks are the ones most likely envisioned when thinking of space projects, and they are certainly important, we find that the most difficult and expensive risks to address are market related risks. A large, early, long lasting and high quality market opportunity will generally attract enough private capital to overcome technology development risks, overcome competitive risks and satisfy financial risk concerns.

Unfortunately, most commercial space markets start small, are slow to develop, may have restricted time frames of activity and involve either a high degree of political risk from government customers, a high degree of payment risk from commercial customers (and individuals) or both. This is compounded by the fact that in many cases very, very substantial front loaded investment is required before the business model can be validated in the marketplace. The need to make up for the lack of strong up front markets drives much of the large scale support required whether in the form of financial support or NASA/government acting as the "anchor tenant" and/or initial market through some form of advance purchase agreement. As Futron reported recently in its report, "Commercial Lunar Transportation Study Market Assessment Summary" conducted for NASA:

- Private equity firms that have sought 20% - 25% returns when investing in satellite communications businesses, say they would need 30% returns to invest in commercial space companies given the extra risks involved.
- Earlier stage investors seek 40% to 50% returns over a 7 year period and in most cases do not see how those returns can be achieved without NASA acting as a major anchor tenant and consistent early customer. [Note: These are not NASA guaranteed returns of 40% to 50%, but projected returns if the business plan works. They are meant to compensate investors for the high risk of failure as most early stage investments do not generate positive returns at all.]

2.1.2 Investor Interest in Space

Our key findings as they relate to the various classes of investors most important to NASA's commercialization efforts are:

- **Founders, Friends and Family**: There is robust interest from engineers and entrepreneurs to start commercial space businesses and these founders have been willing to risk their careers and a good percentage of their net worth pursuing their business plans. However, these founders and their friends and family can only take the businesses so far.
- **Angel Investors**: The angel investment community is active today, but has not embraced commercial space opportunities to any meaningful extent. Most of the opportunities are too capital intensive for them to be capable of funding, or to get the returns they expect. There is also healthy skepticism regarding the size and timing of the market opportunity and an aversion to investing in any business requiring government support or having the government as a dominant customer. Where investments have been made it has frequently been a function of personal enthusiasm for space.
- **Space Capitalists**: Somewhat unique to the commercial space industry is the willingness by successful high net worth entrepreneurs, who have a passion for space development, to invest capital made in other commercial activities into bold new commercial space projects, often run by them. These are serious businesspeople, however, in most cases, their willingness to invest their time and money is driven by more than just a profit motive, although they tend to believe they will achieve significant returns in building new commercial space companies. The lack of a pure profit motive is also not to suggest that their motives are largely philanthropic, but there is often a strong desire to do something with their capital that will have a profound and positive impact on the world while enjoying an endeavor of significant personal satisfaction. Even with these sustaining motives and large personal fortunes, the amounts of capital required for success can quickly stretch such space capitalists to their limits. With lots of skin in the game and often significant privately funded progress, these entities represent prime candidates for NASA financial support, assuming of course they can compete for and win such support and it is offered in a consistent manner free of undue political influence.
- **Venture Capital**: The venture capital industry has plenty of funds that invest in early stage ventures, but has put very little money to work in commercial space. The reasons cited are similar to those of the angel community: high technical risks, poor market visibility, high levels of investment required and unpredictable political risks. In addition, as institutional investors they do not have the latitude to pursue their personal interests over the financial interests of their limited partners.

- **Private Equity Firms**: Private equity firms represent a very large pool of potential capital and have a significant amount of unemployed funds seeking new opportunities. Moreover, unlike the prior investor classes, they tend to be agnostic in their view of the government as a customer. However, they are the most risk averse of the investor classes of interest requiring enough revenue and cash flow visibility to cover the high degree of leverage they employ in achieving desired equity returns.
- **Strategic Investors**: The large and often publicly traded aerospace firms represent an enormous pool of talent, technology and financial resources, but they tell us they have a fiduciary duty to their shareholders not to engage in risky ventures of a size or nature that could negatively affect their earnings or ability to pay dividends. Examples given to us include the EELV "disaster" of the 1990s where aerospace firms wrote off billions of dollars because they misjudged the size of the commercial launch market. The VentureStar experience is another example from the 1990's of a large risk that did not pay off, in this case for Lockheed Martin. There is an added issue of concern expressed to us by one large aerospace firm that if their commercial space efforts fail they can be sued by shareholders and represent attractive deep pockets for litigators whereas a failure of a stand-alone private commercial space company will not as likely involve shareholders seeking recovery of lost money from other corporate assets since there rarely are any. NASA should not expect large aerospace firms to risk their companies on major commercial space projects. However, they do appear to have strong interests in competing for contracts and participating in commercial space activities when the risks are appropriate.

2.1.3 Lessons Learned from Prior Investments

Based on a review of recent space-related investments, including the commercial satellite industry, and several detailed case studies, we identified several lessons learned by investors that may influence their future activity in this sector. The key findings by risk category are:

Technology Risks:

- Any rocket development business plan is risky in terms of cost and schedule risks to field a reliable vehicle (Kistler, Beal, SpaceX, VentureStar),
- Catastrophic launch and in-orbit failure risk is frequently too much for many investors to accept, even when failure insured,
- Most business plans can benefit from taking "baby steps" versus bold major accelerated development efforts. It builds investor confidence and allows redirection of technology and solutions to better match market opportunities (DC-X, Blue Origins, Masten and Armadillo)

Market Risks:

- Commercial space market opportunities have been attractive to a small number of institutional investors, but these investors have been unforgiving for performance lapses and schedule slips (Kistler),
- Commercial markets have tended to take longer to develop than expected (XM Radio, GeoEye/DigitalGlobe, Satellite Broadband)
- NASA/U.S. Government frequently needs to be the anchor tenant and/or dominant early customer (GeoEye/DigitalGlobe),
- Having the government as your primary customer means you lose control over execution of your business plan. Your schedule becomes the Government's schedule (SPACEHAB),
- Commercial practices and solutions can deliver considerable savings to government customers, but it takes a while for the value creation to be recognized (SPACEHAB, GeoEye/DigitalGlobe)
- Lack of good market knowledge has been a constraint on business plan development and capital formation (NEAP/SpaceDev, BlastOff!),
- Lack of market visibility can sometimes be mitigated by inclusion of strong strategic investors in new entrepreneurial companies to signal the strategic company's confidence in the market opportunity (Hughes/XM Radio)

Financial Risks:

- Delays are costly. Commercial space businesses have often taken a decade or more to finance during which time cost goes up, markets change and competing technologies develop. Only the most intrepid of entrepreneurs with the soundest business plans have been able to "boot strap" their companies and survive this test,
- Entrepreneurial companies using traditional government aerospace firms as their contractors have found cost control difficult to manage (e.g. Kistler, SPACEHAB). For instance, the first SPACEHAB module flown in 1993 cost twice the estimate given to the company in 1990. As other advisors to NASA on innovation have mentioned, disruptive technologies generally need to be developed outside of and away from the traditional contracting and management practices of large, bureaucratic organizations (Scaled Composites was a disruptive innovator that developed away from those influences). Where large organizations have had success with creating disruptive technology on a tight budget and/or schedule it has often been achieved through spinning out the business unit so it had more autonomy or creating a special entity outside the core operations of the company (e.g. Lockheed's Skunk Works),
- Space Capitalist support is very helpful to start companies, but rarely enough to fund a major space infrastructure project through commercial operation (SpaceX, Beal, Orbital Recovery). One exception was the founding of PanAmSat by Rene Anselmo, who by betting his entire fortune on the launch of the firm's

first satellite was able to get into commercial operation and attract the level of private capital needed to enlarge his satellite fleet,

- Significant "skin-in-the-game" from founders and private investors is important, but not always a good indication of the overall merits of a business plan as compared to plans with less prior investment in hand (Kistler),
- Institutional investors rarely revisit an investment opportunity even if prospects materially improve (Kistler),
- Loan guarantees may not be enough support, if the other business risks make it difficult to attract equity capital (IOSTAR),

Competitive Risks:

- Two is a big number in space. Rarely is there enough market opportunity versus the risks and capital involved to support several competitors on a sustainable basis, however, not having at least two can also be problematic,
- Other countries will also support and subsidize their space industries,

Political/Regulatory Risks:

- The nearly unanimous feedback we received in dozens of calls across a wide spectrum of private industry participants is that NASA, as a whole, has a serious perception problem. It is seen to be uninterested in commercial solutions, too risk adverse, and prone to change its mind,
- Several of the respondents, particularly among the entrepreneurs and early stage investors, were even more negative, saying NASA/U.S. government has rarely been a good partner and sometimes has been a direct competitor (e.g. launch services), [Note: There is definitely a significant degree of sampling bias here as these entrepreneurs and investors were less likely to have benefited from some of NASA's more successful programs (e.g. SBIRs, aeronautics, comsat technology development). Their comments were limited to their particular projects or investments.]
- However, when NASA/U.S. Government really wants to help create a commercial capability they can take risks and do so very effectively (Orbital Sciences-TOS, COTS, GeoEye/DigitalGlobe)
- Government policy changes have had large impacts on companies and their ability to raise capital. Government support needs to be more lasting and consistent as it has been recently with the commercial remote sensing industry,
- Several entrepreneurs have purposely avoided any ties to NASA/U.S. Government as a customer given their concerns over the reliability of the relationship and other factors such as regulation, oversight and even competition. While this view is not necessarily unique for entrepreneurs, who may seek some sustainable base of commercial business before venturing into the government market, for commercial space companies it has tended to

reduce those companies' ability to demonstrate a real and early market opportunity and get financing (Rotary, BlastOff!),
- Use of NASA facilities and services often comes with uneconomic costs or environmental liabilities,

Execution Risks:
- Management matters. In the end, it is the management team that largely determines success when a company must navigate multiple risks and changing market conditions (Sirius Radio).

2.1.4 NASA's Commercial Space Support Programs

Using the findings from investors' general risk profiles, their appetites for investing in space and lessons learned from previous space-related investments, we analyzed the ability of NASA's current and suggested support programs and activities to address these general risk categories for different kinds of investors and the general applicability of these programs and activities to space commercialization (leaving for our second report an analysis of NASA's options for lowering barriers to investment for each of NASA's currently selected commercialization priorities).

Our key findings regarding NASA's various support programs and activities are as follows:
- Most of NASA's current support programs and activities are beneficial and serve an important purpose. They should be continued and in many cases enlarged and expanded,
- In some cases, simply by altering the way existing programs are applied, greater commercialization benefits can be realized – for example by working with industry to ensure that procurement requirements do not prevent or preclude dual use solutions and in fact are structured to encourage them where possible.
- However, NASA's current programs and activities are not sufficient to accelerate space commercialization or to achieve the major new capabilities and industry participation desired by NASA,
- Good ideas exist for new programs and activities to increase NASA's ability to support space commercialization. Some of these ideas will require new legislation and some may be politically difficult to achieve,
- The best support ideas focus on risk reduction, not upside enhancement, for instance investor tax credits versus tax holidays,
- Best support ideas work in partnership with private investors not in competition, for instance: (i) using matching funds to lever federal investment while gaining market focused discipline, (ii) using a purer In-Q-Tel strategic investor model versus mixing a strategic investor objective with a venture capital organization

model as in Red Planet Capital and (iii) loan guarantees versus direct equity investments,

- NASA needs to provide several different support roles depending on the stage of commercial development, including:
    - **Improving Perceptions:** Changing private industry's perception of NASA/U.S. Government as a reliable and enthusiastic public-private partner for commercializing space (and necessary cultural changes),
    - **Fostering Innovation**: Fostering broad based innovation, basic science, early R&D and STEM education to build a base for future technology development and expand potential solutions and new applications,
    - **Supporting Technology Development**: Supporting technology development from prototyping through flight proven status and commercial off-the-shelf availability,
    - **Demonstrating New Capabilities**: Supporting flight demonstrations of new space systems and technologies,
    - **Validating Markets**: Acting as a first purchaser of new technology, an anchor tenant for first missions and/or a major early customer in order to help create new commercial space markets and attract private capital,
    - **Enhancing Capital Formation**: Reducing capital requirements and investor exposure and/or lowering downside risk and enhancing upside return potential through shared investment and/or credit support to support construction and deployment of major new space infrastructure.

2.2 Conclusions & Options

Our basic conclusion is that the private investment risks facing investors in commercial space are significant and broad based, but not insurmountable if addressed by a mix of well designed, appropriately funded and competently managed support programs. There is a significant amount of private capital available for "good" investments, but substantial risk mitigation by NASA/U.S. Government will be required before meaningful levels of investment are made in commercial space business plans. The support "tools" available to NASA are numerous and there is really no limit to what can be achieved if there is political will and sufficient buy-in across NASA. Of course, the reality is NASA's budget is finite and already has many worthwhile and competing priorities. In addition, financial support only goes so far – there needs to be an addressable commercial market somewhere on the horizon for the commercialization to be sustainable. Where that horizon is far off, NASA may have to accept that for the near term, it *is* the market, and focus on market building as well as technology development. The payoff to NASA of diverting a material amount of its scarce resources to support commercial space industry development has to be a belief that by doing so, it will be able to unleash a significantly larger amount of private capital that will in the end generate dual use

technologies and capabilities that will more than compensate NASA for its investment. Just as NASA investment has benefitted the private sector (and society at large) through spinoffs, so private investment can benefit the NASA mission.

NASA has many options for achieving its space commercialization goals. We organize our preferred options according to the six support objectives listed above. These options are generally cross-cutting in nature; applicable to a broad range of current and future NASA commercialization priorities.

2.2.1 Improving Perceptions

There are numerous ways NASA can work to change its perception within private industry. The COTS program has already had a major impact in perception, yet the fear is that it was a special one-time event versus a sign of things to come. Ideally, industry would like NASA to embrace a policy of progressively outsourcing those of its activities most ready for commercialization as part of a gradual de-nationalization of a space industry created in the Cold War. Obviously, this involves much risk and dislocation to careers, ongoing missions, and the stability of NASA Centers and Directorates. There are no illusions on our part that this would be politically easy or even widely popular within NASA. Perhaps the key factor that may enable such a gradual evolution are the benefits NASA may gain when it commercializes less challenging activities and thereby frees up budget resources and human capital to pursue more difficult, rewarding and expensive missions.

The specific options we believe NASA should consider to improve its perception with private industry include:

(1) **Setting Internal NASA / Commercialization Boundaries**. NASA can make an agency wide determination as to which applications are and are not available for commercialization and on what time frame. This determination should be reviewed and updated periodically (e.g. every four years) with the intent to push more applications into the commercialization camp. Once in that camp, the areas commercialized need to stay there unless the commercialization proves unsuccessful in providing the government the technologies and services it used to provide itself at costs, schedules and risks that are no less favorable.

(2) **Making Public Policy Statements**: NASA could issue frequent, clear and strong public statements regarding its support for private industry and space commercialization, and its specific plans for the near term.

(3) **Creating a Well Staffed Central Interface for Commercialization**: In order to facilitate the increased commercialization activity authorized by Congress, more staffing will likely be required. Practicality and efficiency suggests this staffing be centered at headquarters with support teams at each Center and Directorate. This group could serve as the key interface between NASA personnel, Centers

and Directorates and private industry for all matters related to commercialization support. The group could also house and train industry ambassadors for the mutual interchange of technology and planning. We believe an internal group such as this is preferable to creating something like an independent national Space Authority. We are aware that NASA has had similar commercial groups before (i.e. Office of Commercial Programs, Space Product Development Office), but believe such an office may be more essential and effective today given (i) the potentially larger budget for commercial space support, if appropriated, and (ii) the generally higher levels today of private industry activity, investment and commercial success.

(4) **Engaging in Consistent, Integrated and Early Stage Planning**: Every significant new NASA initiative and mission could include early stage analysis as to the potential for commercialization and the benefits/risks of doing so. This activity could become part of NASA's standard operating procedure, so that it becomes part of the culture and mind set, just as NASA already includes assessments of the role of private industry as part of acquisition planning.

(5) **Changing Focus from Creating New Supply to Building New Demand**: A consistent critique of NASA is that its heritage and mindset is focused on creating new space capabilities, infrastructure and technologies in the hope that markets will then develop around them. This is reminiscent of the "if we build it, they will come" philosophy that saw several billion dollar satellite companies go into bankruptcy. The suggestion is that NASA needs to evolve to a more demand versus supply driven paradigm. Primarily, this means greater focus on building markets and market demand before or in parallel to creating new "supply".

(6) **Corresponding Frequently with Private Industry:** NASA could make an increased effort to understand and stay abreast of private industry's changing needs and capabilities. Also, keep private industry briefed on NASA's commercialization plans and initiatives. The "ambassadors" mentioned above could lead this effort.

(7) **Funding Market Studies for Emerging Commercial Space Markets:** One way NASA can show its support for emerging space markets is by funding and sharing market studies with private industries. These market studies can help private companies attract investors as they will be viewed as less biased.

(8) **Focusing More Effort on Supporting Sectors Important to Industry:** One theme we heard repeatedly by industry and investors is that more emphasis should be placed on supporting development of existing space-related industries with proven markets and demand such as satellite telecommunications, pharmaceuticals and materials research. Support for these industries can help improve U.S. competitiveness and keep us on the cutting edge of technology in markets already exceeding hundreds of billions of dollars annually. Such support can also help mitigate the harmful effects of ITAR on global market share and increase the potential of achieving valuable returns on our ISS investment.

(9) **Finding Ways to Provide More Reliable Contractual Support:** One of the major industry and investor complaints is political risk and contract reliability. Space projects have very long development periods and are difficult to fund without consistent and reliable contracting and other support. Ways to achieve this stability include long term contracts with commercial termination language, alternative multi-year budgeting and loan guarantees. NASA could also consider paying for political risk insurance premiums as a standard practice when contracting with private industry.

2.2.2 Fostering Innovation

NASA, and in particular the Office of Chief Technologist, already does a good job of creating interest in space and fostering innovation, but a more ambitious commercialization agenda may require an increase in the intensity and funding of NASA's current activities. In particular, the options we suggest NASA consider include:

(1) **Using Brokers to Increase Patent Licensing**: NASA has created a wealth of technology and intellectual property that could be commercialized. The best way to maximize the licensing of these patents is to provide incentives to a third party broker to find bidders. [Note, an RFI was issued by NASA with responses due by October 18th.]
(2) **Increasing Funding for the IPP Seed Fund:** This program has been very popular and successful and should be considered for significant expansion.
(3) **Enlarging the Centennial Challenge Program**: The Centennial Challenge Program has achieved amazing results with extremely modest funding and in addition has elicited significant interest from many new and non-traditional sources (small non-aerospace companies, inventors, student groups, hobbyists). We suggest that in addition to more "small" challenges, NASA sponsor competitions with larger prize awards offered to a wide range of privately funded U.S. competitors. A modest amount of funding could also be set aside to have third parties organize and run the competitions with NASA retaining control of the judging and prize awards.
(4) **Facilitating Space Access Contests**: To build excitement for space and the sense of public participation, NASA could contribute or sell "seats" on launches to the ISS. These "seats" could be used to facilitate competitions organized by job type and run by non-profit organizations (e.g. Teachers in Space) and/or theme oriented ones run by corporations (e.g. ESPN) for both average citizens and high profile celebrities to go into space (provided they meet certain fitness and psychological requirements). We would avoid lotteries as they build less excitement, you never know who may win and the winner may chicken out or wish to sell his golden ticket.

(5) **Increasing STEM Education Initiatives**: STEM related jobs are becoming increasingly important to our economy and future global competitiveness. Increased funding for high profile support of STEM education is one way NASA can boost its profile with students, support space industry corporations and enhance its involvement with academic organizations.

2.2.3 Supporting Technology Development

NASA has many worthwhile programs like SBIR/STTR and FAST that do a good job of supporting technology development. The major problem we have seen in our research is that these programs only take a company so far and often end too soon for the company to be attractive to private investors like venture capitalists. The company then gets stranded in "death valley" and NASA/U.S. Government either loses or has delayed access to important new technology. NASA's support for these early stage companies is also limited to technology development and does nothing to prove out the market opportunity. A coordinated technology/market support effort, for those companies that qualify, would generate superior results and could be worth a reallocation of funds in future budgets. The options we suggest NASA consider for new funding include:

(1) **Adding Two more Phases to SBIR/STTR Grants**: For those companies successfully completing the initial SBIR/STTR phases, consider offering another round or two of increased funding (e.g. $2 million, $5 million) provided they are developing technology important to NASA, are competitively chosen and obtain matching private investment.

(2) **Establishing an In-Q-Tel Style Strategic Investment Entity**: NASA should seriously consider creating its own strategic investment entity or contracting with In-Q-Tel to provide this function. The key purposes of this direct investment entity would be to (a) reach innovators not likely to be involved in SBIR/STTR programs or Centennial Challenges and (b) increase the match between small business technology development and NASA's mission needs. We do not believe the Red Planet Capital model or any entity structured in any way like a venture capital firm would be as effective or politically sustainable. Private investors want strategic government partners, not competition on their investments.

(3) **Creating Super Competitions**: Centennial Challenges are great for inspiring innovation from individuals and small companies, but more difficult technology challenges (e.g. SSTO RLV for smallsat delivery to LEO for under $X/kg) will require levels of funding beyond the financial abilities of most of these participants. A competition offering a much larger prize and open to larger companies could allow NASA to achieve the same funding leverage it enjoys in the Centennial Challenges only on a much larger scale. These super competitions may also allow smaller participants who may have won smaller Centennial Challenges to team with larger companies to compete for the larger prizes.

(4) **Improving Access/Cost to NASA Facilities and Services**: NASA has several facilities and capabilities of interest to commercial space companies, but they are underutilized due to lack of awareness, significant "red tape" and often non-economic pricing. That is not to say that all Centers and all facilities are in demand and capable of hosting private industry, but for those that are, shared use may increase NASA's ability to maintain and even improve the facilities. We suggest two options:
   - Use third party brokers to market NASA's facilities and services to private industry, paying commissions based on revenues generated. As long as the pricing achieved exceeds marginal cost and perhaps some reasonable floor, the extra utilization (if on a non-interference basis with NASA needs) should be a win-win.
   - In lieu of cash grants, offer free or subsidized use of NASA's facilities and services to winners of NASA competitions. This can be done through issuance of "Good For Services" coupons to winners.

2.2.4 Demonstrating New Capabilities

We list technology demonstrations separate from technology development given the magnitude of financial support required to conduct flight demonstrations of new space systems and technologies, however, in most cases these demonstrations will first require the development of new technologies, components and subsystems. The options we suggest NASA consider for supporting the demonstration of new space capabilities include:

(1) **Doing More COTS-style Programs**: The COTS program combined with the Commercial Resupply Service (CRS) program contracts that followed have been one of the most successful and game changing commercialization efforts ever undertaken by NASA. The combination of the milestone driven funded Space Act Agreement and the two-winner competition with large contracts semi-attached and awaiting successful development has addressed virtually every risk category facing investors.
   - Technology Risk: NASA experts choose best solution then fund development.
   - Market Risk: NASA acts as major anchor tenant de-risking flight for future commercial customers
   - Financing Risk: NASA support is a grant with no equity dilution to investors. Financing is provided subject to milestones being achieved.
   - Competitive Risks: Creates virtual duopoly.
   - Political Risks: $500 million NASA investment speaks loudly as do the billions of dollars of ISS contracts, especially given the obvious cargo delivery needs.

- Execution Risks: NASA had external VC help vetting the management teams and business plans (although did not work in Kistler case)

(2) **Using Free Flight Challenge Programs**: For those companies seeking to flight qualify new hardware, test a new process in a micro gravity environment like the ISS or validate new business models that require low cost access to space, what they really need is financial support to cover the cost of space access. A series of NASA lead competitions to select the most promising new business models or technologies for implementation and/or testing in orbit could have as its prizes free flights to space or to ISS, as a ride along payload on a NASA launch, or even a dedicated launch. Providing a free launch to such a business could "prime the pump" by validating their business model, leading to increased purchase of launches that lower launch costs for all, including NASA. In the case of ISS, we would envision such a program as an interim step to seed the usage and early success opportunities for the ISS National Lab. Such a program could help attract additional paying customers and generate private capital interest toward a post-2020 privatization of ISS.

2.2.5 Validating Markets

The single most important and restrictive risk category to capital formation is market related risk. No matter how good a job NASA does in mitigating the other risks, if the market side of the equation is not solved it is highly unlikely that sufficient private investment will be obtained. Here are some options we suggest NASA consider to help validate and build commercial markets:

(1) **Being Customer #1 for Small Scale Initiatives**: If NASA has thought enough about the promise of a new technology that it has supported a company with SBIR/STTR grants or prize awards, we believe it may make sense in many cases for NASA to go one step further and offer to buy the first product or service resulting from such technology development. The sooner NASA can commit to being a customer, the greater chances the company will have to raising necessary capital to complete development. In many cases, all that may be required is for NASA to agree to buy serial #1 of the product. Offering to buy an end product or service should also greatly increase the probability that NASA's technology development funding results in capabilities that fit its mission needs.

(2) **Using Advance Purchase Agreements for Large Scale Initiatives**: For major space infrastructure projects and new space capabilities important to NASA (such as cargo delivery to ISS), NASA may need to enter into advance purchase agreements and may even need to be the dominant customer for an initial period of time before commercial enterprises are prepared to contract for the new service. This will almost certainly be the case for any in-orbit servicing application or new LCRATS developed vehicle. In the Futron study mentioned

earlier, NASA taking a strong leadership role in the market was believed to lower pricing by 10% versus baseline whereas NASA being only an occasional buyer could lead to prices 40% higher than baseline. That level of price swing in what is required to close a business case will be determinative to success or failure in many commercial space business plans.

(3) **Using Open IDIQ-style Advance Purchase Agreements for Certain Recurring Needs**: When NASA knows it will have a definable and recurring need for a specific service (e.g. fuel delivery to an in-orbit depot) it may make sense to offer to buy such services from the lowest bidder that can satisfy certain minimum qualification (e.g. flight proven systems) on or after a certain date for a set time period and/or a set amount. This is equivalent to offering a pot of gold at the end of the rainbow and then challenging the private sector to find out how to get to the end of the rainbow. If the pot of gold is big enough, it may offer sufficient market incentive to overcome many of the other barriers to investment. The trick will be finding a politically sustainable way to guarantee the pot of gold will still be there in future years when private industry shows up.

(4) **Offering Debris Bounties**: There are many international and indemnification issues to address, but NASA could study the feasibility of offering financial "bounties" to companies moving orbital debris to graveyard orbits or de-orbiting the debris. This could also be combined with salvage rights enabling resale of such debris if and when a market ever develops for in space scrap or after in-orbit repair capabilities are developed. Oddly, we find that this might not even require Congressional legislation as the President already has the constitutional right to issue Letters of Marque to private companies, federally commissioned to remove dangerous ships (debris) from sea (space). Such commissioned companies are even granted salvage rights. A less dramatic option would be to pick a specific piece of debris controlled by the U.S. and offer a bounty to the first company that can move it to a desired location.

2.2.6 Enhancing Capital Formation

Lastly, one of the important commercialization roles for NASA to serve is the facilitator of capital formation. This generally will involve reducing the amount of private investment and lowering the downside exposure. For very capital intensive projects it may also mean providing low cost capital so that the business can generate the level of equity returns required by private investors in a competitive capital market. The options we believe NASA should consider include:

(1) **Creating a Space Development Tax Credit Program**: Refundable tax credits provide an immediate reduction in the potential loss an investor might suffer and also enhance the upside return when the market potential might otherwise not provide sufficient investment incentives. The U.S. Government has

frequently used targeted tax credits to support research and development and the general development of industries deemed important to the nation. The recent legislation proposed by Senator Nelson is a good example of such an effort, although extending qualification to investment in any U.S. commercial space company, not just those residing in certain regions and engaged in a narrowly defined set of commercial space activities, would be more broadly supportive. However, if the scored costs of any tax credits were to be offset against NASA's budget, either directly or indirectly, we would not suggest this support mechanism as an option for consideration.

(2) **Establishing a Flow-Through Share Program**: For more mature publicly-traded commercial space companies, there are merits to establishing a tax credit program based on the flow-through-share concept. Basically, investors who purchase newly issued shares of stock in a qualifying company get a tax deduction for development expenses not claimed by the company up to the purchase price of the shares. Flow-Through shares often also include other Federal and State tax credits to be used in the tax year of investment. Similar programs have been very effective in Canada in making them world-class in targeted industries like mining. The trick will be in determining who qualifies. The test may need to exclude those aerospace companies that have a majority of their business from government contracts (other than fixed price contracts). As of now, there are few likely candidates, so this is primarily an idea for the future.

(3) **Creating a Loan Guarantee Program**: At some point the amount of capital required becomes so large that the project cannot reasonably be financed on an all equity basis. The required market returns on that amount of capital are just too hard to achieve on space projects which have long development cycles and limited initial markets. One solution is to add a material percentage of lower cost debt financing to the capital structure. The difficulty, of course, is that lenders are very risk averse and would not normally lend to such ventures without some form of government subsidization or guarantee. In most cases, an outright guarantee would be required. That would create the lowest cost debt and increase the chances of closing the investment case for the private equity investors. The risk, of course, is that such loans may default and cause the government guarantee to be called. To reduce the risk of these default events, a specialized group should be created external to NASA to due diligence these opportunities and properly structure the loans to best protect taxpayers.

(4) **Creating a Space Private Investment Corporation**: One proven way to fund and manage a loan guarantee program is through a corporation created by a government trust fund. Such an entity could also address important insurance matters affecting the commercial space industry, like high first time premiums on new in-orbit servicing missions, and make direct loans to private equity funds to leverage their investments in commercial space to get a multiplier effect on investment. This, in fact, is exactly what the Overseas Private Investment

Corporation does in its efforts to support the development of under-developed foreign countries important to the U.S. We would not leave this role inside NASA as the goal would be to have the scoring for any such program off of NASA's budget. We also do not believe using the Federal Financing Bank concept or a Space Authority structure makes sense for providing credit support. The first is focused primarily on financial risk and the latter primarily on boosting development. The entity required for managing credit support needs to have a dual focus of development and financial risk management.

(5) **Solving the Issue of Indemnification**: The potential liabilities associated with operating in space can be so large that private industry and investors just cannot cover them with insurance or take the risk that their businesses and investments will be wiped out due to a single event, often largely out of their control. There is a real need for liability caps and consistent, long term government indemnification. We suggest NASA seek legislation to provide for long term government indemnification subject to certification of operators by the FAA or another regulatory body.

(6) **Providing Valuable Non-Monetary Considerations**: On a longer time frame, we suggest NASA/U.S. Government look into the merits of offering commercial entities non-monetary considerations to induce capital investment such as was done with land grants to fund the build-out of our national railway system. Property or resource rights to lunar and other celestial bodies are the obvious analogy, but other intangible assets may also be of value such as the gates, slots and routes held by airlines. One example of such intangible assets NASA could consider employing is long term lease rights to racks on ISS.

3 Risks

Investing in commercial space companies entails evaluating all of the normal risks of building and running a business in a rapidly evolving competitive market, plus additional risks unique only to space companies. We would also argue that even some of the traditional risks are heightened in intensity due to the requirement of space operations. To provide an overview of these risks from an investor's perspective, we have organized them into categories and sub-categories as presented below.

Once you have reviewed the sheer number and seriousness of all of the risks involved, you might wonder why any sane person invests in new industries and new businesses at all. In fact, historically, roughly half of angel stage investments have gone to zero value and a very high percentage of venture stage investments generate negative returns. Two of the main reasons investors take these risks are: (1) they are seeking average returns superior to those generally expected from investments in safer more mature businesses, and (2) they believe they are smart enough to analyze the risky

opportunities and pick the winners. So the keys to successfully fostering new industries are to (1) provide enough support to improve investors' chances of earning returns commensurate with the levels of risk they are being asked to take, and (2) help these investors feel smart enough to navigate around all of the risks by mitigating the ones that offer true barriers to investment.

3.1 Technical Risks

When investors consider space-related businesses, the first risks that typically come to their minds are technical in nature. This is rocket science after all and space has proven over the years to be a challenging environment in which to conduct commerce. The old joke is that the best way to make a hundred million dollars in space is to start out with a billion. So let's start our review of risks by discussing the various kinds of technical risks that investors face.

3.1.1 Developing new technologies

Investors want to understand the risks involved in developing any new technologies required to provide the intended service or product. In some cases, this risk is simply the challenge of taking one or more components or sub-systems from a current technology readiness level (TRL) to flight qualified status. In many instances, this is largely a matter of funding additional engineering and testing. The risks in these circumstances translate primarily into budget and time to market considerations. In other cases, there are serious technical barriers to overcome and basic scientific knowledge has to be extended through research before engineering and testing come into play.

Most investors, including even venture capitalists, refuse to accept high levels of technology development risk. They simply do not have the skills necessary to make such risk judgments. Because of this reluctance, most commercial satellite ventures will not include unproven technologies in their designs. They want only flight proven hardware with good heritage that insurance companies can easily evaluate. In cutting edge commercial systems like the original Iridium constellation, investors had to gain comfort that certain technologies, such as satellite-to-satellite links, had already been proven to work on non-commercial systems or in government funded flight demonstrations. For many of the new commercial space systems now envisioned there may not be any non-commercial systems or flight demonstrations to instill investor confidence.

Example: The VentureStar commercial transportation effort was predicated upon development and proof of technology via the X-33.

3.1.2 Difficulty of manufacturing and integrating space systems

Independent of the risks of developing new technologies, investors also care about the level of risk involved in manufacturing and integrating the systems required to provide the service or product. It is the difficulty and complexity of bringing these technologies and systems into commercial operation that determines the costs and timeliness of getting to market and the likely price points that can be achieved. Greater complexity and difficulty lead to higher development costs, longer development periods and thus higher price points required for the service or product to achieve an acceptable return on that investment.

In the commercial satellite industry, these manufacturing and integration risks have been brought down over time through repetition and learning curve effects. They are no longer as serious a concern with investors. Common spacecraft buses are used and most payloads share many well tested off-the-shelf components. However, for many of the new commercial systems of interest, the manufacturers and integrators will be starting nearer to the bottom of the learning curve. To investors that means greater cost and schedule risk.

Example: Estimating cost and schedule for something as revolutionary as the first Space Shuttle or something as large and complex as the International Space Station is inherently more challenging than quoting price and completion dates for a geostationary communication satellite using proven technology.

3.1.3 Technical obsolescence risk

Even if investors determine that the technologies are in hand or easily developed and that the required space systems can be manufactured and integrated for a reasonable and predictable amount of funding and in a timely manner, there is still the risk that some other technical solution enters the market offering superior value to customers. This is the risk of technical obsolescence. In areas of rapid innovation like aerospace and where time to market can be long, this risk can be very material in the minds of investors and almost impossible to evaluate.

New technologies can emerge from existing competitors, or new domestic or international entrants, and may even utilize purely terrestrial solutions. For instance, those deploying satellite broadband services to service rural customers must worry about the penetration of wireless broadband solutions into their geographic markets. In evaluating satellite broadband technologies investors had to therefore also evaluate the sustainability of the technology in providing superior value to its customers. There will

be many instances in the funding and development of new commercial space capabilities where new technologies may obsolete the technical solutions employed. For instance, a major break-through in ion propulsion could significantly lessen the economic benefits of in-orbit fueling.

Example: During the period between when satellite radio was conceived and deployed, other digital music and programming technologies emerged such as iPods and streaming via the mobile wireless internet.

3.1.4 Launch, operational, and re-entry risks

Lastly, getting into commercial operation frequently requires first getting into space. Access to space is not only expensive it involves risks of catastrophic technical failures during each phase of the launch, transfer to orbit, and system deployment. Once properly placed in orbit and deployed a space system can still experience a serious loss of capability or functionality, including total failure, for any number of reasons. A partial list of possible failure modes would include: component failure, damage from radiation or solar weather, space debris and even flight operations error. While these launch and operational risks can generally be insured, rates can be high or not available on reasonable commercial terms for new systems with limited flight heritage or operational track record.

Furthermore, insurance typically only covers the cost of replacing the satellite or space system being launched, a re-launch of such hardware and perhaps the cost of reinsuring the next launch. Insurance rarely is available or, if so, affordable to cover the opportunity costs of not being in business, and the continuing cost of capital during delays. Furthermore, a launch failure involving commercial crew delivery to ISS or space tourism could have a tremendous impact on the future demand for such services or at a minimum involve a lengthy investigation and re-engineering of systems involves. Even without the loss of human life, a two or three year delay in getting into business caused by a launch failure can be devastating to a development stage entrepreneurial business. Likewise, an in-orbit operational failure can destroy tremendous commercial value in terms of lost customer backlog and corporate reputation. Lastly, as some new commercial space applications will involve re-entry for human and/or valuable cargo, a catastrophic failure during re-entry could result in similar losses of life, value, time and reputation.

For this reason, many investors will not consider businesses that have a single point failure of this magnitude (i.e. those that involve satellite launches) regardless of how high the recent reliability of the intended launch service or space system. Those investors who are willing to accept this risk want to be paid handsomely for it. In many cases, commercial satellite companies have been forced by investors into building and

sometimes launching a live spare just to cover the risk of launch or in-orbit failure. Not many businesses are forced to build two factories and leave one idle just in case the other one burns down, but that is the normal situation for many companies operating in space. New commercial space capabilities may face similar requirements from investors, in terms of redundant or spare infrastructure and systems.

Hopefully, some of the new commercial systems envisioned will help mitigate these risks for investors by providing in-orbit servicing capabilities to repair, refuel or reposition space systems. But until such time, in-orbit failure risks for unproved systems will continue to be a barrier to investment.

Example: Space Imaging's first attempted launch of its IKONOS remote sensing satellite ended up in the ocean and therefore eliminated the large time to market advantage it would have otherwise enjoyed.

One of the consequences of the drive to minimize launch failure risk is the high degree of vertical integration in the launch services industry. Launch vehicle manufacturers realized they would not sell many rockets unless they could minimize failures and show the market high reliability rates. This has led launch vehicle manufacturers to control much of the satellite integration work on their rockets and virtually all of launch operations. This vertical integration has enabled the launch companies to aggregate experience and expertise across all factors affecting reliability, but some would argue it has come at the price of reducing competitiveness and innovation. An independent launch services industry capable of buying launch vehicles from multiple manufacturers could help improve the end user's availability of launch options and lower the cost of access to space. An independent launch services industry would also remove the barrier to innovation posed by satellite manufacturers often having to go to their direct competitors to launch their new ideas.

3.2 Market Risks

While technology frequently grabs the attention of investors, users and media, it has generally not been the primary reason for commercial failure. Certainly, technical risks have played a major role in whether companies have even gotten funding and on what terms, but once those funding decisions have been made and those technical risks have been accepted, the space systems have tended to get built, launched and successfully operated. Apparently, if given sufficient funds and time, most technical solutions for commercial space systems can be realized. The bigger problem and the primary reasons for commercial failure have instead been market related.

Technical and market risks are also somewhat inter-connected making it hard to distinguish in some cases the nature of the risk. For instance, one can argue that the

original Globalstar and Iridium services failed because an insufficient market existed. Alternatively, one could argue that the handset sizes, per minute pricing and functionality (e.g. no in-building calling) achievable through the technology employed did not attract a large enough market whereas smaller handsets, lower pricing and better link margins through superior technology might have succeeded. That is after all, the hope of these companies' second generation systems. But for the purposes of this report, we will consider the original Globalstar and Iridium commercial failures to be the result of insufficient market size (or at least the pace of market development), since both of these companies used state of the art technology and their systems did work as planned.

Technical design and market risk can also be interconnected by the very nature of a project design. For example, Iridium could not assess the real market demand for its service until after it was operational – i.e. after the funds had been expended. In contrast, a fixed satellite service operator like Intelsat generally is already participating in the market and has a very good idea of a new satellite's market demand, often even pre-leasing much of the capacity pre-launch.

It is, of course, not just the probable size of the market that matters to investors, although this is certainly a key factor, it is also important to understand the likely make-up, quality and addressability of the market, how quickly the market will develop, how long the market opportunity will last and the overall uncertainties in these market expectations. As discussed below, market risk is probably even more multi-faceted than technical risk. Market risk is also an area investors tend to believe they are experts at evaluating and so devote considerable efforts to analyzing. For all of these reasons, historical importance to failures (and successes), complexity and investor focus, we believe market risk is generally the most important risk in terms of barriers to investment.

3.2.1 Market size

When investors consider new investment opportunities one of the first and most critical areas of focus is market size. By market size, investors mean both the total market potentially addressable by the company and the percent of this total addressable market (TAM) likely to be penetrated at any given time by the company. If the market is large enough to support healthy sales volume and demand strong enough to allow for good pricing, then ways can generally be found to overcome most other risks and barriers.

Predicting market size for a new service or product can be very challenging. Investors tend to base their judgments on their personal knowledge and experiences within similar or adjacent industries and frequently hire consultants who specialize in market

size determination and characterization. These consultants compare the new service or product to existing alternatives and conduct interviews with potential customers. The consultants then analyze the data and responses using methodologies and metrics refined over years of practice. Using personal judgment and market studies, investors will arrive at their best estimate as to market size and the likely characteristics of demand. What these both generally boil down to is the value proposition offered to the market by the new service or product. A high value relative to alternatives generally means a large market opportunity, so investors tend to focus a lot on the value proposition being offered.

Example: Given the large demand for cable television and customer dissatisfaction with having only one option for pay television, investors in satellite television companies like DIRECTV and EchoStar had good reasons to believe their multi-channel digital services would be able to capture some reasonable share of this enormous market.

3.2.2 Market quality and reliability

Having a large market to address is important, but it also matters to investors what types of customers make up that market. How hard is it to market to these customers, how likely are they to pay their bills, and will they still be there next year?

The ideal situation for investors is to have a customer base similar to that of the large Fixed Satellite Services (FSS) companies (e.g. Intelsat, SES). These FSS companies sell to a moderate number of large, often multi-national, telecom and media companies with very strong credit ratings. These FSS customers are loyal and pay on time. They also generally contract for service for periods of 3 to 15 years, giving the FSS companies billions of dollars of contractual backlog. Furthermore, the services there customers provide to end users tend to be of high value and resistant to recessionary economic pressures. Lastly, their customer base tends to reflect a diversity of applications and geographic markets reducing the importance to the business of any one region or application.

A generally less desirable case would be to serve a market made up of numerous individual customers of less than stellar credit quality, who pay month to month, require expensive customer service infrastructure and billing and can easily switch to a competitor or drop the service entirely. This is typical of the satellite TV business, for example. As in this example, if it is a mass market consumer application, it may still be an attractive business, but the challenges of serving this kind of market is incorporated into investors' risk analyses and influences the returns they seek. That is to say, even if the dollar size of the two markets were identical, this lower quality, less certain, more complicated consumer market would be given a higher discount rate to its future cash flows to reflect the higher degree of risk.

Example: WorldSpace had a global allocation of valuable L-band spectrum for a satellite radio service and a billion dollars of private capital to execute its business. However, its initial target markets of Africa and India proved difficult to serve profitably as few potential customers could afford a pay radio service. So, although the market was theoretically very large, the quality of the market was low and difficult to monetize.

Another major consideration of investors is the role the government or governments play in the makeup of the market. The government can be a crucial customer in terms of providing market demand, especially for building new markets, but governments can change their agendas and funding priorities from time to time, often drastically and quickly. In some cases (e.g. Beal Aerospace) companies have even complained that the government is a competitor. If the business case will only close for investors with a large government presence in the market, many investors will simply not take the chance that the government will continue to be there.

In some cases, the government need is so critical, significant and long term that investors can gain comfort that government demand will not change materially from one Administration or Congress to another. An example of this scenario is the U.S. military's demand for bandwidth from FSS companies. Many investors have gotten comfortable that the military's likely future satellite bandwidth needs so exceed the existing or planned government owned satellite capacity that it is a relatively safe bet that purchases of commercial bandwidth will not go away in the near term.

For several proposed new commercial space markets, initial commercial demand may be weak or highly uncertain. In these instances, government may need to be a major anchor tenant or even dominate the market for some period, if the industry sector or new space capability is to be funded in part by private investors.

Example: The U.S. government needed to step in and support the commercial remote sensing industry once it became apparent that commercial demand was not large enough to cover the infrastructure and operating costs. The initial size, quality and reliability of the commercial market were overestimated.

Once created and sustained with government market support, the new space industry may over time transition into a more commercially driven market relieving the need for further government support. If government is acting as an early major customer for the industry or even just providing material but transitory support, then investors will want to understand what technology roadmap and/or evolution in commercial demand will be required to wean the industry off this government support. So, in other words, how the make-up of the market is expected to change over time is very important, not just the size of the market.

3.2.3 Market development timing

It also matters greatly to investors exactly how the market develops over time. Is there a large pent up demand to be immediately served or will the market build slowly at first before reaching some tipping point and then accelerating?

If the ultimate market potential is the same in terms of cumulative size, the return on investment is likely to be much higher in the former case for a variety of reasons. Basically, earlier market demand means earlier free cash flows: (1) to fund dividends, buy-back shares or reinvest in new assets/ventures (earlier return on investment has a higher net present value than later return on investment), (2) to fund operations and avoid the need for additional investment, and (3) to support nearer term liquidity opportunities for investors.

Example: Satellite broadband providers like WildBlue and Hughes launch expensive two-way broadband satellites to serve residential and enterprise customers based on both an assumed total addressable market size as well as an anticipated rate of market penetration in terms of subscriber additions. If the rate of subscriber additions is slower than anticipated in the early years, and then higher in the later years that shift in demand results in lower cash flows and lower investor returns even though the total number of subscribers may be the same under the two cases.

In addition, investors may prefer to invest in an opportunity with a smaller initial market to a larger one, if the growth rate of the smaller market is expected to more than compensate for the time value of the potentially larger returns to be received over a longer period.

Example: Many proponents of the space tourism market (e.g. Virgin Galactic, Space Adventures, XCOR) expect its ultimate market size to be very large even though the current market size may be more modest. They are investing based on expected growth.

3.2.4 Market longevity

Longevity of the market opportunity is also important to investors. By longevity, we mean: how long will customers continue to want the service or product? When is the market expected to reach maturity and start to decline as superior alternatives enter the market place? If the market window stays open for many decades there is a much better chance to get a good return on investment, particularly if it takes a long time to get a capability into the market. This market risk is also tied to the market development risk above. If there is a large initial market or the market develops quickly then market

longevity becomes less important as investors can still achieve a decent return. The risk of technical obsolescence also plays a role.

Example: The satellite radio operators took many years to achieve FCC approval and get their systems into commercial operation. It also took many years and lots of capital to achieve a subscriber base of roughly 20 million due to many factors such as a reliance on the schedules of automotive manufacturers. During this period, the industry has run into many new forms of audio competition (e.g. iPods, smartphones, Internet radio over wireless broadband) that either did not exist at the founding of the satellite radio industry or was not at that time a material threat. The total duration of the market opportunity is being affected by this new competition.

3.2.5 Market uncertainty

The return investors require on their investments is largely a function of the size, timing and uncertainty of future cash flows. So, it is not just the probable answers to the above market questions that matter. The uncertainty of those answers also matters greatly to investors. From a corporate value stand point, the enterprise value of a company can be estimated by discounting back to today the free cash flows expected to be generated by the business in the future. If those expected cash flows have less certainty, meaning higher variability, investors will apply a higher discount rate to them making them worth less today. So, for instance, an expected annual market opportunity of $1 billion with high predictability may be discounted at say 10% per year whereas a market that may be anywhere between $0 and $2 billion per year may carry a discount rate of say 20% despite the fact that the average expectation of the market is the same $1 billion. Thus, even though the expected market size is the same in both cases, the more uncertain market will be worth far less to investors and that will affect their appetite to make the investment and influence the return expectations on their investment.

Example: Given its novelty, the size, timing and duration of the in-orbit servicing market are each very hard to predict. In some cases, the development of the market requires the customers to fundamentally change the way they conduct their businesses. It may also be true that commercial customers will not begin to utilize these services until government customers have executed several successful missions, the timing of which is hard to predict.

3.3 Financial Risks

One could debate whether or not financial risk should even be considered an independent risk category. The amount of capital required, the timing of the capital needs, the predictability of future operating cash flows, the likely investment horizon

and timing of liquidity events and even the uncertainty of all of the above are to a large part all driven by the magnitude and nature of the other risks covered herein.

While there is indeed a great degree of interrelatedness, we cover financial risk separately for two main reasons. First, the availability of capital is not solely dependent on the merits or risks inherent in any particular investment opportunity. There is a larger, often global, economic and capital markets environment in which the financing has to be accomplished. In bad capital markets, not even good, low risk deals can get done. In the recent financial crisis, credit for all but the largest companies simply evaporated. Similarly, the U.S. initial public offering market at the time of this writing has also been closed to all but a handful of companies.

Second, the magnitude and timing of capital needs, or uncertainty thereof, can in itself be a barrier to investment regardless of the other merits of the deal. Some investors will simply not take part if the amount of capital required to be placed at risk is too large versus their fund or portfolio size or the allocation they have for various asset classes. Investors may also decline very attractive opportunities if the investment horizon exceeds their fund's exit objectives. Furthermore, early stage investors must estimate and accept the risk that the venture will be able to raise the generally larger amounts of capital required at later stages. In periods of uncertain future capital markets vitality, many such investors will reduce their investment activity in fear of their capital becoming stranded in underfunded ventures. Here, therefore, is a presentation of what we believe to be the key financial risks that serve as a barrier to investment in commercial space.

3.3.1 Magnitude of capital required

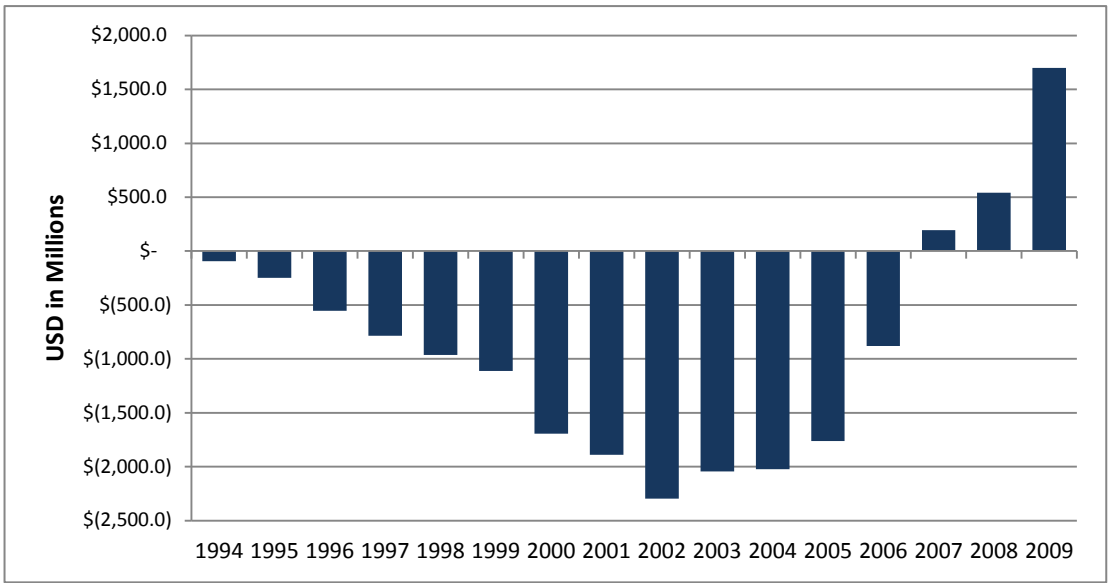
The most obvious financial risk is the absolute amount of capital required by a company to achieve commercial operation and sustainability. What most investors focus on is the amount of capital expected to be required (with some cushion for contingencies) to reach cash flow breakeven.

Breakeven is generally defined in one of two ways: (1) the company has positive or at least zero earnings before interest costs, taxes, depreciation and amortization (EBITDA), in other words its operating cash flow is not negative, and (2) the company is generating enough cash flow from operations to cover its expenses, capital expenditure needs, debt servicing costs and pay taxes, in other words its after-tax free cash flow available to either pay down debt, pay dividends or invest in new projects is not negative. The free cash flow definition of breakeven is obviously harder to meet than the EBITDA definition and most investors of early stage companies focus primarily on the capital and time required to reach EBITDA breakeven. This is because in the case of adversity companies can drastically curtain capital expenditures – meaning that if they have breakeven or

better EBITDA they can wait out the problem(s) and after they are resolved raise additional capital. Consequently, investors believe that once a company achieves EBITDA breakeven it has far better access to additional capital.

Investors will also often adjust the EBITDA values to exclude certain onetime, non-recurring expenses to better reflect what a "normal" operating period might look like. Sometimes these adjustments exclude certain costs of growth such as subscriber acquisition costs on the theory that were the company to stop funding growth its cash flow would be at the higher adjusted EBITDA level. Since it is generally easier and quicker to reach EBITDA breakeven on an adjusted basis, it can be easier to attract investors and their capital if they are willing to invest on that basis. In high growth mass market consumer applications this is typically the case. For businesses selling primarily to corporate or government customers, such adjustments are generally not deemed appropriate.

Example: Below is a graph showing the cumulative negative cash flows and cumulative investment for EchoStar, one of the most highly valued commercial satellite companies in the world. Notice both the magnitudes involved as well as the time periods.



EchoStar cumulative operating cash flow minus capex, 1994-2009

3.3.2 Timing of capital requirements

There is an even more primal issue that investors face when evaluating opportunities in the commercial space or satellite industry. Before they analyze the projected total amount of capital and time required to achieve cash flow breakeven, they must first get comfortable with the frequently large upfront investment required just to design,

manufacture and launch the space segment component of the business. Achieving cash flow breakeven may be several additional years and many millions of dollars after that initial launch date. This upfront capital requirement is rarely less than $100 million and can easily extend into the billions, before commercial service even commences.

Commercial space and satellite businesses that require large upfront investments are thus faced with two major barriers to investment. The first is that large, front loaded investments mean the "clock" on expected returns on capital starts ticking sooner and on these larger amounts. For instance, if an investor contributes $100 million at an expected annual rate of return of 30%, he or she expects to receive $371 million upon exiting the investment at the end of five years. However, if that same $100 million investment was split into $20 million capital contributions in each of the five years, then that same 30% return expectation would suggest a $235 million liquidity event in five years. That extra $136 million gets added to the total amount of value investors expect management to create. The required timing of the capital investments therefore also greatly influences the total amount of capital the business may need.

There is even a multiplier effect. On top of the extra capital required just from having more money at risk sooner (compounding at the return rate), the fact that more capital is at risk during this pre-operational phase means investors will perceive greater risk. This flows naturally from the fact that a huge investment is made years before market receptivity can truly be tested. Returns required by investors in these circumstances tend to be higher just to cover this added timing risk.

A related issue is that investors like to preserve the "option to abandon". An ideal business plan involves gradual expenditures that allow validation of the complete business model (i.e. technology, market and ability of the management team to execute) on progressively greater scales. As validation is achieved on smaller scales, it effectively de-risks the investments required to scale up. Conversely, if the project fails on a smaller scale, it can be abandoned without a incurring a massive loss. This embedded option is valuable to investors and affects their willingness to put capital at risk.

For many of the commercial space businesses on NASA's priority list, the pre-operational periods can represent years. It takes at least two years to get even the most generic commercial geosynchronous satellite from contract signing to orbit. For newer, more complicated space systems, the development stage can last a decade or even longer. SpaceX was founded in 2002 and achieved its first fully commercial launch in 2009, a period of 7 years. And that is considered quick, even remarkable for fielding of a new rocket.

For these projects, it's hard enough for investors to put a large amount of capital at risk, but to then have to wait years to see if the market will even like the service or product is often just too much risk to accept, regardless of how nicely the market studies look and how cool the technology is. Without strong corporate and/or government anchor tenants to guarantee a meaningful initial market, these expensive long development stage projects often have a hard time getting funding. The old adage "if we build it, they will come" just does not work any longer with the investment community. In the rare cases, where investors (other than Space Capitalists) have backed a business without substantial upfront customer backlog it has been because they were joined in the investment by leading industry participants making large strategic investments.

Example: In order to commence its commercial satellite broadband service, WildBlue had to buy a large portion of specialized capacity on an existing satellite (Anik-F1), construct gateways and a network operating center and raise capital for marketing and a customer service organization before really knowing the attractiveness of its service to consumers. Investors were therefore taking a large risk that subscribers would show up in sufficient numbers as opposed to using their capital to fund growth over time for a proven service as its market developed. The fact that a powerhouse venture capital firm like Kleiner Perkins Caufield & Byers invested early in WildBlue and in multiple rounds of financing, was in part attributable to the presence of strong strategic investors like EchoStar Satellite Corp., Liberty Media Group, Intelsat, and the National Rural Telecommunications Cooperative, among others.

3.3.3 Investment horizon and liquidity

Financial risk is not just a function of the amount at risk and the timing of an investors capital contributions, it is also driven by the length of time one's investment has to stay in place before liquidity can be achieved. Simply put, the longer an investor thinks their capital will be committed and at risk, the greater exposure they will feel to market and economic forces and the higher return they will demand on that investment. For the space industry, where there is frequently a multi-year pre-operational phase, investment horizons can often be quite long. Many investors avoid investing in start-up or pre-revenue space companies for this reason alone.

As will be discussed in Section 4.0 Investors, institutional investors generally invest from a fund with a specific targeted investment horizon. In most cases, these institutional investors want to exit an investment within a three to seven year period. If a commercial space company takes three to seven years just to get into service, there are zero to four years left for revenue generating operations before the desired exit date. Institutional investors will therefore tend to limit their investments to companies that are either (i) past or near the end of the pre-operational phase or (ii) expected to grow

rapidly once commercial operations commence, so that enough value can be created to cover return expectations.

For many commercial space companies, this exit requirement may limit the pool of potential investors to high net worth individuals and strategic corporations, which can be more patient with their investments.

The likely path to liquidity also matters to investors as some are more uncertain and depend on favorable external conditions. If the business is expected to generate strong free cash flows the exit can be achieved organically through dividends, stock buy-backs or even recapitalizations of the company. Generally, however, investors assume the exit will involve either a sale to a strategic buyer, a leveraged buy-out (LBO) by financial buyers or an initial public offering (IPO).

Companies that are thought to make excellent strategic acquisition candidates in the future, particularly if there are a significant number of likely bidders, are deemed to be less risky. Strategic exits can also be at higher values as the buyer generally will pay a premium for acquiring control of the company and may also pay for synergies expected to be gained. An IPO on the other hand does not include a control premium and typically is marketed at a discount to expected trading value (the IPO discount). An LBO can include a control premium, but may not generate the same level of synergies for the acquirer thereby reducing the value offered for the company.

Companies that must rely on access to the public equity markets for an IPO exit are deemed more risky as the window for IPOs often closes for long periods of time, sometimes even years. The same is true for an LBO exit, as private equity firms that lead LBOs require healthy credit markets to leverage their equity investments and credit markets can also be cyclical as we experienced in the last recession. However, some level of credit is generally available so the LBO exit is generally more available than an IPO. The mergers and acquisition market that drives strategic exits also experiences significant cycles in deal volume, but a good company can generally achieve an exit at some price.

Recent exits for investors in space and satellite companies

Exit date	Company	Exiting investor	Investor Type	Holding Period (yrs)
September 2010	Asia Broadcast Satellite	CVCI, ADM Capital	Venture Capital	4
December 2009	Orion Propulsion	Tim Pickens	Founder	5
October 2009	WildBlue Communications, Inc.	Liberty, Intelsat, NRTC	Strategic	6
October 2009	WildBlue Communications, Inc.	Echostar and Telesat	Strategic	9
October 2009	WildBlue Communications, Inc.	TRW	Strategic	13
October 2009	WildBlue Communications, Inc.	Kleiner Perkins	Venture Capital	10
October 2009	WildBlue Communications, Inc.	David Drucker and others	Founder	14
May 2009	DigitalGlobe	Morgan Stanley	Venture Capital	10
May 2009	Universal Space Networks	Warburg Pincus, Pistol Creek, et al.	Private Equity	13
May 2009	DigitalGlobe	Walter Scott and Doug Gerull	Founders	17

Exit date	Company	Exiting investor	Investor Type	Holding Period (yrs)
December 2008	Surrey Satellite Technology Limited	University of Surrey	Strategic	23
December 2008	SpaceDev, Inc	Jim Benson	Founder	11
December 2008	SpaceDev, Inc	Undisclosed	Angels	9
January 2008	MicroSat Systems	ITN Energy Systems	Strategic	7
August 2007	AeroAstro, Inc.	Rick Fleeter	Founder	19
August 2007	AeroAstro, Inc.	Elbit	Strategic	4
June 2007	Intelsat	Zeus Holdings	Private Equity	3
June 2007	Swales Aerospace	Tom Swales and others	Founder	29
November 2006	Orbcomm	PCG	Private Equity	1
July 2006	PanAmSat	KKR, Carlyle, Providence	Private Equity	2
March 2006	New Skies Satellites NV	Blackstone Group	Private Equity	2
January 2006	Space Imaging	Lockheed, Raytheon	Strategic	8
August 2004	Intelsat Ltd.	INTELSAT IGO group	Strategic	3
July 2004	Spectrum Astro	W. David Thompson	Founder	16
May 1997	PanAmSat	Anselmo	Founder	13

The IPO exit can also be less desirable for investors, because underwriters rarely let investors sell more than a fraction of their stakes in the IPO. Ideally, the money raised is supposed to be for growth, not to facilitate current investors exiting the business. Investors therefore have to wait for six months or longer for a lock-up period to expire before they can start selling their shares into the public market. Generally, the pre-IPO investors need to wait for underwriters to conduct a secondary offering to move an appreciable block of their stock efficiently without driving down the price.

3.3.4 Financial projection uncertainty

Just as with technical and market risks, the degree of uncertainty regarding likely capital requirements, the funding schedule, the predictability of operating cash flows and even the liquidity exit can itself be a material risk for investors. If investors find these financial aspects of the business plan more difficult to evaluate, they will charge extra in terms of required return on investment. In most cases, significant financial uncertainty in the business plan will lead most investors to simply decline the investment. If they cannot create a detailed pro forma model of expected cash flows and capital requirements that they feel reasonable confident about, many investors will choose not to risk their capital regardless of the returns promised. This is particularly true of institutional investors who have a fiduciary duty to their limited partners to conduct thorough due diligence and invest only after they fully understand the business and its prospects. For individual and angel investors, this requirement does not exist and they may often choose to accept a far higher level of financial uncertainty. Of course, they also want to be paid for taking these extra risks. Strategic investors may also shy away as they have corporate approval processes similar to that of institutional investors, but may in some circumstances accept more financial uncertainty if there are sufficient synergies for them or other reasons to invest besides just financial return (e.g. access to a key technology).

3.3.5 Return on investment

The required return on investment is really a measure of the composite risk of the venture as perceived by investors, so it seems odd to think of it as a risk in and of itself. It is generally not thought of as a barrier to investment, but a cost of investment. We list it, however, because in many cases space related businesses not only have high required rates of return driven by the composite risk of the business, they also require significant amounts of capital with long investment horizons and limited market size. The combination of these things can have a multiplier effect, as mentioned earlier, pushing up the amount of capital required and then the ROI in a vicious cycle that prevents the business model from closing. For instance, a business case might close despite the technical, market and other risks requiring a 40% ROI, if the business plan only required $5 million of capital, had a two year likely exit and a huge market opportunity (e.g. Internet media, software). If those same technical, market and other risks required a 40% return, but the business plan required $2 billion of capital, a ten year investment horizon and served a finite niche market then the business case would not close for most investors. An iPhone app developer may be able to achieve 40% ROIs on a small investment and over a short time frame, but most commercial space businesses needing far more capital and much longer development periods will probably not achieve such high ROIs. The required ROI thus serves as a real barrier to investment because it just cannot be achieved.

3.4 Competitive Risks

Every new industry, if it proves profitable and sustainable, will inevitably attract competitors. These competitors compete for the market opportunity, but also in the early stages they compete for the *funding* opportunity as well – since investors are more likely to invest before a lot of competitors emerge. Generally, competition occurs from the very beginning as several entrepreneurs are likely see the same potential in the new market. Consumers and governments also see advantages in having competitors to drive down prices and drive up quality and so encourage the formation of robust competition. Next to death and taxes, the third thing one can be assured of in life is competition.

While competition can be a good thing in helping markets develop and giving consumers / customers comfort that alternatives exist, too much competition represents a risk to investors. This is especially true, if the particular company investors are being asked to back does not have a defensible niche in the market. Investors do not expect a monopoly or even sustainable market dominance (although that is desired), but they do want there to be enough barriers to entry such that new entrants cannot easily take market share from the company they back. So, when evaluating a new investment opportunity, investors not only assess the number of competitors in the sector and their

relative strengths and weaknesses, they also focus intently on the barriers to further competitive entry.

3.4.1 Amount of competition

Investors would of course favor deals in which their company faced only minimal competition. In the real world, if the market pie is shared among many competitors then both overall revenues and the profit margins associated with them are reduced – making it harder to close the business case and achieve the desired ROIs. Only very large markets with manageable technical and other risks can support a significant number of strong competitors.

Operating a space business carries with it all of the normal risks of running a business plus many unique risks associated with operating in space (e.g. launch risk, catastrophic failure). This inherently higher level of operating risk generally means the space sector cannot sustain a large number of competitors over the long haul if it is to achieve investor returns commensurate with the assumed risk. In addition, operating a space business often requires substantial capital commitments with large minimum investments, long development periods and high fixed costs. Consequently, scale in the form of high market share provides significant advantages. That "Space is Hard" and cannot sustain high degrees of competition is not controversial among industry participants or investors. Three competitors is frequently unsustainable even a duopoly does not guarantee profitability. In space "Two is a Big Number".

To illustrate this point, notice that for the U.S. market there are now:

- 2 U.S. satellite TV companies (DIRECTV and DISH Network)
- 2 U.S. satellite broadband companies (Hughes and ViaSat/WildBlue)
- 2 high resolution remote sensing companies (GeoEye and DigitalGlobe)
- 1 satellite radio company (Sirius XM Radio)

Six different companies sought to compete in the direct broadcast satellite (DBS) market, but only two survived. These two companies have from time to time sought approval to merge given intense competition from triple and quadruple play packages (i.e. video, broadband, VoIP and wireless) from their cable and fiber competitors.

Given the increased difficulty of making money in space-related ventures, investors tend to avoid business plans that cannot demonstrate a clear ability to protect a sizable share of the market. As these barriers to entry are often hard to sustain, especially in a rapidly evolving market, governments have often taken it upon themselves to help limit competition through licensing and government contracts. For the DBS industry, the FCC auctioned orbital slots and frequencies requiring hundreds of millions of dollars to even get into the business. This eliminated all but the strongest players. Of the three original

remote sensing companies, the government through its ClearView program backed only two forcing the third to sale its assets to one of the ClearView awardees. The government wanted at least two suppliers, but recognized the market was not big enough to sustain a third participant. The satellite radio industry was created at its inception to be a duopoly when the FCC chose to award only two licenses, although this was also driven by a need to provide both participants with sufficient spectrum to operate a commercially viable business. In this case, the FCC had both the DBS experience as a model as well as knowing the difficulties WorldSpace was facing trying to build an international satellite radio business. Even the duopoly proved to be too much competition and eventually the FCC agreed to let the two firms merge to survive intense new terrestrial competition (e.g. Internet radio, MP3, smart phones). An even earlier example is the case of American Mobile Satellite Corporation (AMSC). AMSC was the first licensed mobile satellite services (MSS) company in the U.S. When the FCC reviewed the applications for L-band and S-band frequencies to offer MSS services from geostationary satellites, they realized there was not enough market for all to survive, especially given the limited amount of spectrum available to support a business. The FCC therefore had all of the applicants form a consortium and issued a single license. AMSC's successor company, SkyTerra (now LightSquared), has continued to struggle to execute its business plan and achieve profitability. Two is a very big number in space.

3.4.2 Nature of competition

When evaluating the competitive landscape, investors focus on more than just the number of competitors or even the comparative value propositions the competitors offer to the market. Investors also focus on the nature of the competitors, in particular: (i) their financial strength, (ii) the political and regulatory framework they operate under, (iii) whether they are being subsidized by government, and (iv) their access to additional markets and technologies.

If all competitors have to compete within the same regulatory framework, have roughly the same financial strength, and are limited to the same markets then it is easier for investors to evaluate a company's probability of competing successfully based on the relative merits of the service or product being offered and such considerations as the quality of the management team. However, if for instance, the investment opportunity involves backing a start-up entrepreneurial space company to compete against a large aerospace company, or an international company operating under less costly regulatory requirements, or a company enjoying significant government subsidization, or a company whose technology and offering also has a large terrestrial market application, then it will be much harder for that investor to conclude the start-up will be able to successfully compete.

The key questions investors ask are:

1. **Financial Strength**. Do the other competitors (or likely entrants) have superior staying power if the competition gets intense? Do they have stronger balance sheets? Do they have significant internally generated cash flow to support this new business? Do they have superior access to capital and at lower costs? For example, if Boeing were to decide to compete with versus partnering with Bigelow.

2. **Regulatory Framework**. If this is an international market, and many commercial space businesses will be, do our domestic companies face a more burdensome and costly regulatory environment? For example, the U.S. aerospace industry lost its leading market shares for satellite manufacturing and launch services due to the requirements of ITAR compliance.

3. **Government Subsidies**. If this is an international market, do foreign companies enjoy the benefits of government subsidies not offered or matched by the U.S.? Numerous examples of this impact, especially in the launch services industry and manufacturing where export credit agency support can make or break a business plan in terms of its competitiveness.

4. **Market Access**. Do any of the competitors have access to other and potentially larger markets for their service or product to help amortize development and operating costs? Examples here could include industrial robotics companies versus pure space robotics, pharmaceutical companies versus zero-gravity R&D firms, and hybrid terrestrial/space communications companies versus pure play MSS or FSS companies.

The nature of competition can therefore be a high barrier to investment independent of the number of competitors and one that may only be overcome by the host government mitigating development risks, equalizing the cost of capital through grants or loan guarantees or providing equivalent subsidization.

3.4.3 Barriers to entry

Regardless of the amount and nature of the competition, what investors are really trying to determine is the company's ability to gain and protect a profitable share of the total market. If the company's offering and team are strong enough, it may not matter as much that there are a large number of strong competitors. For instance, if the company has proprietary technology that enables them to provide an equal or better service or product for some particular market niche at half the cost of the competition, then that is a pretty impressive barrier to entry. If on the other hand, the proprietary technology provides only marginal or temporary advantages or is subject to a high

degree of technical obsolescence risk, then investors will not consider it to be a meaningful barrier to entry.

Companies without a clearly understood set of barriers to entry represent higher risk propositions for investors. Here is a partial list of barriers to entry that investors seek when evaluating businesses:

- **Intellectual Property**: patents, trade secrets or proprietary technologies (often referred to as the "special sauce");

- **Regulatory Barriers**: government licenses and permits, such as spectrum licenses and permits to use or access government property (e.g. ISS docking or experimental space on ISS), particularly if only a few are allowed, and contracting preferences and set asides, for instance to preserve a share of the market for small or disadvantaged businesses;

- **Long Term Contracts**: locking up major customers under long term contracts can be a barrier to entry for competition;

- **Strategic Relationships**: exclusive partnerships with key strategic parties important in the value chain for delivery of the service or product, preferential access or superior purchasing terms with key vendors and suppliers;

- **Human Resources**: exclusive access to top management and technical talent, particular when required skill sets are generally hard to find (e.g. ion propulsion scientists, top secret clearances);

- **Scale**: Certain business naturally become more economical to offer as they scale. To the extent that a business can achieve scale, and thus lower costs faster than competitors, it can provide a powerful barrier against new competitors; and

- **First to market**: The space industry is notoriously conservative – service and component buyers want proven solutions – and no one wants to be the crash test dummy. Whoever successfully addresses a market opportunity first has a unique advantage over all their competitors until such time as they too have achieved successful entry via their first client.

3.5 Political and Regulatory Risks

Some risks are external to the specific company involved, but still very important to investors. We discussed financing risk above, which can be a function of general economic or capital market conditions independent of the merits of the investment

opportunity. Another important category of external risks is political and regulatory risks, basically risks that emerge from the fact that companies must operate within a political and regulatory framework and can thus be influenced positively or negatively by the governments that are important to its operation. Below is a summary of the key political and regulatory risks that apply to commercial space.

3.5.1 Government policy & space budgets

Since many commercial space businesses require (and have historically received) some form of government assistance, financial support, contracts or other forms of risk mitigation to lower barriers to investment and close the business case, any changes to such government support can be material and in some cases even determinative. The key factors that affect the level and nature of the government support are: (i) policy, (ii) budgets, and (iii) implementation. Each of these factors involves risks investors strive to understand and estimate.

Presently, the Obama Administration has taken a strongly supportive policy position toward government support of commercial space and has requested a significant amount of NASA's budget to support commercial activities. However, the Senate and House of Representatives are independent bodies with their own set of policy wishes and budget priorities. Investors can choose to lobby Congress and the White House for a favorable outcome, but for the most part investors will have only moderate influence in the policy decisions, especially given the almost inevitable existence of equally strong competing interests.

For investors, the ability for government policy to change dramatically, sometimes even within one Administration, is a clear, mostly uncontrollable and often catastrophic risk. Many investors have been burned in the past because of such policy changes and are highly reluctant or even refuse to invest in any company with material exposure to policy changes. For example, the "all payloads must go on shuttle" policy prior to the Challenger disaster essentially halted investment in the expendable launch industry, only to be reversed after the disaster. If the commercial space business in question cannot survive without continued government support, as an anchor tenant perhaps, then many investors will not take the risk that such support will continue to be there.

To better understand this risk; let's break it down to three key factors. The first derives from the fact that one Administration or Congress cannot bind another. This is, of course, the exact opposite of the contractual nature of most commerce. Once private sector parties agree, successors to such contracts cannot simply void them, even if they are willing to pay termination damages.

The second key factor is that policy and budget changes often happen on a yearly basis during the normal budget cycle, or they can be driven by the two year Congressional election cycle or every four years following a Presidential election. For an industry like commercial space with very long development periods and long payback periods for investors, this instability is completely inconsistent with the long term planning required for success and investor comfort.

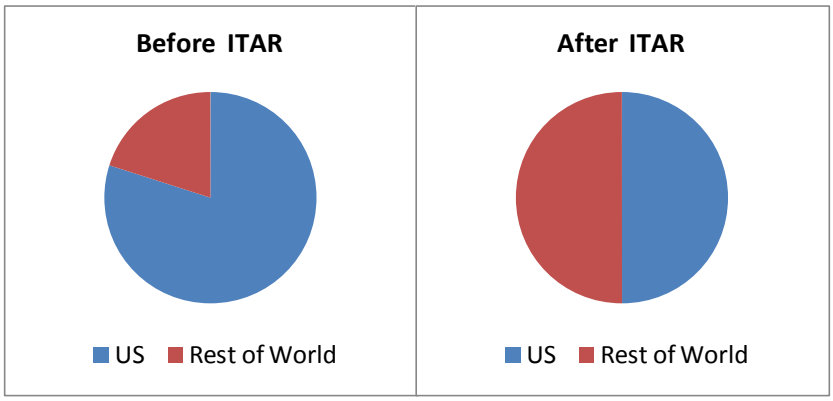
The third key factor is that policy and budget decisions are often perceived by investors to be driven more by political considerations such as jobs in a given district than by scientific or engineering merits or the long term economic and competitive sustainability of the industry. In an investor's mind it is bad enough that a key risk factor to their business can change dramatically and over a short time frame, it is perhaps even worse that such decisions can be based on political versus purely economic considerations.

3.5.2 Regulatory requirements and compliance costs

Government also represents additional potential risks to companies and their investors through regulations and compliance with various laws and treaties. The risk is both in the failure to comply as well as the added cost compliance requires.

The most prominent of these regulatory risks is International Traffic in Arms Regulations (ITAR) first established in 1976 and currently managed by the Department of State. As almost everyone in the space community knows, ITAR is a set of U.S. regulations controlling export and import of defense-related articles and services on the U.S. Munitions List (USML). Unfortunately for the space industry many technologies, components and systems associated with rockets, satellites or other space systems fall on the USML. Considerable pressure for the space industry has been building over the last decade or so to get many of these items removed from USML, however, no material legislative progress has yet been achieved. Industry feels the major impact of ITARs is to depress or even preclude their sales to non-U.S. customers. Since international competitors do not generally have an ITAR equivalent, or have a much less restrictive version of export controls, domestic companies feel they are placed at a considerable advantage.

This concern is not without justification as the U.S. has lost considerable market share to international satellite manufacturers and launch service providers over the last 10 years.



Approximate US share of satellite manufacturing market before and after ITAR reform

Another important governmental risk facing commercial space companies is the potential impact of international treaties. The overarching framework for international space law was established in 1967 with the Outer Space Treaty. The treaty has been signed and ratified by 98 countries, including the U.S., and another 27 countries have signed the treaty but not yet ratified it. The treaty exclusively limits the use of the Moon and other celestial bodies to peaceful purposes and expressly prohibits their use for testing weapons of any kind, conducting military maneuvers, or establishing military bases, installations, and fortifications. The treaty also states that the exploration of outer space shall be done to benefit all countries and shall be free for exploration and use by all countries. The treaty therefore explicitly forbids any government from claiming a celestial resource such as the Moon or a planet, since they are the Common heritage of mankind. However, the country that launches a space object retains jurisdiction and control over that object. The country is also liable for damages caused by their space object and must avoid contaminating space and celestial bodies. As such, the country of incorporation for a commercial space company bears an international responsibility to authorize and supervise any activities of the company in outer space.

To date, this authorization and supervision has been limited primarily to the launching of commercial satellites (FAA) and the coordinated use of electro-magnetic spectrum by the FCC in the U.S. and the International Telecommunication Union (ITU) for global coordination. While these two requirements have at times represented obstacles to achieving commercial operation, well backed companies have tended to be able to satisfy all necessary regulatory requirements. However, as commercial use of space broadens in both applications and destinations, government authorization and supervision is also likely to expand to meet the Outer Space Treaty requirements. As the nature of any new regulations is uncertain, investors face an added risk that future compliance may be costly or even uneconomical.

There is also the issue of liability. The 1972 Convention on International Liability for Damage Caused by Space Objects places strict liability on the party causing the damage.

New commercial space applications such as in-orbit servicing or refueling, therefore, carry new risks of operations which can be enormous in scale. The traditional way businesses handle such risks is to purchase property and casualty insurance, but for some of these new risks no insurance market currently exists or may not be available on reasonable economic terms. The potential liabilities may also be too large for insurance underwriters to bear, for instance a rocket or satellite re-entering and hitting a major city. In some cases, the only way around this obstacle is for the host nation to provide indemnification.

Recognizing this fact, and also the competitive disadvantage of the U.S. not providing indemnification, Congress extended government indemnification for FAA authorized launches for another three years - until the end of 2012. This is the fifth time indemnification has been extended since the original Act in 1984, yet extension is never a certainty. Today there is less than two and a half years of approved indemnification versus launch manifests that can cover a period of similar duration. Investors must therefore weigh the risk of owning equity in a business that may not have this crucial indemnification in a few years. So far, indemnification has not faced a serious test, but if the government were to become liable for catastrophic losses would voters and Congress be likely to extend the indemnification protection once it expires? As it is, payment of claims is not even automatic, but requires Congressional approval and no funds have been set aside by Congress to cover potential losses.

To support new applications such as space tourism and in-orbit servicing will require material modifications and extensions to current Federal indemnification, or else the U.S. will risk losing these industries to other nations. If the Administration and Congress are willing to provide additional indemnification to support these new commercial space industries, they will also need to create new regulations for authorizing and monitoring space activities. There is thus an overhang of unknown future regulations that could impact the expense of future operations and the competitiveness of U.S. companies.

3.6 Perception Risks

For the space industry, there is another risk that is prominent in investors' minds. Even if they are sold on the merits of the business plan and are eager to back the management team, they are still faced with an ephemeral hurdle called perception. The general perception of the company's probability of success among prospective strategic partners, vendors, employees, customers, regulators and additional investors may be so bad that regardless of the brightness of the company's actual unbiased prospects it could still fail. In the space industry, perception quickly becomes reality when the founders' capital runs out. Here are a few of the perceptions widely held by parties that can influence the success of new commercial space ventures:

- Other than point-to-multi-point broadcast satellites, no one has consistently made money in commercial space without substantial government support;
- Commercial space is the quickest way to lose tons of money;
- Investing in space is a psycho-sexual decision, not a purely financial one. Investors can always find higher risk-adjusted returns on Earth;
- Only governments or billionaires can or should develop space;
- NASA requirements will be unachievable or too costly for industry;
- NASA is interested in performance and customized solutions, not low cost standardized solutions;
- NASA not interested if technology not developed in house. A very large "Not Invented Here" (NIH) syndrome;
- Even if NASA does support you, they or some other governmental entity will one day subsidize a competing system;
- Government wants to pick winners versus letting the market decide winners; and
- U.S. government only interested in space defense applications and exploration/science. Willing to let international competitors dominate commercial space.

These perceptions are powerful, but they are not insurmountable. They do, however, require extra support in the early years of a business to overcome the generally negative set of expectations out there. Clear, unwavering and long lasting support is also key. The goal is that one day soon the commercial space industry will have a major success for investors and this government support will become less important. Some believe SpaceX may provide that catalyst.

This phenomenon of a big corporate success changing investor perspectives over night is often referred to as space having its "Netscape moment" after the first wildly successful Internet IPO. It is important to note, however, that Netscape was soon overwhelmed by Microsoft and many investors lost their shirts in the dot com bubble. The analogy that may make more sense for commercial space is for a "Microsoft moment." By that, we mean a new company coming in with disruptive technology and an innovative business model saying to mature industry "you go ahead and sell the important computer hardware, we'll just focus on this unimportant little operating system". For LCRATS that might be, "You make the important launchers and hardware, we'll just focus on efficient operations for reusability, reliability, maintainability and then buy 100s of them." In other words, the best way to change perceptions and get away from the necessary government support may be to change the way companies do business in space: changing perceptions, by changing business models. As noted earlier, such a change of business models may be extremely difficult to achieve for the vertically integrated launch services industry. However, reliability levels for many long standing

launch vehicles and their constituent components may be strong enough to encourage some business model experimentation by new entrants.

3.7 Execution and Operating Risks

Last in our list, but certainly not least, are the set of risks pertaining to executing the business plan and operating the business, particularly in a space environment. Other than the unique aspects of operating in space, these risks are inherent in any business and investors are used to making informed decisions about management teams and business plans.

3.7.1 Management quality

The first of these risks is the quality of the management team. That is what business plan execution really comes down to, the people. Many investors will tell you this is their first and primary focus. They invest in people not business plans. In some cases, some weakness in the team is acceptable to investors if it consists of one or two positions which can be readily filled.

The key spot is the Chief Executive Officer. Investors tend to want a CEO who has successfully been through the start-up process, knows how to manage at each stage of growth and has accomplished a profitable exit. They also seek CEOs that are passionate, intense, great communicators and inspiring leaders, yet also humble enough to have a realistic view of the challenges ahead and willing to take advice and be coached when necessary. Often, with new space companies, what investors get as CEOs are non-business oriented engineers or aerospace/defense program managers who have never built a commercial business from scratch. Worse yet, many of these same CEOs believe they have all of the answers and that the risks are nothing to worry about. To make matters still worse, these types of space CEOs often are in the business primarily for the intellectual satisfaction of realizing their technical solution as opposed to maximizing shareholder value. Because investors often expect this viewpoint from space startup CEOs, companies often are perceived as “guilty until proven innocent” and must first prove this is not the case to attract capital.

Management risk is not necessarily a risk NASA can do much to mitigate. NASA can include management quality in any decisions to award prizes, grants or contracts, but as often as not the evaluating teams might be more impressed with management’s technical sophistication and solutions, or government program management experience, versus their skills as private business managers and ability to attract private capital. The best judges of management quality are the independent investors who seek first of all a return on their capital.

3.7.2 Availability of qualified employees

While this has not been a major issue to date, the poor state of Science, Technology, Engineering and Math (STEM) in our educational system points to a potentially troubling future situation as the baby boomers and Apollo generation retire. In "The Space Report 2009," the Space Foundation reported that the U.S. space industry employs more than a quarter million Americans and at salaries nearly twice the national average. However, the Space Foundation points out that "it is unclear whether the U.S. education system can drive growth in the number of new skilled science and technology graduates, especially those with advanced degrees, needed to replace veteran U.S. space workers who are retiring" and that "there is widespread anecdotal evidence that not enough new professionals are arriving to replace them."

In many cases, if the U.S. cannot make substantial improvements in its K-12 STEM education, much of the technical talent necessary to execute the commercial space business plans may need to come from abroad. As the Space Foundation points out nearly 60% of students in key space fields are temporary residents and more than half of graduate level engineering students are temporary visa holders. To the extent government policy restricts the number of skilled scientists and engineers entering the U.S., new space businesses could be constrained in their ability to execute their business plans.

Hopefully, the excitement inherent in some of the new commercial space activities being developed could help inspire students in the U.S. to focus on careers in STEM.

3.8 Risks inherent in operating in space

Despite the relative low percentage of catastrophic failures of space systems, the mere fact that a company can experience a total loss (in some cases not only of the asset, but of the entire business) and that this loss is largely unfixable and unpredictable makes this risk loom very larger in investors' minds. Many investors will simply not take risks of this magnitude regardless of the probabilities involved.

For the most part, however, these are a set of risks investors have learned to evaluate and accept. There are occasionally component failures, but designers have long ago adopted double or even triple redundancy in key components. The radiation and temperature environment is harsh, but designers have learned how to radiation harden components and do extensive ground testing for quality control. Solar storms can subject space systems to energetic particles, but rarely is there a major system malfunction as is suspected with the recent Galaxy 15. Even space debris, a significant

and growing problem, has only caused one known commercial loss (i.e. the Iridium 33 collision with Cosmos 2251).

Given all of these potential failure modes, one would think that insurance premiums for operating in space would be huge yet they tend to be roughly 1-2% of the assets value per year. Some companies do not even insure their fleets choosing instead to self-insure with in-orbit spares. These are important risks, but between system design, careful operation, sparing and insurance, the market has for the most part figured out how to manage this uniquely space risk. It adds complexity and cost, but has rarely been an insurmountable barrier to investment.

What the market does not seem to have priced in yet, is the possibility of spacecraft destruction or disruption due to acts of war, especially space systems important to the U.S. government's command and control networks and situational awareness. These risks may not be covered by insurance or indemnification.

4 Investors

Now that we have covered the types of risk facing commercial space companies and investors' general perceptions of those risks, it will be helpful to look in more detail at the risk tolerances and investment criteria of different types of investors as these can vary significantly. In particular, in this section, we provide summaries of the major categories of investors (i.e. founders, angels, venture capitalists, corporations) describing what they look for in an investment, and what risks they focus on. We also provide examples of investors for each category along with some anecdotes and opinions we have received in recent interviews. The objective is to use this information to help design activities and programs that target the government support in a way that efficiently meets the needs of the investment community.

4.1 Founders, Friends & Family

4.1.1 Description

For a large percentage of past and current commercial space companies, initial funding was provided by a small group of individual founders who typically make up the senior management team. In some cases, these founder funds were augmented by seed capital from a friends and family round (i.e. people who know and trust the founders and like their business plan).

Most founders and their friends and family investors are not considered "sophisticated" financial investors by professionals even if they have very distinguished careers and academic backgrounds. The reasons for this perception are that their investment decisions involve other than pure financial criteria and objectives and they are not experienced in evaluating early stage business plans and management teams. For instance, some of the founders objectives can be related to desires to: (i) control one's career, (ii) improve one's life style, or (iii) contribute something of importance to humanity, a legacy. Likewise, the friends and family investors may be investing because they (i) want to support a friend or relative (or had trouble saying no), (ii) trust and believe in the founders' abilities, even if they don't understand the business plan, or (iii) see a way to make a huge return on their investment, but do not appreciate all of the risks.

Examples of recent commercial space founders (excluding the category of Space Capitalists founders) include:

- Eric Anderson (Space Adventures)
- Jim Benson (SpaceDev)
- Bob Citron (SPACEHAB)
- Peter Diamandis (Zero Gravity Corp)
- George French (Rocketplane)
- Jeff Greason (XCOR)
- Bill Gross (BlastOff!)
- David Gump (LunaCorp, t/Space, Astrobotic)
- Gary Hudson (AirLaunch, Rotary Rocket)
- Michael Kelly (Kelly Space and Technology)
- Jerry Larson (UP Aerospace)
- David Masten (Masten Space)
- George Mueller (Kistler Aerospace)
- Burt Rutan (Scaled Composites)
- David Thompson (Orbital Sciences)
- Dennis Wingo (Orbital Recovery Corp.)

4.1.2 Typical investments

These initial financings rarely exceed $1-$2 million in size and are generally done as common stock. Founders often allocate some amount of free or low cost stock to themselves for founding the company and contributing intellectual capital and other assets (e.g. patents). Investors of cash are then given a percentage of the company, generally a minority interest, at a value largely determined by the founders. It should also be noted that these founders are often from aerospace engineering and/or program management backgrounds with little experience running start-ups or operating outside of a government cost plus contracting framework.

While often critical in getting new space companies off the ground, these financings will generally only support initial corporate organization, hiring of key people, business plan development and perhaps some initial technical studies and development work. Additional funding is soon required from new sources to advance the company's business plan. In some cases, the next source of funds is from government grants, contracts or prizes as mentioned above. However, these sources are rarely sufficient to cover all costs of operating and growing the company. Unless the founder or founders are wealthy individuals, an additional source of external financing is generally required if the company wants to grow. This next round can come from angel investors or angel groups, high net worth space enthusiasts, venture capital firms, or strategic corporations. In all cases, these new investors will look anew at the people, assets and business prospects of the company and come up with their own thoughts on valuation. Frequently, the new implied valuation (i.e. the value that 100% of the company would be worth if all shares were sold at the offering price that the new shares being sold to investors) will be close to or even lower than the implied valuation for the friends and family round and the form of security is generally some form of preferred stock with liquidation preferences over common stock.

4.1.3 How NASA can help

The combination of seeking high returns as a founder and also being driven by other personal goals, means founders, friends and family will typically accept a much higher degree of risk than most other investors. Furthermore, they tend to have much more patience in terms of the investment horizon and exit visibility. What NASA can provide these investors is:

- Access to technology licensing, personnel and facilities
- Small level of funding through SBIR type programs or innovation grants

- Forum for competition to secure prizes and NASA vetting of management team, technology and business plan

It should be noted that getting to this early stage is relatively simple, and as such the field of companies at this stage is very large, and the average quality of the companies is quite low. Expending a lot of effort on companies is probably not the best use of NASA resources. As the companies advance in the life cycle, natural "winnowing of the field" will reduce the potential resource requirements for NASA while simultaneously increasing the average quality of the pool of companies.

4.1.4 Risk mapping

Below is a mapping of risk perception by founders, friends and family against the risk categories described in Section 3.0. 'High' means the risk is one of primary importance to angel investors in determining their willingness to invest. 'Moderate' means the risk is a moderate concern but of secondary focus and all other spots on the table are for risks of less significance although not necessarily of zero concern. This scheme will be used throughout for each type of investor and is based on our best estimate as to the average of a spectrum of perceptions for each class of investors. Individual members of each investor class will have their own particular set of risk perceptions and priorities.

Founders, Friends & Family Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	
Market: Size	High
Market: Quality and reliability	Moderate
Market: Development timing	High
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	High
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	Moderate

4.2 Angels and Angel Groups

4.2.1 Description

Angel investors are typically high net worth individuals that focus on investing in early stage companies not quite ready or large enough to attract venture capital or other forms of institutional or corporate investment. Sometimes angel investors screen investment opportunities as part of a group of like-minded investors located in a given city or region or with particular industry expertise (e.g. New York Angels, Boston Harbor Angels, Space Angels).

Individual examples include:

- Esther Dyson (Constellation Services International, Space Adventures, XCOR)
- Stephen Fleming (XCOR, Constellation Services International)
- Shelley Harrison (SPACEHAB)
- Ramin Khadem (Odyssey Moon)
- Aneel Pandey (XCOR)
- Pete Ricketts (Orbital Outfitters, XCOR)
- Jud Traphagen (Zero Gravity)
- Lee Valentine (XCOR, Constellation Services International)
- Howard Morgan (Zero Gravity)

4.2.2 Typical investments

The size of these financings generally falls in the $500,000 to $1.5 million range with individual angels typically investing $25,000 to $500,000 each. These investors tend to focus on the senior management team, particularly the CEO, the market opportunity and the business plan. They want a CEO who can adjust to the market, the possibility for high growth with a reasonable competitive landscape and a business plan with a clearly thought out value proposition. They are willing to invest in pre-revenue companies and take a high amount of technology and market risk.

For taking these risks angels expect “outsized” returns on their investment in the 50% plus IRR area based on “realistic” projections. These high return expectations drive them to invest in technology companies where a small investment can be levered into a comparably large market opportunity. They do not usually require a controlling stake in the company for their investment, but do want a meaningful minority position (i.e. 20% to 50%) and Board representation. Given how early they are entering a company, they tend to have reasonable exit expectations in the 7 – 10 year range, though if an earlier exit is apparent they do look upon this favorably. A key focus for angels is that the

management team can use their money to materially increase the company's valuation before the subsequent financing rounds. As such, tangible near term milestones (i.e. with 18 months or less) that can help attract the next round of capital are attractive to these investors. Being able to articulate a clear and compelling use of proceeds is therefore very important.

Here is how one early stage investor summed up his investment criteria:

i. CEO who is a product visionary with an infectious passion and intensity
ii. Strong technology lead
iii. A business model that can be understood in 30 seconds
iv. Company has a prototype being trialed by prospective customers
v. Ability to generate revenues in 6-9 months
vi. A business that needs no more than $1-$2 million in financing to generate a $25-$50 million exit (Note: a 25x return means a 50% IRR over an 8 year period)
vii. Potential for an upside of another 10x

Satisfying angel investor criteria like those above can be very challenging for most commercial space companies. They can certainly have an infectious visionary CEO and perhaps even a convincing technology lead, but many space related business plans are too complicated to describe in 30 seconds and it is generally cost prohibitive to have a prototype of a space system for market testing prior to angel funding. The development phase can also be far longer than 6 – 9 months and take far more capital than a few million dollars. A 25x return can also be extremely challenging given the larger amounts of capital required. If instead of $1-2$ million the business requires $100 - $200 million, then a 25x exit valuation would need to be $2.5 – $5.0 billion. In short, for these reasons the angel community has not been very supportive of commercial space deals historically. There are of course exceptions and a few individual angels do focus some of their time in this "space".

The result of low angel participation is a phenomenon often referred to as "Valley of Death". Founders, friends and family start a company. They achieve some level of success winning government grants, prizes and SBIRS type awards and then face a funding wall. They are still too early stage and small for most venture capital firms, even more so for private equity firms and uninteresting to most angel investors. In some cases they may be interesting to angel investors, but need more than the typical $1 million or so of capital available from angel investors to reach the next major development milestone.

4.2.3 How NASA can help

There are really three primary solutions: (1) provide an earlier revenue opportunity for the companies by purchasing prototypes, technology demonstrations or development

data, (2) bridge the funding gap with larger grants, matching grants, prizes and SBIRS type programs, or (3) award contracts to buy products or services that can then be used to demonstrate to investors market demand. We note in each of these three cases that any support provided would need to be driven by NASA mission objectives and other agency requirements. Another key is to demonstrate a clear government need for the service or product to better establish the market opportunity and stable government policy and regulations. This could be achieved in a number of ways, including public statements of policy and government funded market studies. Government support could also be demonstrated directly and strongly through a focused investor tax credit program. Properly constructed, such a tax credit program could represent a fourth solution to encouraging enhanced investor participation.

4.2.4 Risk mapping

Below is a mapping of angel risk perception against the risk categories described in Section 3.0.

Angel Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	High
Technical: Launch & in-orbit operation	
Market: Size	High
Market: Quality and reliability	Moderate
Market: Development timing	High
Market: Longevity	Moderate
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	High
Financial: ROI hurdle	High
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	High
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	High
Execution / Operating: Availability of talent	

4.3 Space Capitalists: High Net Worth Space Enthusiasts

4.3.1 Description

Luckily, for the commercial space industry there is a special class of investors not seen in many other industries. These are the space capitalists, a group of very high net worth individuals that happen to be space enthusiasts. They tend to have earned their fortunes through high technology endeavors, though not always, and have strong technical backgrounds combined with significant entrepreneurial success. Their motivation is generally to use their entrepreneurial skills, technical know-how and wealth to create an innovative company that pushes the envelope and achieves some important new capability. Examples from the past and today in alphabetical order, include:

- Walt Anderson (MirCorp, Rotary Rocket, LunaCorp)
- Paul Allen (SpaceShipOne)
- Andy Beal (Beal Aerospace)
- Jeff Bezos (Blue Origin)
- Robert Bigelow (Bigelow Aerospace)
- Richard Branson (Virgin Galactic)
- John Carmack (Armadillo Aerospace)
- Tom Clancy (Rotary Rocket)
- Chirinjeev Kathuria (PLANETSPACE)
- Walter Kistler (Kistler Aerospace, SPACEHAB)
- Elon Musk (SpaceX)

We also add that, as noted by Alexander MacDonald of NASA in his paper titled "A Brief Note on the Economic History of Space Exploration in America," the presence of these wealthy space enthusiasts is nothing new. Prior to the space age, the way these Space Capitalists used their wealth to support space exploration was to finance astronomical observatories and expeditions. Mr. MacDonald lists 19 observatories, two transits of Venus expeditions and a Harvard endowment spanning the period from 1831 to 1939. Represented on a 2008 GDP ratio equivalent, these projects were typically in the $100 million to almost a billion dollars range. The largest contribution on this GDP equivalent basis was the Lick Observatory which cost $700,000 in 1876 and would represent a $1.22 billion investment in 2008 on a GDP equivalent basis. The man who made this investment was James Lick, then the richest man in California, who used 17.5% of his estate for the observatory. Applying that percentage to today's richest person in California would yield an investment for space of $3.9 billion.

4.3.2 Typical investments

What separates these investors from traditional founders or angels is that they are able to act in both capacities, plus have sufficient financial resources to bridge the company through the "Valley of Death" stage and even past some or all of the venture capital stage. In some cases, these Space Capitalists have invested in excess of $100 million in their ventures. They are certainly looking for a high returns on their investments, but are also driven by more than just financial returns. They have long investment horizons and have been very tolerant of risks, delays and set-backs. Yet, despite deep pockets and the patience of Job, several of the companies these wealthy visionaries founded went bankrupt and most of the others are still a long way from proving commercial sustainability. At some point even the Space Capitalists need to attract new sources of capital.

4.3.3 How can NASA help

What can NASA do to support these investors? Mostly it comes down to helping them attract the large amounts of private capital reserved for more mature growth stage companies. This requires first making sure the company has enough financial resources to complete a first mission or technical demonstration, thereby mitigating much of the technical risk. Second, institutional investors at this stage (e.g. later stage venture capital firms) also want far greater clarity on the market opportunity. This generally requires some level of contractual backlog and/or revenues from repeat customers. A program like COTS and its follow-on activities satisfied both these requirements, plus limited the degree of future competition.

Beyond financial concerns, in our conversations with investors they cited several others ways NASA could materially aid their efforts. Providing assistance with working through the maze of regulatory and government contracting rules was one such area. In addition, some investors complained that the government directly competes with private startups in the space industry, making it hard to project market share and attract capital. Greater policy clarity and consistency would help in this instance.

4.3.4 Risk mapping

Below is a mapping of Space Capitalists risk perception against the risk categories described in Section 3.0.

Space Capitalist Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	High
Market: Quality and reliability	Moderate
Market: Development timing	Moderate
Market: Longevity	Moderate
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	

4.4 Venture Capital investors

4.4.1 Description

The first professional or institutional money a business raises is typically from a venture capital (VC) firm. By professional or institutional we mean an entity that has fiduciary duties to its investors to seek appropriate risk adjusted returns based on an agreed set of investment goals and criteria. Personal likes and desires to further a particular technology or industry are not supposed to influence the investment decision. This doesn't mean that venture capitalists are industry agnostic - venture capital firms will typically focus their efforts on a few industry sectors so that they can build and leverage industry specific expertise and relationships. Industry focus also allows venture firms to build a portfolio of similar or adjacent businesses to diversify their risks in the sector and at times benefit from intra-company synergies.

Examples of venture capital firms that have been active in the space and satellite sector include the following:

- Desert Sky Holdings (XCOR)
- Draper Fischer Jurvetson (SpaceX)
- Founders Fund (SpaceX)
- Khosla Ventures (SkyBox Imaging)
- North Bridge Venture Partners (O3b)
- Kleiner Perkins (KaStar – now part of ViaSat)
- BEA Associates (SPACEHAB)

4.4.2 Typical investments

A typical venture capital deal involves an investment of $15 - $50 million. Deals in the $5 - $15 million range and over $50 million do get done, but are out of the mainstream or "sweet spot" for most VC funds. Some venture firms will do earlier stage, seed capital rounds in the $1 - $5 million range either as a focus or as a side fund to the general investing activity, but this is a small segment of the VC market. VC firms will often co-invest together to share the risk, especially on larger deals, although one firm tends to act as the lead investor (and thus does the most extensive due diligence). Like angel investors, VC's want a large stake in the company for their investment, generally 25% or larger. This requirement implies a rule of thumb that VC's want to invest in firms that have valuations roughly 2-3 times the size of their intended investment. Generally they do not seek control positions, but there are occasional exceptions. They tend to be active versus passive investors and their investment usually requires one or more seats on the company's Board of Directors. VC's want to help guide management in

execution, and if necessary redefinition of the business plan, and want to have significant influence over the CEO position, future financings and the timing of exits and other liquidity events.

Whereas founders, friends, family and often angel investors will take common stock, VC's virtually never take common stock for their investments. The most common form of equity security used is convertible preferred stock, although convertible debt securities and common with attached warrants are sometimes used. In most every case some form of downside protection is required in the form of liquidation preferences over the previous classes of equity investors and preferred dividends on their investment. Annual Rate of Return expectations vary from the 40%+ range for seed capital rounds to the 30%+ range for the larger and later stage growth capital investments. In addition to these return expectations, VC's would like the investments to have the potential for 10x type value appreciation. Investment horizons tend to be in the 5 to 7 year range although not all VC funds achieve full exit of their portfolio companies within this time frame.

In deciding whether to invest, VC's focus intently on the senior management team, especially the CEO. Other key areas of focus are the total market opportunity and the company's competitive advantage to gaining and keeping market share. For the market opportunity, later stage VC's prefer companies that have already gained some initial acceptance of their service or product in the market and need capital to support growth while earlier stage VCs may take more market risk. Negative earnings and cash flow are generally tolerated (even expected), but pre-customer, pre-revenue companies are much less attractive and harder to finance, although there are some industry exceptions (e.g. biotech). As to competitive advantages, intellectual property such as patents can be important, but only to the extent they are relevant to the company's value proposition (e.g. performance, price or manufacturing cost). VC's will tolerate some technology risk, but want to see proof of concept of the core service or product fully demonstrated.

Popular venture capital backed industries include such sectors as Biotechnology, Software, Medical Devices, "Cleantech" (i.e. alternative energy and related technologies), Semiconductors and Media & Entertainment. What these industry sectors have in common is the ability to serve a large market relative to the size of the required investment, quickly scale and achieve strong sustainable profit margins. Aerospace broadly, and commercial space more specifically, have not historically attracted much mind share or capital allocations within the venture community as they frequently have the opposite perception: a large investment relative to a limited niche market – with the government frequently being the only customer, poor scalability and difficult trade-offs between margin and growth. In addition, as mentioned above under Political Risks, many venture capitalists will not invest in companies where the government is a major

customer or where government support is critical to success. Investors may also shy away from government dominated businesses for the more general concern over high customer concentration and high customer negotiating leverage, just as they would with any other dominant customer.

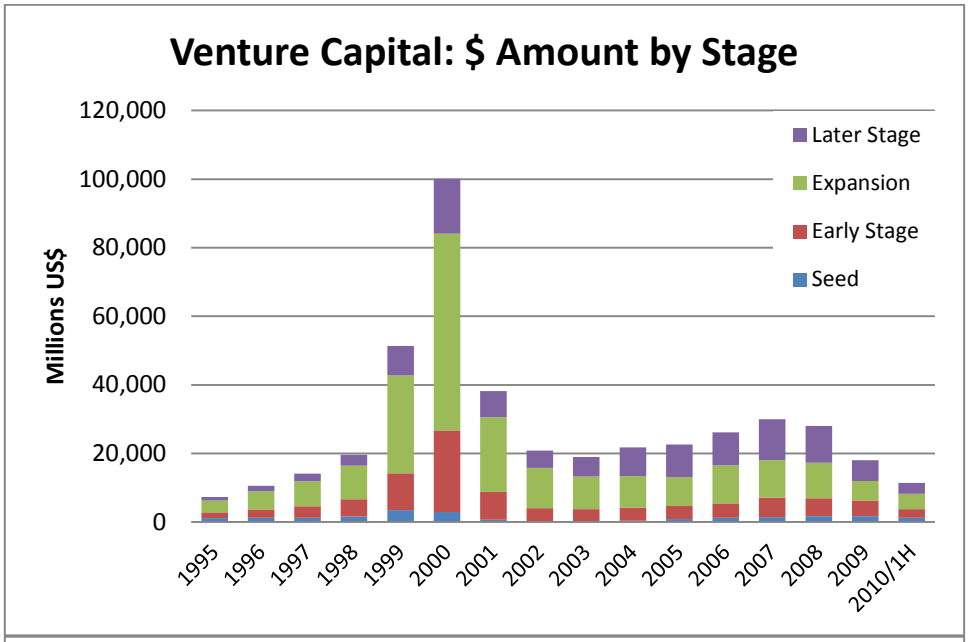
Below is the industry breakdown of VC investments for the first half of 2010. Note that Aerospace is not broken out as a separate industry sector, nor is commercial space or the satellite industry. Whichever category(s) include the relevant space deals, they are unlikely to be a major component of that category(s) deal volume.

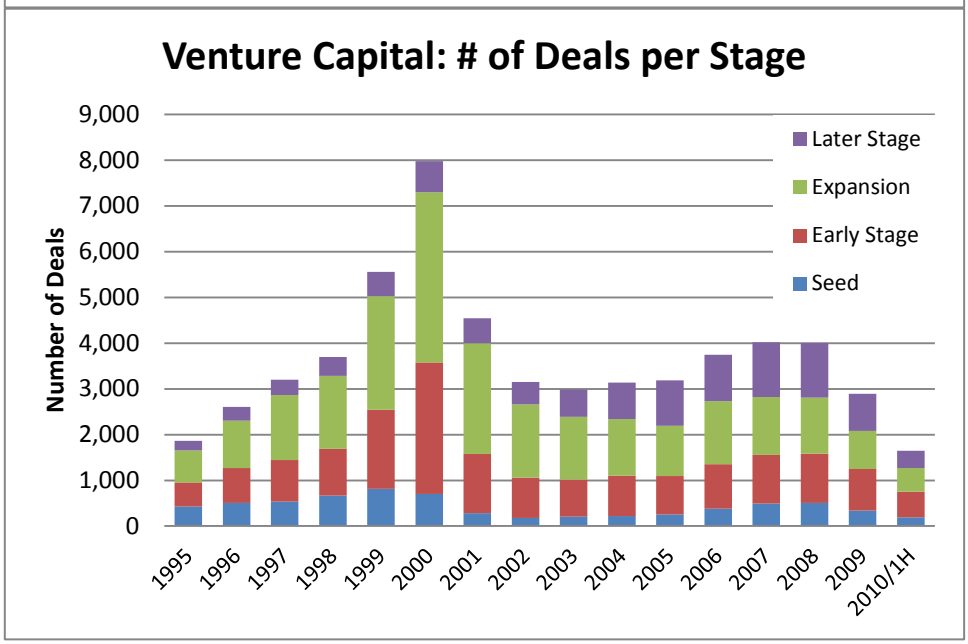
Venture Capital Investment: 2010 First Half

Rank by $ Amount		Rank by # of Deals	
Industry	**$ Millions**	**Industry**	**Deals**
Biotechnology	$2,109	Software	389
Industrial/Energy	1,940	Biotechnology	243
Software	1,760	Medical Devices	163
Medical Devices	1,295	Media & Entertainment	162
IT Services	737	IT Services	137
Semiconductors	658	Industrial/Energy	131
Media & Entertainment	655	Semiconductors	69
Telecomm	487	Telecomm	66
Financial Services	392	Consumer Products	54
Consumer Products	258	Business Prods & Services	46
Electronics	241	Financial Services	42
Computer	237	Electronics	36
Networking/Equipment	237	Networking/Equipment	34
Business Prods & Services	216	Computer	34
Retail	91	Retail	16
Healthcare	63	Healthcare	14
Other	11	Other	10
Total	**$11,387**	**Total**	**1,646**

Despite these negatives, there have been some venture supported deals for commercial space and satellite companies as discussed in Section 5.0 Financings, but the total volume of venture financings is miniscule compared to the $290 billion invested in the last decade.

Venture capital investing is cyclical like most capital markets (see below). The overall deal volume as well as the size and stage of VC investments vary significantly over time. Notice the large spike of the dot.com era in 1999 to 2001 and the secondary peak in 2007/2008. At the time of this writing (Q3 2010) The current transaction volume has returned to more normal levels and is on track to exceed 3,000 transactions worth over $20 billion this year despite the recessionary environment and lack of confidence in market demand and exit opportunities.





4.4.3 How can NASA help

The answer is similar to that for the Space Capitalists: (1) providing support, tied to identifiable NASA needs, that improves the company's chances of securing sufficient financial resources to complete a first mission or technical demonstration, without overly diluting equity investors and destroying the VCs return on investment, and (2) providing greater evidence of at least the government side of the market opportunity.

This could be done by helping to fund a flight demo, buying the first service or product or being an anchor tenant. Given that VC's are more risk adverse than the Space Capitalists, their need for government support to get over the barriers to investment are likely to be more extensive. For instance, VC's would benefit from NASA evaluations or other validations of the technical teams as some of the technical aspects of the business plans may be too new or complicated for them to judge accurately. NASA can also create barriers to competitive entry by limiting its relationships to a small number of firms it has vetted through competitive development programs, prize competitions and contract bidding. Other firms and their prospective investors would then have to close their business cases without meaningful expectations of NASA support and contracts. Lastly, what speaks loudest for VC's is "skin in the game". Were NASA to provide grants to match private capital commitments or establish a captive venture fund or strategic investment entity of its own and co-invest alongside the VC's that would send the clearest signal to the market that the company was important to NASA and worth supporting. Depending on structure, this support could also meaningfully increase IRRs for the VCs to allow them to reach their target thresholds for investing. We note, however, such direct investing by NASA may prove politically challenging and would need to look strategic versus financially driven.

4.4.4 Risk mapping

Below is a mapping of Venture Capital risk perception against the risk categories described in Section 3.0.

Venture Capital Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	High
Technical: Launch & in-orbit operation	Moderate
Market: Size	High
Market: Quality and reliability	High
Market: Development timing	High
Market: Longevity	High
Market: Uncertainty	High
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	High
Financial: Time to Exit	Moderate
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	High
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	Moderate
Perception	High
Execution / Operating: Management quality	High
Execution / Operating: Availability of talent	Moderate

4.5 Private Equity investors

4.5.1 Description

Like venture capital firms, private equity firms (PE firms) manage funds contributed by limited partners and thus have a fiduciary duty to such partners to conduct thorough due diligence on all investments and seek the best risk / reward investment opportunities available within their defined investment category and criteria. Smaller PE firms often limit themselves to one or a few industry sectors to focus their expertise and build portfolios of companies, but many PE firms are generally industry agnostic.

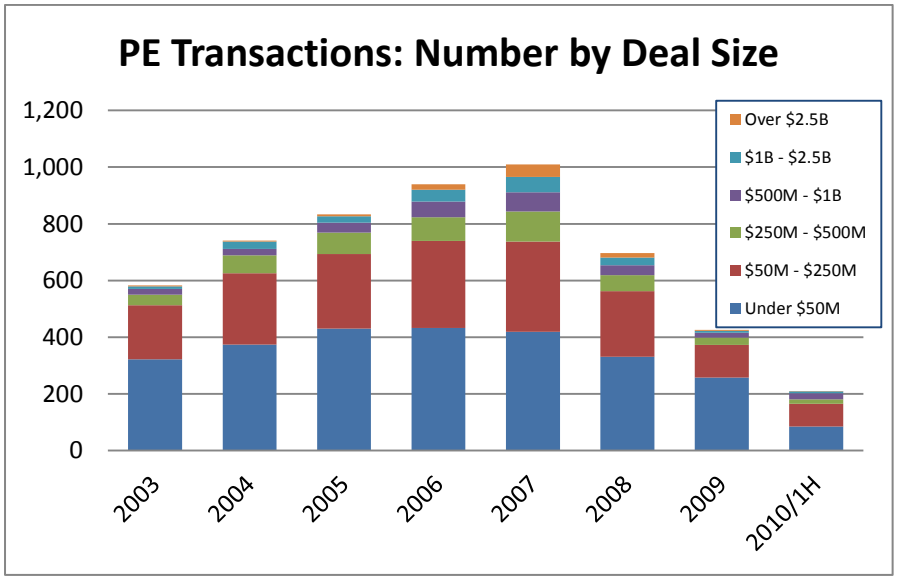
The overarching feature that separates PE firms from VC firms is their reliance on leverage to achieve above market returns on their equity investment. PE firms therefore focus on more mature companies that have predictable enough revenues and cash flows to support moderate to high levels of debt on their balance sheets. Some hedge funds also have an ability to invest a small percentage of their total funds in private transactions. In these cases, we are treating them as PE firms and do not cover hedge funds separately. Similarly, many sovereign funds frequently engage in private equity transactions and would be covered in this section in those circumstances. Note, however, that hedge funds and sovereign funds also invest much of their capital in publicly traded securities, distressed debt, currencies, real estate and other alternative classes of investments that do not align with the primary growth capital needs of the commercial space industry.

Examples of PE firms that have invested in space-related companies include:

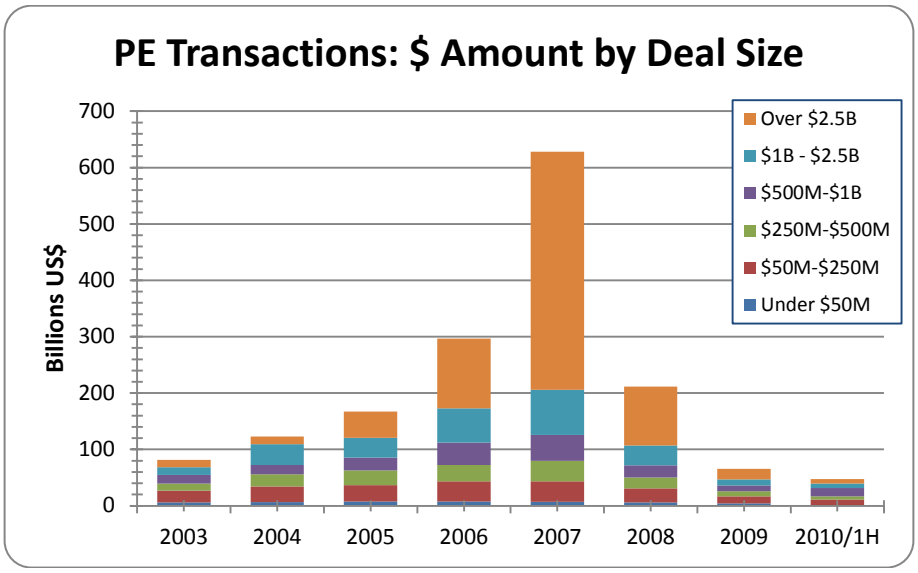
- Aabar Investments (Virgin Galactic)
- Apax (Intelsat, Inmarsat)
- Apollo Global Management (Intelsat, Hughes, SkyTerra)
- BC Partners (Intelsat)
- The Blackstone Group (New Skies Satellites, Sirius)
- The Carlyle Group (PanAmSat)
- Comvest (Emerging Market Communications)
- Harbinger Capital Partners (SkyTerra, TerreStar)
- KKR (PanAmSat)
- Madison Dearborn Partners (Intelsat, XM Radio)
- Mubadala (Yahsat)
- Permira (Intelsat, Inmarsat, ABS)
- Providence Equity Partners (PanAmSat)
- Warburg Pincus (Universal Space Network)

4.5.2 Typical investments

PE firms generally prefer to put more money to work in any single investment than a typical VC deal. Amounts vary widely, but are typically in the $25 million to $250 million range. The chart below shows the number of total PE transactions by deal size since 2003. The level of PE activity for the first half of 2010, measured by number of deals, is roughly the same as for 2009, but considerably off the 2007 peak and even the softer 2003 period. The larger deals are particularly hard to get done in this environment of tighter credit.

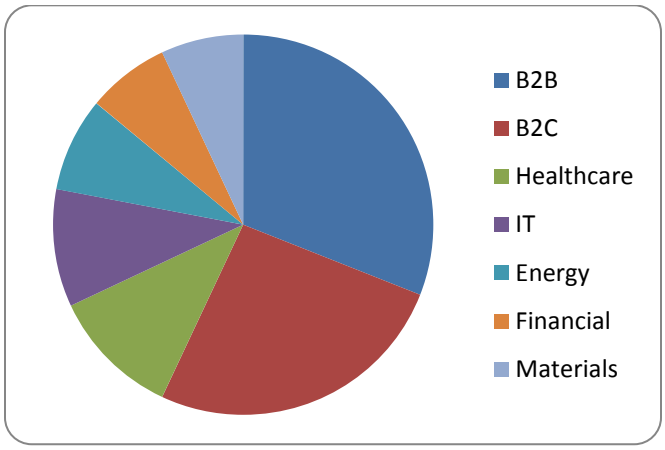


The total level of investment by PE firms is considerably lower than the 2007 peak, as measure by total dollar volume, but consistent with other recessionary and post-bubble periods and on pace to match or exceed the level of activity in 2003 by total dollar volume. Even in “bad” years, PE firms can invest $50-$100 billion and in “good” years multiples of that amount, so they represent an important source of capital for late stage companies.



PE firms generally invest alone unless the transaction size is large in comparison to the size of their fund. Typically, a PE firm will want a portfolio of roughly 20 investments for any given fund, so a $1 billion fund would seek investments in the $50 million range. As many PE funds can be billions of dollars in size, the minimum attractive deal size can exceed $100 million or more.

PE firms invest in almost every industry, but certainly focus on those with sustainable/predictable customer demand and assets than can be used as collateral for debt. For the second quarter of 2010, here is the industry breakdown for completed PE transactions:



Unlike the VC firms, PE firms typically want to own or control the companies in which they invest. At the very least, they must have a known path to control for selection of CEO and determination of exit financings. Internal Rate of Return expectations of PE firms are generally in the 25% - 35% range, still high versus public equity market

expectations, but lower than expected VC or angel investor expectations. As mentioned above, much of this return is also expected to come from levering the equity investment versus from pure growth and value enhancement. Desired investment horizons tend to be in the 3 – 5 year range, although many exits do not fall within that time frame. Exits tend to be sales to strategic buyers or other PE firms, although IPOs and follow-on secondary equity offerings are used for some liquidity events. In many instances, the PE firm will take much of its money off the table prior to exiting through debt recapitalizations. The table below illustrates the transaction structure and exit for a hypothetical PE transaction under two different market conditions. Notice that in the strong market case, although the entry price may be higher, if more leverage can be obtained, the actual cash investment may be the same or even less than during weaker credit markets.

	Weak Market	Strong Market
The Purchase:		
Target EBITDA	$50 million	$50 million
Valuation multiple	6x	9x
Enterprise value	$300 million	$450 million
Leverage multiple of EBITDA	3x	7x
Debt amount	$150 million	$350 million
Equity investment	$150 million	$100 million
The Exit:		
Exit year	5	5
EBITDA growth / year	15%	15%
Exit year EBITDA	$100 million	$100 million
Exit multiple	7x	10x
Exit enterprise value	$700 million	$1 billion
Debt interest accrual (blended rate)	8%	10%
Debt to be repaid	$220 million	$564 million
Equity value	$480 million	$436 million
IRR	**26%**	**34%**

The key assumption under both cases above is the ability to grow operating cash flow (EBITDA) by significant amounts during the investment period. If PE firms do not believe this cash flow growth is readily achievable they are unlikely to invest as there will be little certainty of paying off the debt and selling at a better valuation multiple. For commercial space businesses with long, zero revenue, zero cash flow development periods up front this means it is almost impossible for PE firms to close their business cases and make investments. PE firms are much more likely to consider a commercial space investment after the technology is developed, the service or product has been launched and the market potential is known with some degree of certainty. Therefore, while PE firms are less likely to be a source of development capital they can, under

certain conditions, be a source of significant growth capital, if the growth is backed by funded backlog from credit worthy customers.

When PE firms evaluate transactions they focus on the market potential of the business during and somewhat past the intended investment horizon and the company's sustainable competitive advantages to protect that market potential. They also focus on the entire senior management team, particularly the CEO. Whereas angel and VC investors look for a CEO and management team that can lead additional capital raising activities and quickly adapt to changing innovation and market conditions (since the final business plan often bears little resemblance to the initial one), PE firms look for teams that can successfully operate a company with a high debt burden while still protecting and even gaining market share. This often involves a different skill set than the entrepreneurial management team and it is not unusual for PE firms to replace much of the management team once they become the owners.

Major private equity investments in satellites since 2000

Date announced	Private Equity Acquirors	Acquisition	Enterprise Value (millions USD)
10/15/2003	Apax, Permira	Inmarsat	1,524
4/21/2004	KKR	PanAmSat Corporation	4,300
6/6/2004	Blackstone Group	New Skies Satellites NV	956
8/17/2004	Apax, Permira, Apollo, Madison Dearborn	Intelsat Ltd.	5,000
10/25/2006	Apax	Telenor Satellite Services	400
6/19/2007	BC Partners, Silver Lake	Intelsat Ltd.	16,400
9/13/2010	Permira	Asia Broadcast Satellite	Not announced

The PE firms need for predictability also focuses attention on the political risks of commercial space opportunities. PE firms will rarely take any material political risks such as defunding of major space programs with changing Administrative or Congressional priorities. However, several prominent PE firms do focus considerable attention on industries supported largely by government contracts, such as aerospace/defense and homeland security. In these cases, there is generally either a diversity of government customers and programs to lower the risk of any one contract being cancelled or the particular sector is in such obvious and critical demand that the risks of decreasing revenues is hard to imagine (e.g. cyber terrorism).

4.5.3 How can NASA help

If the PE firms are evaluating commercial space companies in the traditional mode, then the companies are most likely mature businesses not requiring much support from government other than continued contractual purchases of services or products. This generally requires a stable political and regulatory framework. If on the other hand,

there is a desire to tap into the considerably larger sizes of PE funds versus VC funds for development stage funding, then enough government support would be required to both limit the downside risk and enhance the upside financial gain. For instance, if the commercial space company needs lots of capital, but could not by itself attract lenders to provide the kind of leverage PE firms require, the government could provide loan guarantees or loan subsidization. We purposely use the word “government” here versus NASA as we believe any such loan guarantee program would need to be established and administered externally to NASA. Ideally, to limit the downside risk of loan defaults, NASA and/or DOD and other government agencies could agree to be anchor tenants and purchase sufficient services or products to at least cover operating costs and repayment of the government guaranteed debt.

4.5.4 Risk mapping

Below is a mapping of Private Equity firm risk perception against the risk categories described in Section 3.0.

Private Equity Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	High
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	Moderate
Market: Size	High
Market: Quality and reliability	High
Market: Development timing	High
Market: Longevity	High
Market: Uncertainty	High
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	Moderate
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	High
Competitive: Nature of competition	High
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	Moderate
Perception	Moderate
Execution / Operating: Management quality	High
Execution / Operating: Availability of talent	Moderate

4.6 Strategic corporate investors

4.6.1 Description

One of the most important classes of investors and acquirers of firms in the space industry are the larger and more mature aerospace/defense companies. This is a natural consequence of two facts: First, these firms have access to lower cost capital than earlier stage or smaller firms. As such, these firms can to a certain extent realize an arbitrage when they invest or acquire firms with higher costs of capital (i.e. that are considered more risky). The second is that unlike most market participants, these actors have strong in-house expertise that allows them to better evaluate space investments, providing further risk mitigation. These investors tend to be the major aerospace/defense prime contractors, but some of the larger subcontractors and third tier companies can also be active. Their activity can be either external, as with any investor or acquirer, or internal through corporate funding of new business units. For this report, we will treat the internal investments as similar in concept to the external investments, although in reality it is generally far easier for a company to get approval to do internal investments under their complete control and using people they know versus making external investments in new businesses being run by others, especially in the case of minority investments.

The most important and active strategic investors / acquirers are those with good access to financing and strong operating cash flows to reinvest. Some investors also have evolved to have acquisitions and dispositions as a specialized skill set, and effectively operate as publicly traded private equity firms (e.g. General Dynamics, L-3). The availability of financing to complete a transaction is rarely a serious concern for these entities, except for the largest of deals and development programs. In fact, some of the larger companies have been known to complete ten or more small transactions in a given year. Examples of strategic investors / acquirers include:

- ATK
- Boeing
- Com Dev
- General Dynamics
- Honeywell
- L-3
- Lockheed Martin
- Loral
- MDA
- Northrop Grumman
- Orbital Sciences
- Raytheon

4.6.2 Typical investments

Strategic investors, by their very nature, are investing because of synergies that the new investment has with their existing operations and investments. As detailed below, these

synergies can include enhanced revenues, reduced costs or other benefits that accrue to the investor, the target or ideally both firms.

Because realizing the full strategic benefit of a transaction often requires the ability to direct the operations of the target, Strategic investors have a very strong preference for control or complete ownership in a transaction – even more so than private equity firms.

While strategic investors / acquirers typically seek more than just a financial return on their transactions, the financial aspects of the transactions are, however important, as many of these firms are publicly held. As public companies they owe fiduciary duties to their shareholders not to engage in overly risky investment activity or to incur substantial earnings dilution or dilution over a material period of time. Given the above financial considerations, some of the more important and frequent strategic reasons for investing or acquiring include:

a) Gaining an important new technology that can then be applied across a broader product line (i.e. buying innovation versus internal R&D);
b) Gaining exclusive access to a technology believed critical to winning a particular near term and large contract;
c) Gaining access to a new customer, generally government agency or military branch, with hopes of cross marketing the firm's existing capabilities to that customer (e.g. NASA);
d) Gaining additional "wallet share" with existing customers from either the target or acquirer by cross selling the respective firms' products or services to the other firm's customers;
e) Gaining an entry position in an emerging high growth industry sector versus trying to build an internal organization to compete for market share (i.e. buy v. make decision);
f) Gaining valuable human resources needed to support R&D, marketing, service provisioning or management (e.g. PhD's with top secret clearances);
g) Gaining market share in an existing business at an attractive valuation multiple (e.g. buying 8(a) companies at their size limits for contracting preferences); and
h) Gaining additional scale so as to exercise greater market power with common vendors, customers or both.

The deal size for such a transaction can be anything from roughly $10 million to billions of dollars. The big aerospace/defense firms generally prefer not to buy development stage companies (unless the technologies are very "hot" and proprietary). Usually, the businesses have already developed their technologies and products to flight readiness or at least a very high TRL. If it is a service, the businesses are generally already providing the service and have repeat customers.

In this sense, the strategic companies act similarly to PE firms in terms of the risks they are and are not willing to take. The major difference of course is the strategic companies are unlikely to use leverage to close the transaction and generally will enjoy far more immediate synergies and cost savings. Because of these advantages, strategic investors and buyers will generally be able to pay a higher price (valuation) than the pure financial players. This makes them very important in the life cycle of a company from the perspective of the earlier investors as the strategic buyers can be the preferred exit and liquidity event. The downside from the seller's perspective is that strategic firms often take far longer to close given an often more complicated internal approval process and their strategic rationales for doing the deal can change or go away. Speed and certainty of closing can therefore be a key advantage for PE firms. As financial entities with limited or no operational capability of their own, PE firms also tend to keep more of the management team in place whereas strategic companies may seek to remove redundant positions and consolidate administrative and even engineering functions.

As noted previously, strategic firms will generally seek to acquire all or a controlling interest in a company versus just making a minority investment. There are, however, some exceptions. Strategic firms will also enter into joint ventures (JV) with other companies, contributing not only cash, but also technology and access to people and facilities. For a new commercial space company, such JVs can be extremely valuable although with a significant increase in complexity and corporate decision making. In many cases, the JVs are limited to just one or a few sectors of the overall market opportunity, for instance, one government customer or one application. A recent example would be Boeing and Bigelow Aerospace's joint venture to develop the CST-100, a crew vehicle to access orbital space stations.

4.6.3 How can NASA help

The strategic companies are primarily interested in government contracts, but where substantial and risky technology or systems development are involved they may require risk mitigation to limit the downside. Government funding support for Lockheed to develop X-33 is one example. Strategic companies also desire political stability and reasonable regulatory conditions.

4.6.4 Risk mapping

Below is a mapping of Private Equity firm risk perception against the risk categories described in Section 3.0.

Private Equity Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	Moderate
Market: Size	High
Market: Quality and reliability	Moderate
Market: Development timing	Moderate
Market: Longevity	Moderate
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	
Competitive: Amount of competition	High
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	

4.7 Investor risks compared

Investor Risk Focus	FFFs	Angels	Space Capitalist	VC	PE	Strategic
Technical: Developing new technologies			Moderate	Moderate	High	Moderate
Technical: Manufacturing difficulty	Moderate	Moderate	Moderate	Moderate	High	Moderate
Technical: Obsolescence	Moderate	Moderate		High	Moderate	Moderate
Technical: Launch, operational, and re-entry				Moderate	Moderate	Moderate
Market: Size	High	High	High	High	High	High
Market: Quality and reliability	Moderate	Moderate	Moderate	High	High	Moderate
Market: Development timing	High	High	Moderate	High	High	Moderate
Market: Longevity			Moderate	High	High	Moderate
Market: Uncertainty			Moderate	High	High	Moderate
Financial: Magnitude of capital required	High	High	Moderate	High	Moderate	Moderate
Financial: Timing of capital needs	High	High	Moderate	High	Moderate	
Financial: Time to Exit				Moderate	Moderate	
Financial: Uncertainty	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Financial: ROI hurdle				High	High	
Competitive: Amount of competition	Moderate	Moderate	Moderate	Moderate	High	High
Competitive: Nature of competition	Moderate	Moderate	Moderate	High	High	Moderate
Competitive: Barriers to entry				High	High	Moderate
Political / Regulatory: Policy & budgets	Moderate	Moderate	Moderate	High	High	High
Political / Regulatory: Regulatory compliance	Moderate	Moderate		Moderate	Moderate	
Political / Regulatory: Treaties & indemnification				Moderate	Moderate	
Perception				High	Moderate	Moderate
Execution / Operating: Management quality				High	High	Moderate
Execution / Operating: Availability of talent	Moderate	Moderate		Moderate	Moderate	

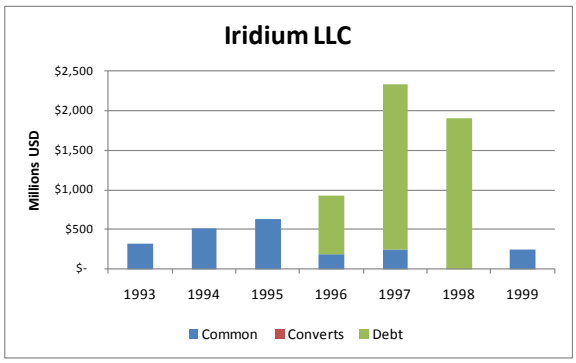
5 Investments

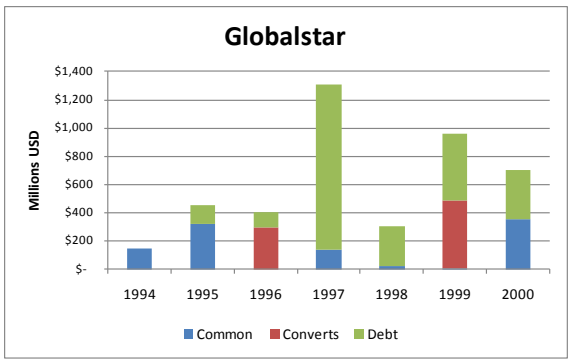
5.1 Select commercial space and satellite deals

5.1.1 Significant Commercial Satellite Financings

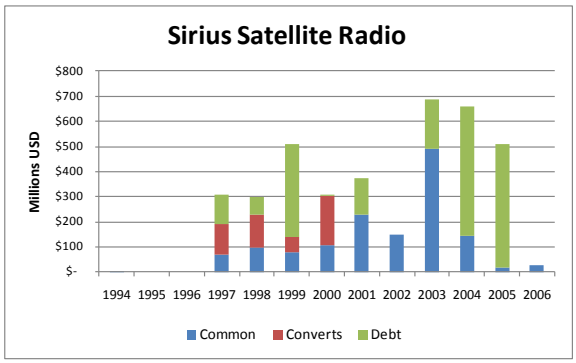
It was not until the 1990s when the capital markets truly opened up for the satellite industry, as interest in global connectivity was sweeping the markets and the technological and market barriers to commercial satellite ventures finally broke down. Moreover, once they got started, the activity became fast and furious as the telecom bubble propelled investor interest. Among the concepts which got their launch in this era include direct broadcast satellite (EchoStar and DIRECTV), commercial mobile satellite services (Iridium, Globalstar, ORBCOMM, AMSC/MSV, ICO), satellite radio (XM and Sirius), broadband (KaStar/WildBlue) and imaging services (EarthWatch, OrbImage, Space Imaging). Although we present the financing history of some of these ventures later in this section, we present here a visual record in graphs of some of the key players of the era. Key elements include the magnitude and type (equity, debt or convertible issues) of the capital that each company was able to raise at each point in time.

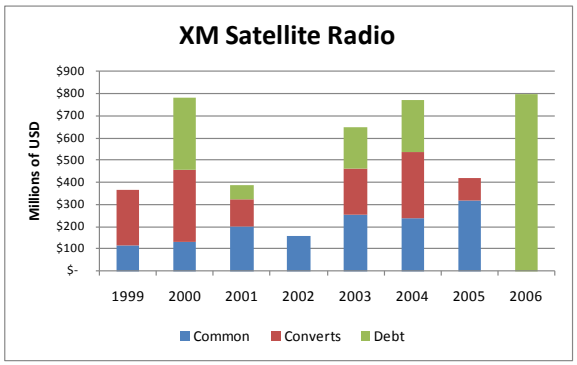
Mobile satellite services – Iridium and Globalstar



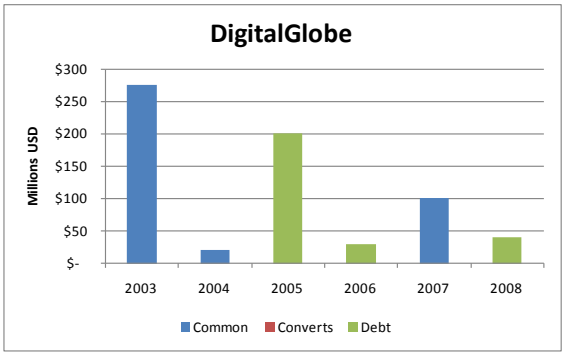


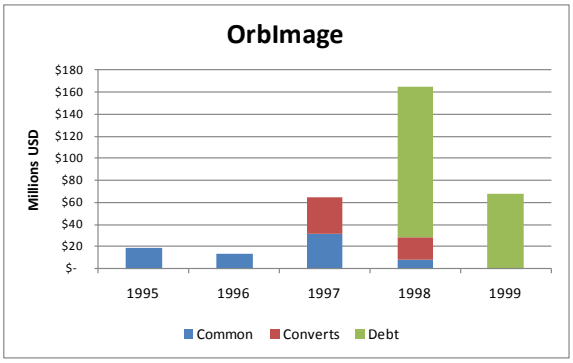
Satellite Radio – Sirius and XM



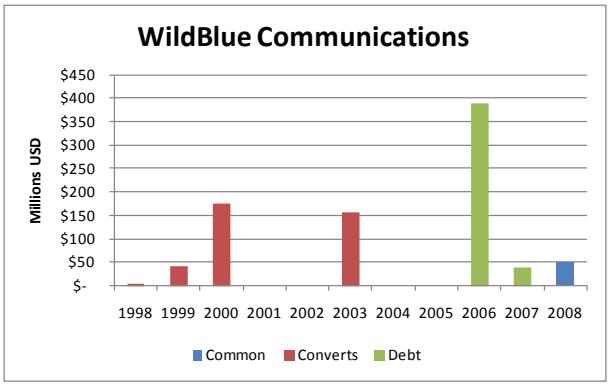


Satellite imaging – DigitalGlobe and OrbImage





Satellite broadband – KaStar/WildBlue



5.1.2 Significant Commercial Space Financings

We present here, to the best of our knowledge, the financings of every significant space project of the last couple decades. These include attempts at RLV companies, companies offering Lunar or NEO transport services, on-orbit services as well as others. Excluded are the traditional launch service providers (ILS, Arianespace, ULA, Sea Launch), most of whom developed their launch vehicles upon heavy government support. Also noted are significant NASA contracts, such as COTS, which contributed greatly to financings. Data is drawn from public sources, include SEC filings.

Company	Major Funding Events
AirLaunch LLC	Capitalized by members. $38.5 million in DARPA, USAF contracts
Armadillo Aerospace	~$4 million from the personal fortune of John Carmack (2002-2010)
Beal Aerospace	~$200 million from the personal fortune of Andy Beal (1997-2000)
Bigelow Aerospace	~$215 million so far from the personal fortune of Robert Bigelow (1999-2010)
BlastOff!	Total funding approx. $17 million. Seeded with $10 million by IdeaLab business incubator (1999). Idealab follow-on financing along with a couple of Hollywood angel investments (2000)
Blue Origin	Personal fortune of Jeff Bezos (2002-2010)
IOSTAR	$10 million from Intraspace

Company	Major Funding Events
Kistler Aerospace Corp.	~$650 million (late 90s), $100 million debt from Bay Habour Partners (2005), Acquired by Rocketplane (2006)
LunaCorp	Angel investor Walt Anderson. Sponsorship deal with Radio Shack.
Masten Space	$300k Series A preferred from 3 investors (2007)
MirCorp	~$30 million from Walt Anderson and Chirinjeev Kathuria (2000)
Orbital Sciences Corporation	Seed led by Fred Alcorn (1982), $50 million from LPs (1984-85), $32.5 million IPO (1990)
Orbital Recovery Corp.	Couple million from Angel investor Walt Anderson (2003) Matched by ESA Artes 4. Strategic investments by Dutch Space (lead strategic investor) Swedish Space Corporation, SENER and Kayser-Threde
Pacific American Launch Systems	$2 million equity primarily from one angel investor (1982-1989)
PLANETSPACE	Personal fortune of Chirinjeev Kathuria. (2005-2010)
Rocketplane (later Rocketplane Kistler)	$46.2 million equity from five investors (2006), $206 million NASA COTS (2006) [later revoked]
Rotary Rocket	Total $30 million invested. Series A equity, $5 million by Walt Anderson, $1 million by Tom Clancy (1996). Series B equity, $2 million by friends and family. Remainder invested by Walt through stock purchases and loans (1997-2000)
Scaled Composites / Mojave Aerospace Ventures	$28 million equity from Vulcan Ventures / Paul Allen (2004)
Space Adventures	$21.8 million equity from 80 investors (2008)
Space Access Corp.	Several millions by founders to develop an ejector ramjet reusable launch vehicle for single stage to orbit vertical take-off and landing.
Space Industries, Inc.	~$30 million estimated for 1980s project to build privately owned space station supported by Space Shuttle life support systems. Founder Maxime Faget supported by partners Joe Allen, and Westinghouse Electric Corp., and investors Roy Huffington, James Elkin, and Walter Mischer.
Space Transport Corp.	$200k from family and friends (2002)
SpaceDev	NEAP personally funded by Jim Benson. (1997-1999) Further SpaceDev (non-NEAP) financing through variety of private placements, PIPEs and debt offerings
SPACEHAB	3 rounds of private financing, several million: Walter Kistler, Al Zesinger / BEA Associates, Shelly Harrison (1985, 1986), $64 million revolving credit (1991), $21.5 million McDonnell Douglas term loan (1993), $3.6 million equity from 5 investors (1995) $43.5 million IPO (1995), Commercial Middeck Augmentation Module contract - $184.2 million (1990), Mir contract - $53.98 million (1995) + extension $38.95 million (1998), Research and Logistics Module Services (REALMS) Contract - $44.86 million (1997)
SpaceX	~$100 million from the personal fortune of Elon Musk. $278 million NASA COTS, $20 million equity from Founders Fund (2008), $15-60 million equity from DFJ, Founders Fund (2009), $50 million equity from Valor, DFJ, Founders (2010)
UP Aerospace	$450k equity from 3 investors (2005), $700k equity from 4 investors (2006)
Virgin Galactic / The Spaceship Company	$100 million initial investment from Virgin Group (2004-2009), $280 million equity from Aabar Investments (2009), $100 million by Aabar to fund small satellite launch (2009)
XCOR Aerospace	Angel investors Lee Valentine, Stephen Fleming, Pete Ricketts, Esther Dyson, Aneel Pandey, Joe Pistritto and others. Boston Harbour Angels (2007), Desert Sky Holdings (2008)
Zero Gravity Corp	$600k equity from 17 investors (2003), $1.3 million equity from 30 investors (2004), $5 million equity from 67 investors (2005), Acquired by Space Adventures (2008)

5.2 Case Studies

5.2.1 Rotary Rocket

Founding and market opportunity: The Roton X, the vehicle that became the basis for Rotary Rocket was a concept that was designed by experienced rocket designers and serial entrepreneurs Gary Hudson and Bevin McKinney. Originally, the Roton X, which was a highly innovative SSTO launch vehicle based on a rocket-tipped rotor propulsion system, was primarily intended by Gary and Bevin to compete for the suborbital XPrize. After the project and team was written up in a 1996 edition of Wired magazine, the concept got the attention of space enthusiast and telecom mogul Walt Anderson. Walt approached Gary about forming and investing into a company to develop and operate the Roton vehicle and asked Gary to put together a business case for it. It was determined that the Roton could compete for the launch of certain small satellites and tourists. The company began operations in the fall of 1996.

The Rotary Rocket Roton

Risks/challenges: The primary challenge of Rotary Rocket was technical. Nobody had ever developed a vehicle with a rotary component before, so the team was breaking new ground and opening themselves to all the risks inherent.

History of financings: The company was initially funded by Walt Anderson, investing $5 million in a Series A equity round with novelist Tom Clancy purchasing a smaller stake for $1 million. Between financings and shares distributed to founders, the company was given a post-money valuation of about $15 million. Later financings included a $2 million

Series B 'Friends and Family' round along with further loans and stock purchases by Walt, amounting to about $30 million capital invested by the end of 1999. In 1997, Barclays Capital was engaged to market a $45 million Series C private placement, but no investors were forthcoming. It was publicly stated that it would require an additional $120 million investment to complete development of the Roton.

NASA or government involvement, if any: The company started off its life with a self-imposed aversion to NASA and any government involvement. As a condition of his investment, Walt required the company board create a resolution that forbade the firm from taking Federal funding or defense contracts.

Business model and business plan execution: Rapidly, the company realized that the vehicle proposed in the original business plan would have to be radically upsized and changed in order to meet the demands of the institutional investment community. At this time, feedback from potential investors focused on the need to serve the proven market for GEO payloads and the heavy LEO payloads being proposed by Iridium. The small Roton was not capable of addressing these markets. At an initial board meeting, the decision was taken to change the vehicle from the original small Roton to a much larger "Kistler K-1 class" launch system, to allow them to compete with other emerging launch ventures, such as Kistler, Pioneer and Kelly Space.

Technically, Rotary became a "bridge too far" after the change in vehicle payload size. Since no angel investor could step forward to supply all the money needed for a smaller demonstrator that lacked market pull, the company had to take the plunge and try to demonstrate that it could build the bigger vehicle or terminate operations early. While termination was suggested as an option a few times in 1998 and 1999, Walt was determined to continue. But both technical and managerial challenges created by splitting operating between the San Francisco Bay Area and Mojave test sites and shops caused insurmountable difficulties. In the end, while they conducted a successful flight test program of a flight-weight demonstrator (but lacking main engine and thermal protection) the company could not assemble either a critical mass of talent or money.

Success or failure: Failure. The company was wound down and disbanded in 2000. As a technical concept, the Roton has not led to similar designs being attempted although certain aerospace ventures arose from the former engineers of Rotary, notably XCOR Aerospace and Space Launch Corporation.

Lessons learned: Management also believed that they created a feeling of ill will with regard to NASA due to the company policy that required them to reject any offer of government funding or assistance.

5.2.2 Orbital Recovery

Founding and market opportunity: Orbital Recovery was born in early 2002 out of the interests and previous ventures of its founder, Dennis Wingo, and its principal financial backer, telecom mogul and serial space investor Walt Anderson. Dennis had been previously involved in a related venture called SkyCorp, which had attempted to demonstrate on-orbit assembly of commercial spacecraft using the ISS. Although initial angel funding and initial NASA contracts had been executed for SkyCorp, in the wake of the tech crash of 2000-2001, follow on private investment was not forthcoming. Walt Anderson, for his part, had been involved in the same time period in a number of high profile but failed commercial space projects, most notably the leasing of the Mir Space Station through MirCorp.

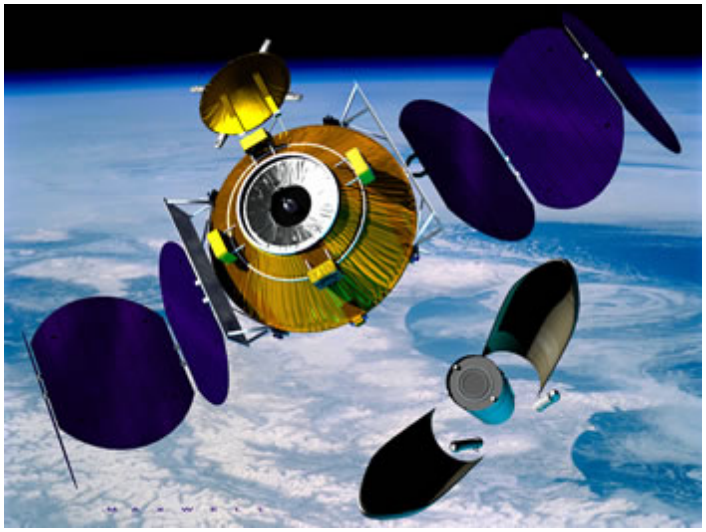
Dennis and Walt had initially planned to found a seemingly lower risk space venture, particularly the construction and launch of a very low cost communications satellite, but the tech crash limited market interest in such a project. Instead, they realized the potential of existing satellites, particular those seemingly near end-of-life communications satellites residing in inclined geosynchronous orbits. These satellites, while still useful, generate far less revenue for operators than non-inclined orbit satellites. At a meeting with a prominent satellite insurance brokerage firm, Dennis and Walt recognized a business opportunity from recovering inclined orbit satellites by placing them back into non-inclined orbits. Their back-of-the-envelope estimates demonstrated that they could offer 10 additional years of satellite life to an operator at only one-third the cost of a replacement satellite. As a result, Dennis and an investment affiliate of Walt founded Orbital Recovery to develop and launch robotic craft that would offer this service to commercial satellite operators.

Risks / challenges: The primary challenge was proving a new market and overcoming perceptions of risk. There were also development and technical risks in designing and building a new spacecraft to provide servicing. Startup financing was not as great a risk as the company was initially backed by a wealthy individual (Walt).

History of financings: Walt Anderson's investment affiliate was the initial investor in Orbital Recovery, seeding the company with "a couple million dollars" of equity. This cash was matched in a public-private partnership by the European Space Agency through the ARTES 4 program. In 2004, this seed round was followed by strategic investments from European aerospace firms, Dutch Space (lead strategic investor) Swedish Space Corporation, SENER and Kayser-Threde. Additional financing rounds were planned to occur following initial technical development and signing of first customers. Although these milestones were met, on the day of the first customer (Optus) signing, Walt Anderson was arrested by the US Justice Department on charges

of tax evasion, throwing the future and funding of the company into question for some time.

The company was eventually "rejiggered" and sought additional funding through ESA and the European industrial team. Terms for a $180 million development program were negotiated through ESA and its partner nations, but implementation was delayed due to difficulties obtaining individual nation approvals, notably from Sweden. Later, in the 2008 / 2009 time period, the company received substantial investment interest (about $100-$200 million) from a consortium from the UAE, but the investors pulled out following the financial crisis which occurred in the country at that time.



ConeXpress, the Orbital Recovery servicing vehicle

NASA or government involvement, if any: NASA was not substantially involved in Orbital Recovery as most strategic and technical work was done in Europe. The European Space Agency was substantially involved, in a variety of programs including ARTES 4, one of ESA's technology development programs and ConeXpress, an existing ESA and Dutch Space project.

ESA involvement presented particular difficulties which are less acute at NASA. Because of the inherent structure of ESA and contributions of member states, large space projects are forced to spread their contracting across multiple countries in favor of national benefit quotas. This helped increase the execution difficulty and the cost of the project. At one point, because costs had increased so greatly the business model became uneconomic and unviable.

Business model and business plan execution: It was decided that Orbital Recovery would execute their business model in the lowest cost and least technically risky way. This ruled out providing on-orbit refueling or power/battery replacement to commercial

satellites, as these services proved to be too technically complicated, presented significant liability risks and had too uncertain a market. Instead they would only provide 'space tug' orbital repositioning services, where a robotic craft would latch onto a target satellite and propel it under the craft's propulsion (rather than the satellite's own propulsion). Even this approach had very substantial technology risk since this technology (i.e. rendezvous and robotic docking with a uncooperative target) had never been proven.

The company issued RFPs for development and construction of their orbital crafts and received responses from major contractors in Europe. In 2003, Dutch Space was appointed Prime Contractor and the program merged with the existing ESA-backed ConeXpress orbital serving demonstration program. Good feedback was generated from major satellite operators and satellite insurance underwriters. An initial customer (Optus) was found and was ready to be signed. The company, however, was derailed on the day of the signing due to the arrest of its major financial backer.

Under the reboot of the company, another European consortium was organized to pursue the opportunity. Major satellite operators continued to be interested, to the extent of conducting advanced contract negotiations. As stated above, funding was found with ESA, but the conditions of the funding (the necessity of spreading expenditures across multiple ESA member states as well as the necessity of employing large aerospace firms) made the project uneconomic.

Success or failure: The company has so far not succeeded in its goals, based on inabilities to find stable financing and to gain cost certainty on technical development. The company has been hampered by the loss of its initial financial backer and the economic crisis of 2008/09. However, according to conversations with Dennis, there are plans to revive the Orbital Recovery and Skycorp concepts as businesses in some form in the not-too-distant future. The proposed technology remains undemonstrated.

Lessons learned: A few significant lessons were learned. One was the importance of diversifying financial sponsorship in cases where a Space Capitalist is the dominant or sole backer of the enterprise. The company was set back by the arrest of Walt, a situation that would be less likely to occur with institutional investors. In this case, however, the business concept was probably not mature enough to attract meaningful levels of institutional investment, so the risk could not easily have been mitigated. Also a significant factor was the high cost of doing business with large aerospace companies and their inexperience (outside of communications satellites and certain imaging satellites) dealing with commercial customers. A major plus was the ability of a government program to buy down technical risk or to match investor funds to support new programs.

Another important lesson was that ESA was willing to lead an effort to fund the business plan given only one or two customers. However, the absence of institutional investor participation suggests that a much larger and more visible market opportunity was required to overcome the high perceived technology risks.

5.2.3 BlastOff!

Founding and market opportunity: BlastOff! was a project of Idealab, a business incubator operated by tech entrepreneur Bill Gross, that was extremely active in the late 90s in promoting and investing in groundbreaking tech companies (Idealab still exists today but with a different focus and level of activity). The idea for BlastOff! originated from Bill in mid-1999 in the midst of commemorations of the 30th anniversary of the Apollo 11 mission to the Moon. As Idealab was, at the time, flush with substantial financial resources and had a mission to pursue extraordinary ideas, Bill decided that it would be of interest to form a business whose purpose was to build and operate a complete unmanned mission to the surface of the Moon (potentially leading into a series of missions). After conferring with Planetary Society Executive Director Louis Friedman and planetary scientist Tomas Svitek on mission feasibility, Bill seeded the company in late 1999.

Risks/challenges: Initially, with funding secured, the primary focus of the company was technology development and in finding appropriate personnel and leadership. Later, the focus became finding a profitable and sustainable business model to associate with the activity (e.g. a lunar mission). Near the end, the major challenge was finding sources of capital to continue the company without its initial financial sponsor.

History of financings: The company was principally funded by the Idealab incubator, starting with a purported $10 million on the outset. Later financings brought additional capital from Idealab as well as small equity investments (single digit millions) from certain Hollywood or tech individuals. Near the end of 2000, as the tech bubble was in the midst of its crash, senior management requested its employee base to draw up and contact lists of potential capital providers in an attempt to continue funding. At least three or four individuals and groups expressed serious interest in investing, however none was able to commit before the company was shut down.

NASA or government involvement, if any: BlastOff! was, in essence, a project of a convergence of tech entrepreneurs, Hollywood marketers, planetary scientists and visionaries who imagined a space project done as an alternative to NASA. This, combined with the “stealth mode” development characteristic of early stage technology ventures, meant that the company worked mostly independently of any NASA projects and had little interaction with NASA during its history. In one notable case, the company specifically avoided NASA involvement, preferring to use the Universal Space Network TT&C capabilities rather than using NASA’s Deep Space Network. On the other hand, the industrial base previously formed though NASA and its contractors was a major source of technical skills, as many early personnel were recently laid-off engineers from recently failed Mars planetary missions (Mars Polar Lander and Mars Climate Orbiter)

Business model and business plan execution: BlastOff! started life as a technical project, with engineers and mission planners defining the technical parameters and initiating preliminary designs of the mission components (lander, rovers, etc). Hiring ramped up quickly, starting in late 1999 with almost exclusively engineers brought on board until the second quarter of 2000. The company intended that the business development component (marketing, sales, etc) would be established by its eventual CEO. Initially, tech entrepreneur and space enthusiast Eric Tilenius was approached for the position of CEO. Reportedly, he intended to bring substantial financial resources to the company as well, but eventually turned down the position. Instead, in April, 2000, XPrize founder Peter Diamandis was hired as CEO, who brought with him a team of over a dozen marketing and business development personnel.

The second half of 2000 was consumed with continued technical development, initial procurements (such as launch vehicle) and initial business model definition. A variety of business models and monetization schemes were explored, including dataset sales, scientific payloads, sponsorship and merchandising, even sales of the right to have small flags planted on the lunar surface (intended for sovereign clients). Even certain high profile Hollywood personalities got involved, including directors Steven Spielberg and James Cameron, advising on the media and entertainment aspects of their initial missions. By the end of 2000, company personnel had reached over 50.

During this time, the tech bubble started its spectacular burst and crash, directly affecting BlastOff!. Idealab was greatly exposed to dozens of dotcom enterprises through its other portfolio companies. Poor performance of these other companies over the 2000 holiday season put a significant strain on Idealab's finances and by the end of the year, Bill announced that they could no longer guarantee financing for BlastOff!. After a frantic search for alternative funding sources, the company was shut down on January 17, 2001. Former company insiders estimate that, at the time, the company was two weeks away from producing flight hardware and about 3-5 months away from any revenue generation.

Success or failure: Failure. The company did not succeed in landing a mission on the moon nor did it come anywhere close to achieving any sustainable business. However, it is believed that the experience of the company was eventually the inspiration for the $30 million Google Lunar X Prize to land a privately developed mission to the surface of the moon.

Lessons learned: In retrospect, BlastOff! was a classic top-of-the-bubble phenomenon, coming near the peak of an era characterized by large amounts of capital chasing leading edge projects with ill-defined business models. More importantly, the company appears to have been founded with interest in the mission first and the market second, a poor basis from which to start any commercial enterprise. However, given its short

history, the company made good progress and barely had a chance to prove out a business model. As no other similar enterprise at its time had anywhere near the funding, BlastOff! may have been attractive to customers for its potential to execute an actual mission, but it never got to find out. BlastOff! also suffered from its over reliance on IdeaLab, and in particular by not seeking significant outside funding sources until it was nearly out of funding. IdeaLab, a successful technology incubator founded by Bill Gross, acted in many ways like the individual Space Capitalists discussed above; with investment criteria and goals somewhat different from traditional investors and a high level of management control. Founders and their early backers often postpone capital raises in a desire to achieve more milestones first in order to reduce the level of dilution to their equity ownership. In the case of BlastOff!, it is very likely that any additional funding would have been under very onerous terms for the early investors, if even possible.

It could also be argued that the perceptions and biases of the founders kept the company from having anything to do with NASA, thereby eliminating a potential partner for cargo space, scientific expertise and technical assistance. Moreover, were the company to have received attractive opportunities to do continuing work for NASA, the ongoing business may have kept the company and its work alive.

Lastly, like many visionary companies, BlastOff! was probably just too far ahead of the markets it sought to serve.

5.2.4 NEAP (a project of SpaceDev)

Founding and market opportunity: The Near Earth Asteroid Prospector (NEAP) mission started life as the primary purpose of SpaceDev, a public entity acquired and branded in 1997 by Jim Benson, a wealthy tech entrepreneur. NEAP was inspired by a recent NASA mission, the Near Earth Asteroid Rendezvous (NEAR) mission, which had successfully launched in 1996 to investigate certain asteroids of interest. Jim wanted to push the objectives of NEAP further than that of NEAR, being interested in prospecting a particular asteroid for mineral resources and potentially claiming it as property for SpaceDev. Jim also believed that the NEAP mission would attract commercial interest, with organizations willing to pay for datasets and payload space on the spacecraft bus. There was also a political motivation for Jim, as he was particularly interested in using NEAP to make a statement about private property in outer space.

Risks/challenges: The major challenge for the NEAP project was to prove a market which had never been offered before – transport and data services to an asteroid. It was unknown what, if anything, anyone would pay for this access and who would be the customer base. There were also technical risks in executing the required mission, which may had involved attempting to land on an asteroid. As well, there were substantial legal and regulatory hurdles, especially if governments or international organizations had been intent on challenging SpaceDev property claims on an asteroid.

History of financings: Although SpaceDev later received substantial investment in both debt and its public equity, the NEAP mission was entirely funded by the wealth of Jim Benson. In 1998, SpaceDev financed the acquisition of certain facilities with $1.8 million in notes payable.

NASA or government involvement, if any: As far as NASA was concerned, NEAP was modeled after NASA's successful NEAR mission to such a degree that NASA formally recognized it as a commercial Mission of Opportunity. This was significant because Commercial Missions of Opportunity had never been included in NASA's Discovery program. In the past, it had been assumed by NASA that Missions of Opportunity would be government missions of other countries.

In late 1998 SpaceDev began the approximately two-year process of working with NASA's Jet Propulsion Laboratory (JPL) to secure scarce Deep Space Network (DSN) tracking time for the mission. By the summer of 1999, JPL and NASA Headquarters formally agreed that NASA was prepared to support the NEAP mission with the DSN.

Business model and business plan execution: SpaceDev and Jim had initially hoped that they could sell the entire mission to one interested customer, but the company was unable to secure a customer. Instead the company offered a variety of opportunities,

including datasets and payload space, publishing a price list on its website. With the exception of a group proposing a multimedia CD to be carried with the craft and a partnership with the University of Arizona to provide a multi-band CCD imaging systems, no customers were forthcoming.

Marketing and business development of NEAP was limited. Most activity was centered on media publicity generated by Jim Benson himself as well as discussions initiated at conferences and workshops. Overall, only about a half of a full-time equivalent was devoted to business development. On the technical side, by 1998, the core team had refined the definition of the NEAP mission. Launch of NEAP was planned for late 2001, with a rendezvous at the near-Earth asteroid Nereus in mid-2002. However, due to program delays, the mission was reprogrammed to another accessible target asteroid. The reprogramming was primarily the result of schedule slips as a result of launch vehicle readiness, funding delays, and priority changes resulting from the poor customer take-up. By mid-1999, SpaceDev had shifted priority away from the NEAP mission.

Success or failure: Failure. SpaceDev never did execute on the NEAP mission and it was never revived. However, in part because of its NEAP efforts, SpaceDev did make a success out of developing small satellite missions and was itself acquired by the Sierra Nevada Corporation in 2008.

Lessons learned: The near complete neglect of market research and validation imposed significant risk on the NEAP program, as was subsequently demonstrated by an inability to secure customers. With a leap of faith, SpaceDev picked a product/service concept first and then tried to find customers versus designing a product/service to satisfy a well understood market opportunity. When this risk was combined with the substantial technical risk of developing the spacecraft and payload, and further layered with the fact that no regulatory framework existed even if the mission was technically successful, the program became unfundable.

5.2.5 Orbital Sciences

Founding and market opportunity: Orbital Sciences grew out of a startup called Space Systems Corporation which was founded in 1982 by David Thompson, Bruce Ferguson and Scott Webster to "develop, test, manufacture and market" commercial space systems. Their original focus was on micro-gravity applications, but they soon saw an attractive market opportunity and existing need they believed they could fill and changed their business plan. As such, in 1983, the company launched an initiative to develop its first product, the Transfer Orbit Stage (TOS), which was intended to serve as a medium capacity (i.e. 3000-7000 lbs to GSO) guided perigee kick motor for satellites launched via the Titan III and Space Shuttle. It was intended to address a gap in the capabilities of the PAM kick motors, which offered relatively limited payload capacity and no guidance capability, and the Boeing Inertial Upper Stage, which offered tremendous capability from a mass, autonomy and guidance perspective – but at a high price (over $50 million per article at the time).

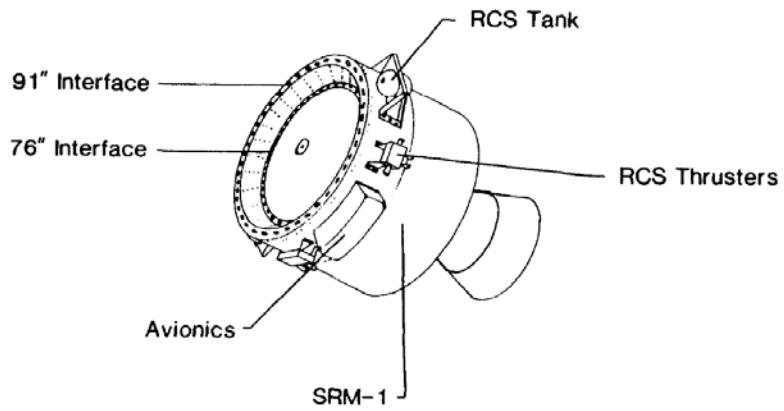
Risks / challenges: To help mitigate risk, Orbital executed a Memorandum of Understanding with NASA in December 1982, followed by a final agreement in April 1983. This MOU included terms that in return for NASA not developing a competing product, Orbital would finance the development of TOS and have exclusive marketing rights for TOS. NASA also agreed to establish a TOS Program Office at Marshall Space Flight Center to provide technical monitoring and advisory input to Orbital, effectively addressing customer concerns about Orbital's technical design. Because one of the customers for TOS was NASA itself, and TOS was slated to ride on a manned vehicle (i.e. Space Shuttle), this was critical and reassured investors that NASA as a logical customer would use TOS, and that NASA's involvement would convince other customers that TOS was technically sound. Using an experienced contractor like Martin Marietta for design and construction of TOS also served to help mitigate development risk and customer safety perceptions.

To help mitigate technical risk, TOS was developed using mostly off the shelf components (i.e. avionics, reaction control system, motor) that had been developed and space proven previously. In addition to technical risk, the TOS effort was also dependent on the compatible vehicles getting flights on their manifests. Ultimately, phase-out of the Titan III, Titan 34D and loss of the Space Shuttle in the 1986 Challenger disaster would greatly limit the market for TOS. Only two vehicles ultimately flew. By the time this happened, Orbital had diversified its revenue streams, so the loss was not threatening to the company itself.

History of financings: Orbital was originally financed through founders and angels, with its first institutional funding round of $2 million in 1983. The initial institutional investors were Rothschild, Brentwood Associates, Norwest Growth Fund and Shearson/American

Express. Subsequently, in 1984 Orbital raised $50 million in equity capital from the sale of limited partnership interests. A key part of the success of this $50 million round was an investment tax credit available to investors. Orbital subsequently completed a $32.5 million IPO in 1990.

NASA or government involvement, if any: NASA played a significant role in the early stages of Orbital Sciences. NASA's initial Memorandum of Understanding and the subsequent final agreement paved the way for attracting private capital. It did so by eliminating issues of competition from NASA, implying that NASA would be a future customer for a defined market, significant technical support and ultimately serving as the launch customer for TOS (with a $40 million contract award for one TOS and an option for a second, awarded in 1986).



The OSC Transfer Orbit Stage

Business model and business plan execution: Orbital Sciences was originally a one product company – with the TOS supplemented with some engineering consulting work. With limited initial design and manufacturing capabilities, Orbital originally focused on the specification, program management and marketing functions for TOS and outsourced design and production to Martin Marietta. As the firm grew, its internal capabilities became more robust and the firm began development of its second major program, the Pegasus launch vehicle as a joint project with Hercules Aerospace. The Pegasus was intended as a lower cost, greater flexibility replacement for the venerable Scout launch vehicle. DARPA served as the launch customer for Pegasus, signing a contract for six launches in 1988, the same year the project was formally launched. In addition to the government small satellite launch market, Orbital was able to vertically integrate by incorporating the Pegasus in its design for its proposed Orbcomm and Orbimage commercial satellite initiatives, which were incubated at Orbital Sciences but were ultimately funded separately for most of their development.

Success or failure: As noted above, the TOS program was relatively short lived – yielding only two launches which were technically successful. However, profits from that

program gave Orbital the capital to develop new aerospace products, and the technical success of TOS gave Orbital a reputation for competence that was key to its raising additional capital and winning new government contracts. This led to Orbital's subsequent Pegasus program, partially funded by DARPA, which set the company on a sustainable growth path.

Lessons learned: The early phases of Orbital Science's development illustrate both successful and unsuccessful risk management and mitigation strategies. The structure of Orbital's contract with NASA, and its outsourcing of production served to mitigate risk and ultimately succeeded at that task. This turned out to be important because the market for TOS turned out to be quite limited. This was driven in part by the transition away from using Space Shuttle for commercial launches and high prices for Titan launches, highlighting a recurrent complaint by interviewees about how shifting government policy and focus introduces additional risk in many space initiatives that is manmade.

NASA's willingness to agree to not develop a competing system, and implied willingness to use TOS for its own programs were critical in attracting private capital. Similarly, DARPA's willingness to commit to a six flight contract for Orbital's Pegasus launcher provided a sufficiently large purchase for the firms to be able to fund its development privately.

5.2.6 IOSTAR

Founding and market opportunity: IOSTAR Corp. was formed in 1995 as an initiative to use nuclear powered rockets as the propulsion system for space tugs. IOSTAR is an acronym meaning In-Orbit Space Transportation and Recovery. The tugs were intended for addressing several potential market opportunities: orbit transfer operations from LEO to GEO, rescue of satellites stranded due to failures, removal of dead satellites from the GEO belt.

Risks / challenges: IOSTAR's business had substantial technical challenges: It required a space based nuclear reactor that had to be developed at Sandia National Labs, a propulsion system that had never been deployed in space and robotic technology (i.e. approach and docking with uncooperative targets) that was also untested and unique. Another somewhat less daunting technology risk for IOSTAR was the use of xenon ion propulsion.

History of financings: IOSTAR was initially founded and financed by its parent company Intraspace Corp. with a total of $10 million. IOSTAR was also assisted almost from the beginning by Sandia National Laboratories which under a CRADA helped design much of the nuclear-powered rocket technology. IOSTAR subsequently sought to place $15 million in equity but was unsuccessful.

NASA or government involvement, if any: IOSTAR successfully lobbied the government to create legislation authorizing the DoD to create a $1.5 billion loan guarantee program to fund a space tug system whose capabilities matched closely what IOSTAR was promising. These loan guarantees required a $7.5 million "investigation charge" to be paid by applicants. The loan guarantees also required the applicant to raise $300 million in equity to qualify for the loan. This funding model was very similar to that successfully employed on the TDRSS program. In this case, however, neither IOSTAR nor any other party met the qualifications and there was no material effort by DoD to actually create the loan guarantee program. No office was established, no program manager was appointed, no funding was provided, no regulations were established, and no public hearings were held.

Business model and business plan execution: IOSTAR never got past the concept stage. The company was never able to secure sufficient funds to be in a position to apply for the loan guarantee, had the loan guarantee program actually been established. Consequently, IOSTAR never attempted either the $300 million equity raise or the associated debt placement. Subsequently, beginning in 2007, litigation erupted alleging mismanagement of the company and its resources that remains pending. As conceived, Sandia National Laboratories would provide and control the nuclear reactors that

IOSTAR would use. IOSTAR proposed that Orbital Sciences provide the spacecraft bus, and that TRW serve as the systems integrator.

Success or failure: IOSTAR failed to raise any capital beyond its initial seed funding. IOSTAR subsequently filed for bankruptcy in 2010.

Lessons learned: While IOSTAR ultimately failed due to internal issues, these issues only emerged after an extended marketing effort for an initial $15 million placement. As demonstrated by the company's inability to raise funds, the multiple layers of technical, execution, and political risk were so daunting that even the "hypothetical" availability of federal loan guarantees was insufficient to attract capital.

5.2.7 Beal Aerospace

Founding and market opportunity: Beal Aerospace was founded in 1997 by Andy Beal to provide launch services for both LEO and GEO payloads. At the time of its founding Beal believed that a low cost provider of launch services could capture a significant portion of the global market for commercial GEO launches, ISS resupply, deployment of large LEO satellite constellations like Iridium and the proposed Teledesic constellation. In the words of its founder, "If you can't build a rocket to GEO, you don't have much of a market other than NASA".

The Beal Aerospace BA-2 second stage engine

Risks / challenges: Beal Aerospace's technical approach was to build what has been called a "Big, Dumb Booster" – that is a design that intends to trade away performance for lower cost and greater reliability. By choosing a design that could not tolerate failure of its engines (i.e. it had no "engine out" capability), Beal gained some potential cost savings in exchange for reduced overall reliability – though it should be noted that this was the same approach all competing designs (i.e. Delta, Atlas) employed. Because of the risks inherent in any new design, some cost growth was experienced during development. Beal estimates that development could have been completed within a budget of ~$500 million (a number similar on an inflation-adjusted basis to SpaceX's estimated development cost for Falcon IX).

History of financings: Beal Aerospace was financed entirely by Andy Beal, who invested over $200 million during development. By his own admission he "hates dealing with 3rd parties" and he had ample personal financial resources to fund the effort. He acknowledges that "personal objectives were part of it" (i.e. his motivation for investing). Surprisingly, Mr. Beal's lack of success and large personal loss on this venture did not dissuade other like-minded Space Capitalists from backing similar visionary endeavors. If anything, they saw how far a privately backed company could get with streamlined decision and procurement processes.

NASA or government involvement, if any: There was little involvement with the federal government by design from Beal Aerospace's inception. In choosing to minimize its NASA contact, Beal stated that he "…didn't want the cost of the NASA interface." The firm did explore use of NASA launch facilities, but due to their perception of the ongoing cost of operations at those sites and environmental liability issues from perchlorate contamination at sites they investigated, Beal chose to launch from international sites. In turn, this brought the firm's activities under the jurisdiction of the Missile Technology Control Regime, which made exporting their rockets to international launch sites problematic. In retrospect, Beal believes it would have been better to stay with existing government spaceports to avoid this issue and to lever the infrastructure in place.

Business model and business plan execution: Beal intended to provide turnkey launch services to government and commercial satellite launch customers. Beal's "clean sheet" design incorporated a minimal amount of components provided by other aerospace vendors so as to avoid baking their cost structure into the Beal design. "When you sub, you get inefficient." By avoiding subcontractors, Beal also intended to avoid the costs associated with contract management.

Success or failure: Beal Aerospace achieved some technical success, notably by successfully test firing its second stage engine, and completed substantial design work. However, in 2000 Beal chose to shut down his company and liquidate its assets. In explaining his decision to shut down, Beal cited potential competition from launchers NASA had under development that were targeted towards the same markets. An additional factor was the bursting of the telecomm bubble, which made it apparent that demand for launch services, especially for large LEO constellations, would be much lower than was projected at the time the company was founded.

Lessons learned: During conversations with Beal, it was noted that some form of indemnification for environmental liability would have made it much more practical for Beal to use existing government facilities – which would have eliminated a significant portion of the problems the firm encountered. Because the NASA launch market represented a significant portion of the total market Beal intended to address, especially after contraction of the commercial markets, the perceived threat from competing government subsidized systems (EELV) would have needed to be addressed for Beal to be willing to commit additional capital to the venture. By depending for a significant portion of the intended revenue base on customers that had substantially unproven business models (i.e. the large telecom constellations), Beal had significantly greater risk than it would have had otherwise. It is interesting to wonder whether or not the existence back then of a COTS program could have made the difference in market estimation and ultimately Mr. Beal's willingness to invest more capital. SpaceX was confronted with very similar market risks, but chose to move forward given the existence of COTS.

5.2.8 X-33/VentureStar

Founding and market opportunity: The X-33 program was a NASA program with an initial contract award to Lockheed Martin in 1996, following a competition which included McDonnell Douglas and Rockwell. X-33 was intended to be a suborbital technology demonstrator for a proposed commercial launch vehicle called VentureStar to be developed by Lockheed Martin. VentureStar was intended as an unmanned orbital launch vehicle to carry shuttle sized payloads to LEO as a commercial service. The intended markets were to replace a portion of shuttle launches for NASA and to provide satellite launch services for commercial customers.

Risks / challenges: The X-33 had significant new technologies, including composite cryogenic fuel tanks, a new linear aerospike engine and a new metallic thermal protection system. In addition to these technologies, the X-33 was intended to be capable of a 7 day turnaround, which required substantial operational method development.

A rendering of the X-33

History of financings: The X-33 was funded jointly by NASA and Lockheed Martin. The contract budgeted $941 million to be contributed by NASA, and an additional $212 million to be funded by Lockheed Martin. The contract specified that the burden of cost overruns was to be borne by the contractor team. Ultimately, the contractor team contributed $356 million to the X-33 program. VentureStar was intended to be privately funded, but was contingent on completion of X-33.

NASA or government involvement, if any: NASA contributed the bulk of the non-recurring engineering funding for X-33, but did not accept any risk from potential cost overruns. NASA also contributed program management and facilities.

Business model and business plan execution: The X-33 was a jointly funded research and development program intended to validate new technologies. In the event of a successful program completion for X-33, VentureStar was to be a privately funded service to provide space transportation services to LEO for both government and commercial customers. Lockheed Martin was joined by Allied Signal and Boeing Rocketdyne as part of the overall commercial team.

While technical and programmatic problems have been cited for X-33, these are beyond the scope of this study. Whatever the cause, there were substantial cost overruns in the development that the commercial partners absorbed for a time, levering NASA's original investment. Considered more appropriately as an R&D partnership for a single-stage-to-orbit (SSTO) rocket, more challenges arose than expected, leading to a re-evaluation of the ideas overall direction. There was also an expectation by the commercial partners that the government would provide loan guarantees for much of the future funding requirements of VentureStar. While legislation for loan guarantees was introduced, it failed to pass through Congress after generating significant resistance from other companies.

Success or failure: The X-33 contract structure was successful in attracting substantial private investment, and provided NASA with good visibility of its cost liability. Furthermore, X-33 achieved partial technical success in developing new technologies; however, it did not produce an operational system. With substantial cost overruns that had already occurred, the failure of the LH2 composite tank was a proximate cause for termination of the program. At the time the program was terminated, the commercial team had contributed greater than 50% more funding than originally planned and approached NASA for additional funding which was not provided. With the loss of the loan guarantees and the lack of additional NASA funding, the cost of overcoming the technical challenges became too much for the commercial partners to take on.

Lessons learned: The financing structure used, by virtue of using shared costs up to a fixed ceiling, resulted in the commercial partners having to accept essentially 100% of the risk of overruns. While this clearly provided them with substantial motivation to avoid overruns, once they did occur it also meant that they had reduced incentive to stay with the program. Because Lockheed Martin was already a substantial provider of boosters to the government, it was also inherently conflicted, though it is unclear if this played an explicit role in the program termination. The use of very substantial amounts of new technology increased the technical risk of the program, but is understandable in the context of an X vehicle. NASA, in fact, may have chosen the most technically risky of

the three proposals intentionally in a desire to truly push the envelope on launch capability. If NASA had instead selected the winning proposal based on least level of technical risk, the probability of success may have improved, however, potentially at the expense of achieving fundamental breakthroughs in capability. In short, the approached used here was the exact opposite of taking “baby steps” and innovating incrementally. It was a bold attempt to leap far ahead.

5.2.9 SpaceX

Founding and market opportunity: SpaceX was founded in 2002 with the ultimate intent "…to make humanity a space faring civilization", and the near term goal to substantially reduce the cost of accessing space though efficient production and reusability. The company's original product, the Falcon I launch vehicle was intended to address the small launch vehicle market, but the company also made it clear that it intended to pursue the Space Station resupply and commercial satellite launch markets with its subsequent Falcon 5 and Falcon 9 offerings. Given the size of the small launch market, the Falcon 1 program should, to an extent, be considered a technology demonstrator with some market potential rather than a product developed purely to address a market opportunity.

Risks / challenges: NASA and commercial satellite launch customers want reliable space proven designs to ensure that their valuable payloads make it to the intended orbit. To illustrate this fact, it can be noted that in 2009 SpaceX customer Avanti Communications went to the extreme step of raising additional capital so that it could address schedule and reliability concerns from its own investors about using SpaceX's Falcon 9 launch vehicle for its Hylas 1 satellite. As a consequence, SpaceX's ability to win commercial customers was limited until it could demonstrate flight success.

The SpaceX Falcon 9 rocket

In turn, to actually produce a working vehicle, SpaceX had to develop the components that go into the vehicle. The business decision to vertically integrate in order to contain costs imposed further commercial risk, by eliminating the ability of SpaceX to use space qualified components demanded by most customers. However, at this stage of development, the gains made in cost containment, schedule control and quality assurance appear to have been a good trade-off for SpaceX. After all, the first goal for a new launch provider has to be to fund a successful flight demonstration. Without that there would be no customers.

History of financings: SpaceX was originally funded from the personal funds of its founder to the tune of over $100 million. Subsequently, in 2008 SpaceX received a $20 million investment from institutional investor The Founders' Fund. In 2009, Draper Fisher Jurvetson committed an additional $15 million and in November 2010, 16 existing investors, including The Founders' Fund and Draper Fisher Jurvetson invested a further $50 million.

NASA or government involvement, if any: SpaceX enjoyed substantial government support for purchase of the first three flights of Falcon 1, though DARPA, the Office of Responsive Space, ATSB and NASA. Development of the Falcon 9 launch vehicle has been supported by the NASA COTS program as described in the next section. SpaceX also uses the government spaceport at Cape Canaveral Air Force Station for the Falcon 9, and is developing a launch facility at Vandenberg Air Force Base for polar missions.

Business model and business plan execution: SpaceX offers its launch services to commercial and government clients on a firm fixed price basis, with transparent price quotes provided on its web site. For the COTS program, in 2006 SpaceX contracted to provide 3 flight demonstrations for $278 million. Subsequently in 2008, NASA contracted with SpaceX to provide 12 flights under the Commercial Resupply Services IDIQ contract, with a value of $1.6 billion.

Success or failure: The first three Falcon 1 launches were unsuccessful, but provided a wealth of engineering data that suggested success was at hand. Subsequently the company successfully launched a Falcon 1 using its own resources. The first Falcon 9 demonstration was a success. The company has amassed nearly thirty launch contracts, including both commercial and government customers.

Lessons learned: During its initial launch program, SpaceX benefitted from government customer support through DARPA, and subsequently through NASA. Likewise, NASA's COTS initiative provided critical funding, helping to fund the development of Falcon 9, giving SpaceX credibility with its customer base and helping to attract outside investment. In the absence of this support, we believe that SpaceX may well have exhausted the funding resources of its founder, and being too early stage at that time to attract outside investment, it could easily have failed. However, although timing was perhaps more favorable for SpaceX, as opposed to say Beal Aerospace, in terms of government support and the visibility of commercial market demand, the greater openness of SpaceX to seek government support and consider government as a potential partner was certainly a contributor to its continued progress as was its early decision to take a "baby steps" approach with Falcon 1 to build customer and investor confidence before pursuing Falcon 9, the real commercial objective.

5.2.10 Kistler Aerospace (also Rocketplane Kistler)

Founding and market opportunity: Kistler Aerospace was founded by Bob Citron and Walter Kistler in 1993 to develop and operate the K-1 rocket, the world's first fully reusable launch vehicle (RLV). Initially, the K-1 was intended to provide affordable access to low, medium and geosynchronous Earth orbit for commercial satellite owners/operators as well as provide logistic support and recovery flights for the International Space Station. It was a two staged, liquid fueled vertical take-off rocket with a fly-back capability and parachute landing assisted by airbags. The two founders brought many years of space and business experience to the venture as well as considerable seed capital, industry connections and goodwill:

- Bob Citron is a serial entrepreneur and aerospace engineer. During his 17 years at the Smithsonian Institution, he helped create and manage the Smithsonian Astrophysical Observatory's Moonwatch Program, the Precision Optical Satellite Tracking Programs (STP), the Smithsonian Transient Lunar Phenomena (TLP) program, and the NASA/Smithsonian Skylab Earth Observing Program. He later founded or co-founded four other companies, including SPACEHAB, Inc. (1983), and Lunar Transportation Systems, Inc. (2004).
- Walter Kistler is a physicist, prolific inventor, and philanthropist. He was considered a pioneer in the development of high-performance aerospace instrumentation and sensors. His Kistler Instrument Corporation made components used in the Apollo manned spaceflights. After selling his company, Kistler played a central role in the startup of several high-technology companies, including Kistler Products, SRS, ICI, Interpoint, Paroscientific, and SPACEHAB.

Kistler later brought in George Mueller to be its CEO and Robert Wang, who had a deep international finance network, to be its Chairman. Mr. Mueller ran the Apollo space program and was highly regarded at NASA and within the space community.

Risks / challenges: The development of K-1 included many significant risks and challenges, including, among many others: (a) future availability of Russian NK-33 and NK-43 rocket engines, (b) recovery and landing systems for the RLV, (c) unique flight profiles, and (d) the cost/schedule risks associated with dependence on traditional aerospace contractors as key suppliers. However, the use of proven Russian rockets helped the company avoid those development risks and use of established aerospace contractors was seen as a technology development risk mitigator. The K-1 also had to be designed with enough payload capacity, after all of the necessary weight margins for reusability and reliability, to be able to serve the commercial satellite market. In addition to engineering challenges, there were also regulatory challenges involved in Kistler's proposed launches and return flights over populated land. Getting FAA approval

and U.S. indemnification for such flights proved too difficult and Kistler was forced to relocate launch operations to Woomera, Australia.

History of financings: Many of the details of Kistler's private financings are not readily available, but the company is believed to have raised funds from Middle Eastern and Asian sources. A summary of key public events is provided below:

- 1997: Northrop Grumman begins work on composite structures for K-1. Receives options to invest up to $180 million in Kistler.
- February, 1997: Space Systems/Loral signs contract in excess of $100 million for 10 launches beginning in 1999. Contract contingent on Kistler's ability to finance and build the K-1 launch vehicle.
- 1998: Contemplated $300 million high yield offering does not happen.
- 1999: Northrop Grumman converts $30 million of payments owed by Kistler to equity after Kistler's inability to pay and then writes off the $30 million because of "uncertainty" about Kistler's viability. Northrop was willing to invest an additional $30 million in Kistler if the company proved it had the financial wherewithal to proceed with its first test launch and up to another $120 million upon a successful test for a total investment of $180 million (did not happen).
- July, 2003: With claims totaling $604.3 million versus assets of $6.3 million and an uncertain outlook for the financing and market demand for its still-unfinished K-1 rocket, Kistler files for Chapter 11 bankruptcy. Bay Harbour Management provides $4.6 million of debtor in possession financing. Creditors included:
    - Several Saudi Arabian investors
    - Aerojet ($99 million)
    - Northrop Grumman
    - Lockheed Martin
    - Honeywell
- February, 2004: NASA announced intention to give Kistler a "sole source" contract, however, SpaceX successfully sued in court to overturn Kistler's sole source contract with NASA.
- September 30, 2005: Bay Harbour Management reduces funding and Kistler reduces headcount until more visibility can be seen in NASA's intentions to use commercial capabilities to support ISS.
- February, 2006: Kistler acquired by Rocketplane Limited, Inc. and renamed Rocketplane Kistler (RpK).
- August, 2006: RpK receives a $207 million NASA COTS contract.
- September, 2006: RpK misses NASA milestone to raise $40 million.
- November, 2006: Alliant Techsystems becomes prime contractor for K-1.
- February, 2007: RpK renegotiates COTS financing milestone to raise $500 million by May, 2007.
- August, 2007: RpK fails to raise money and begins cutting workforce.

- October, 2007: NASA terminates funding for RpK under COTS contract due to missed financing milestone.
- 2009: RpK fails to deliver on promises to State of Oklahoma related to $18 million of tax credits and moves to Wisconsin.
- June, 2010: RpK files for chapter 7 bankruptcy (liquidation).

NASA or government involvement, if any: In the early development period, the government's impact was mostly negative in that Kistler's desire to launch from the U.S. with FAA certification and indemnification was never approved. However, Kistler did have supporters within NASA who were particularly impressed by the large amount of private capital invested and the progress the company had made in developing K-1. NASA attempted to award Kistler a sole source contract which, as stated above, was blocked in court by SpaceX. Later, after Kistler had emerged from bankruptcy as part of RocketplaneKistler, it was selected by NASA as one of only two awardees under the $500 million COTS program after a competition among six firms. Had RpK been able to secure additional financing with the COTS contract in hand, the NASA support would have funded significant development activities.

Business model and business plan execution: In our view, the Kistler business plan started with the right mission (basically LCRATS) and target markets (commercial LEO/MEO/GEO plus ISS). It had a solid management team with industry grey hair and younger talent and its technical solution was also innovative, yet relied on proven Russian rocket engines and required only manageable technology development (e.g. landing with parachutes/airbags). However, the business plan was flawed in several major areas:

(1) Cost estimates - rocket development cost estimates were exceedingly optimistic, especially for a company relying almost exclusively on traditional aerospace firms for the bulk of the development and testing. As an example, the cost projections shown to potential high yield debt underwriters in 1998 had built in 100% success rates on all K-1 test flights and flight operations with no loss of any major systems or stages.
(2) Market size estimates - declining K-1 payload mass capabilities removed Kistler from the attractive commercial GEO market, ISS delays pushed out logistics flight opportunities, and the commercial LEO market opportunity was grossly overstated as Kistler never had a chance to launch the first generations of the Iridium, Globalstar or ORBCOMM constellations and the Teledesic constellation was unfunded and kept being revised for fewer, heavier and higher altitude satellites beyond the K-1s range. At the time of the contemplated 1998 high yield debt offering there was a great deal of uncertainty as to whether there would be any meaningful addressable market by the scheduled availability of the K-1 vehicle.

(3) U.S. Launch facility approval – underestimated difficulty in getting approval for K-1 fly-back over U.S. land mass.

Success or failure: Kistler was backed by serious and talented people, over $600 million dollars and many leading aerospace firms, yet after 17 years of development and a huge helping hand from NASA it listed only $108,250 of assets at its liquidation. It is hard not to call Kistler a failure. However, like many innovative and challenging space projects it is hard to assign all the blame for the failure on irrational exuberance and poor market research. Timing was also a key factor. For instance, a COTS program in 1996 versus 2006 may have provided enough early momentum to raise the required capital during the boom markets of the late 90's. Alternatively, if NASA had held an open COTS-style competition in 2004, rather than giving Kistler a problematic sole source contract, Kistler might have held a better chance to raise the capital it required as it already had a strong lead investor in Bay Harbour Management. During the long development of K-1, there were also the Internet and telecom bubbles bursting in 2001/2002, an Asian financial crisis, the bankruptcies of Iridium, Globalstar and ORBCOMM and the demise of Teledesic. Yet, the failure to complete K-1 was ultimately not for lack of time, effort or support. Kistler was given many chances and had three re-births involving new management and new funding. There was throughout the 17 years the sincere belief that if Kistler could just get the K-1 fielded its revolutionary capabilities would eventually foster new users and applications (if we build it, they will come). Investors had only to be patient, very patient.

Lessons learned: There were six major lessons learned from the Kistler experience:

(1) **Private investors can be sold on large markets, but expect timely performance**. Investors are not patient, nor terribly interested in broad humanitarian or societal goals like demonstrating the world's first RLV. If the technology challenges lead to cost growth and the market opportunity diminishes, the business case no longer closes and money will stop flowing regardless of sunk costs or how close the team is to a successful technical demonstration. Raising money to complete development of a new rocket is not a business unless some entity is paying you to do so. Otherwise, the business case must lead development and not the other way around. If the business case will not close with realistic cost projections and market assumptions, then significant government support may be required in the form of development funding and/or contracts for service.

(2) **RLV development is challenging, costly and uncertain.** Developing a new rocket, particularly an RLV, is very challenging and costs and schedules are very difficult to estimate. Entities engaged in such an endeavor need deep pockets or ready access to capital even in difficult capital markets.

(3) **Cost control difficult using traditional aerospace contractors**. Cost control on projects developing major new space systems is virtually impossible if the bulk of development is done using traditional aerospace contracting. The complexity of managing multiple teams and contractors, sharing data, making decisions and maintaining an assurance of quality inherently drives up costs. This belief was one of the driving forces behind SpaceX vertically integrating to lower development costs. It is also a message we heard from Andy Beal of Beal Aerospace and other space entrepreneurs.

(4) **Institutional investors tend to avoid revisiting failed business plans**. In our experience, once an institutional investor has passed on a given investment opportunity, it is very difficult to get that investment group to revisit the business plan no matter how improved it may be. So that even after RpK won one of the two COTS awards, it had a challenging time getting traction with institutional investors, most of whom had already seen the plan at some point over the previous decade of effort. Institutional investors rarely revisit an investment opportunity they have previously passed on or one that was previously financed, but failed. A firm's track record raising capital and its reputation with private investors should therefore be considered when NASA determines which entities to support or, as in the COTS case, financing milestones should be utilized.

(5) **Prior investment and "skin in the game" not always reliable factors for predicting success**. Large sunk cost investments in development and facilities show serious effort and financial support, but may not be good indicators of future success. In competitions, where some selection factors are inevitably subjective, it is understandably hard not to give credit to organizations that have tried so hard for so many years and risked so much, especially compared to newer companies with a far less developed business plans. Ultimately, however, the best solutions and teams should prevail with the level of "skin in the game" being viewed only in light of what has been accomplished in reducing future development risk and achieving superior performance. This is where outsourced due diligence support can be crucial. COTS was wise to employ outside advisors for business/financial due diligence even if RpK did eventually miss its milestones.

(6) **Baby Steps are usually best**. When judging business plans against a set of performance objectives, preference should be given to those plans based on achieving incremental progress versus jumping right to the full up capability in order to "save" money and time. Baby steps build investor and customer confidence and allow the team to learn from its mistakes and chart a new path when necessary. The SpaceX business plan was based on a series of "baby steps". The Kistler, and later the RpK, plan was to build the K-1 vehicle no matter what. For instance, Kistler/RpK might have chosen to build a reusable first stage at lower

cost and risk as an incremental step; and sought earlier revenues from placing payloads in orbit with an expendable second stage or provided suborbital flights for micro-gravity research or even space tourism. With revenues from these early applications, Kistler/RpK might have increased its chances with investors to fund a reusable second stage.

5.2.11 DC-X

Founding and market opportunity: The DC-X program was conceived by the Citizens Advisory Council on National Space Policy. The council was started in 1980 as an effort to provide the incoming administration with options for the space industry. The 1980 effort included a recommendation to develop a Strategic Defense Initiative (SDI) to provide missile defense. As the SDI program evolved, low-cost space transportation was deemed necessary for large satellite constellations as part of an effective missile shield. In 1989, the DC-X program was presented to Vice-President Dan Quayle as a risk reduction program for Single Stage to Orbit (SSTO) technology. As chair of the National Space Council Quayle helped fund the program starting in 1991.

Risks / challenges: Technical challenges and risks included flight test failures culminating in the final flight of the DC-X which fell over after a landing gear was not properly connected. Assembling the team, using off the shelf components and limited budgets were major challenges for the program.

Political opposition to the program came from a variety of sources. First, there was general opposition to the SDI program and by default the DC-X program. Second, political opposition from the aerospace community existed on the grounds that the VTVL concept would never work. Third, Congressional opposition on the grounds the money could be spent elsewhere within the DoD and NASA budgets. Finally, the program experienced opposition due to the perceived threat of the low-cost DC-X program to more expensive space launch programs.

Political realities emphasized the need for a rapid prototyping approach to building a flying vehicle. Budget and schedule limited the performance envelope of the vehicle while research and X program requirements dictate the need for higher performance.

History of financings:

- 1991 Phase I Competitive Definition Program $12 million for four contractor studies
- 1992 Phase II Build and Test $58.9 million contract to McDonnell Douglas Space Systems for 1/3 scale model
- 1994 ARPA $5 million funding for continued flight tests.
- 1996 DC-XA $50 million NASA Funding for continued flight testing and technology upgrades.

The small amount of program funding, small ground crew, focus on using off-the-shelf technology, and focus on “operability,” were highly unusual for space development programs.

NASA or government involvement, if any: The DC-X program was a government-funded program originally run out of the Department of Defense Strategic Defense Initiative Office (SDIO). Anti-missile defense systems would require significant space-based assets for detection and intercept of missiles. SDIO funded DC-X as a technology demonstration program to lower the cost of space transportation, which as viewed as necessary for deployment of missile defense.

During the flight test program DC-X was transferred from SDIO to NASA. This change reflected a change in political realities. The Clinton administration divided space flight between the Air Force for expendable launch vehicles and NASA for reusable launch vehicles. The NASA DC-XA program added new technology to the vehicle including a graphite-epoxy liquid hydrogen tank, a graphite/aluminum honeycomb intertank, an aluminum-lithium liquid oxygen tank, and an improved reaction control system.

The DC-X in flight

Business model and business plan execution: DC-X was modeled after traditional X programs such as the X-1, X-3 and X-15 flight test programs. X programs are not intended to develop operational vehicles, rather test beds for expanding performance envelopes. Technology development is no substitute for flight testing. X programs are intended to provide real world data to guide the development of future programs and operation systems. The DC-X program was part of an overall development strategy for reusable launch vehicles, which included the subsequent X-33, X-34 and even X-37 programs.

Success or failure:

Successes:

- Proved lean development and rapid prototype paradigm under a government program.

- Demonstrated flight test operations within a government program.
- Rapid turnaround of a liquid-fueled rocket engine.
- Demonstrated handling of liquid oxygen and hydrogen in high tempo operations.
- Demonstrated rocket operations with small ground crews.
- Vertical Take-off and Vertical Landing (VTVL) of a reusable rockets in a real-world environment including cross winds and dust.
- Flight control via gimbaling and differential throttling of rocket engines.
- Demonstrated high angle of attack flights, recovery and landing.
- Developed flight control operations using off-the-shelf system.
- Demonstrated the ability to recover from in-flight accidents including fires and landing on non-prepared sites.

Failures:

- The chief failure of the DC-X program was not a failure to achieve its planned technology demonstration objectives, but that having achieved most of them development efforts were, by plan, switched entirely to new programs (e.g. X-33, X-34) rather than following up on the successes of DC-X more directly with further VTVL funding. A taxpayer-funded research program should ideally complete sufficient research to address the real risks (e.g. aerodynamic controllability) of fielding an actual flight vehicle of similar design (i.e. VTVL). In the case of DC-X, the goal should have included seeing if a follow-on VTVL flight vehicle could be made light enough and capable enough to do SSTO. The DC-X program did not answer this question.
- Effort failed to lead to a flight test of a follow-on VTVL vehicle. This was not so much a failure of DC-X as it was a failure in policy, planning and leadership.

Lessons learned:

- The “build a little, fly a lot” paradigm produced spectacular results. The demonstration of reusable VTVL vehicles spurred the development of several other commercial programs including, Kistler, Blue Origin, Masten Space Systems and Armadillo Aerospace.
- The X-33 and X-34 follow-on programs should have been broken up into smaller pieces. Requirements must be kept simple and avoid adding additional requirements. These follow-on programs ultimately failed due to excessive technology challenges and funding issues collapsing the program under their own weight.
- Disruptive programs must be run away from existing bureaucracy. Programs should be run out of a new office or kept far enough away from existing offices that may be threatened by a disruptive program.
- Program success and continuity can’t be left to insiders. There must be continued outside pressure to keep a program on track.

5.2.12 SPACEHAB

Founding and market opportunity: SPACEHAB was founded by Bob Citron in 1983 and incorporated in 1984. The original concept was to provide a passenger carrier for "tourists" to be located in the Space Shuttle's cargo bay. After discussions with NASA and upon the advice of CSP Associates, the main focus of the business was changed to providing a pressurized volume for the Shuttle bay to facilitate in-space research and unpressurized modules to increase cargo space for re-supply missions. NASA's experience flying the Shuttle had proven the value of the middeck area of the crew compartment, but it was too limited in size to support scientific and commercial research and living accommodations for long duration missions. There was already a Spacelab module available to NASA for free as a contribution from Europe, but it took up the entire Shuttle cargo bay. The SPACEHAB module was a more cost effective solution, doubling the living area for astronauts and quadrupling the area for man-tended research while taking up less than one fourth of the cargo bay of the Shuttle.

The first SPACEHAB Middeck Augmentation Module flew in June, 21 1993, roughly ten years from the company's founding. It was a cylinder with a truncated top measuring 10 feet in length, 13.5 feet in diameter and 11.2 feet to the truncated top. The module included 50 lockers for experiments with power, cooling, data and communications available. In total, SPACEHAB modules would fly on 22 Shuttle missions facilitating research and conducting re-supply of both the Russian MIR space station (7 flights) and the International Space Station (8 flights).

Risks / challenges: The most obvious risk to SPACEHAB was its complete dependence on NASA and one single space transportation architecture, the Space Shuttle. Changes in policy or budgeting at NASA or the failure of the Shuttle fleet would have immediate and dramatic impacts on SPACEHAB's business prospects. There was also the typical "chicken and egg" problem that plagues many large new space endeavors. Investors were reluctant to fund SPACEHAB until they had contractual commitments from NASA to (a) allow the module on the Shuttle, and (b) buy or lease modules for a series of flights, and NASA was unwilling to commit to an agreement before having strong evidence that SPACEHAB was a financially viable entity with a well-developed technical design and plan for construction and testing that would meet NASA's stringent safety and technical specifications.

History of financings: In the absence of any meaningful financial support or contractual commitments from NASA and with no deep pocketed founders, SPACEHAB was left to bootstrap the company starting with a series of small private investments. These early rounds were followed by venture capital fundings and support from strategic investors. With increased traction at NASA and the execution of NASA contracts, partly achieved

through the hiring of former senior NASA managers as SPACEHAB executives, larger financings from banks and other investors were consummated. Here is a summary of the early financing history as best we can reconstruct it:

- 1983-1987: Bob Citron provides initial seed capital in the form of loans and equity and is later joined by a group of friends, family and angels in a second and third private financing round. In total $2.2 million is raised in these three rounds. SPACEHAB also engages in cost sharing studies with Aeritalia (later Alenia Spazio) and McDonnell Douglas who would act as prime and subcontractor, respectively. These sources of financing allow SPACEHAB to complete its Phase A studies.
- 1987: The Challenger accident is a huge setback for SPACEHAB shutting down Shuttle flights for two years and significantly delaying the funding and development of the SPACEHAB module. Because of the Challenger accident, a fourth private round goes undersubscribed and the firm is left with insufficient funds to complete its Phase B preliminary design efforts.
- 1987/1988: SPACEHAB completes a fifth private placement raising $1.8 million from BEA Associates (Al Zesiger) and Poly Ventures (Dr. Shelley Harrison). McDonnell Douglas and Aeritalia also make equity investments and accept subordinated debt in lieu of payment.
- March, 1988: NASA agrees to include SPACEHAB flights on its Shuttle manifest beginning in 1991.
- Spring 1988: The government of Taiwan offers to finance SPACEHAB's $75 million estimated cost (Taiwan had been excluded from NASA projects because the U.S. did not officially recognize its government). However, the President of Taiwan dies before the deal is completed and the new government is not interested.
- August 1988: NASA and SPACEHAB negotiate and execute a Space Systems Development Agreement (SSDA) which acts as a launch services agreement for NASA to provide transportation to space for the SPACEHAB module. The SSDA involves SPACEHAB paying NASA $28 million per flight for six flights ($168 million) to carry its module. The major facilitating condition in the SSDA is a deferral by NASA of normal pre-flight progress payments until one month after launch. Without this deferral, SPACEHAB would not have been able to raise additional equity and bridge loans. Note, that NASA was charging SPACEHAB for these flights, not paying it for use of the module or for the technology demonstration despite being the largest and most obvious beneficiary.
- 1989/1990: SPACEHAB secures four customers for leased module space for a total of $50 million.

- November, 1990: SPACEHAB competes for and wins (was only company to respond) a contract to provide services using a commercial middeck augmentation module in cooperation with NASA's Centers for Commercial Development of Space (CCDS). NASA agrees to buy two thirds of SPACEHAB's capacity for the six shuttle flights for a price of $184 million. The contracting vehicle was a Joint Endeavor Agreement (JEA) allowing NASA to provide standard transportation services at no charge with SPACEHAB providing the hardware, the principal investigator and covering any services required. With the signing of the JEA, SPACEHAB is able to close an equity financing involving Mitsubishi Trust Bank, Industrial Bank of Japan and Chemical Bank. SPACEHAB also receives approximately $10 million in funding from Taiwanese private investors. With these financings, SPACEHAB raises approximately $40 million of equity. The estimated cost of the module is now $92 million.
- March, 1991: Chase Manhattan agrees to provide SPACEHAB a $64 million revolving credit line. With these funds, SPACEHAB is able to authorize McDonnell Douglas to complete final design and construction of the module. Ultimately, construction by McDonnell Douglas proved too expensive and the SPACEHAB module was built by Alenia Aerospazio. The key to obtaining this credit facility was the availability of political risk insurance, a unique policy underwritten by approximately 150 insurers led by Lloyd's of London. Without this insurance policy in place, Chase Manhattan would not have been willing to take the risk Congress would terminate the SPACEHAB contract.
- 1991: Price Waterhouse completes an analysis of NASA lease and purchase alternatives for the commercial middeck augmentation module that finds it would have cost the US government over $1 billion to develop and operate an equivalent capability using standard cost plus contracting.
- June, 1993: The first SPACEHAB module flies on the Shuttle. The final cost of the two modules plus DDT&E was $150 million, more than double the 1990 estimate. By February, 1995, the SPACEHAB module has flown three times carrying experiments for 46 companies, 27 universities, 8 research institutions and NASA.
- July, 1995: SPACEHAB signs a $54 million contract to provide cargo re-supply services to MIR on four Shuttle missions.
- December, 1995: With the success of the first three Shuttle flights and the MIR contract, SPACEHAB is able to complete an initial public offering at $12 per share. However, within a year the stock price would trade down to $8 per share due largely to the volatility and unpredictability of revenues and earnings tied to Shuttle flight schedules, the low rate of Shuttle flights carrying SPACEHAB modules, lack of long term contractual commitments for the new double module

being developed and a failure of the micro-gravity research to evidence the enormous commercial advances touted by management.

- 1996: SPACEHAB begins building a new double-sized module to meet what it sees as growing demand for experimentation in space.
- 1997: SPACEHAB receives a Research and Logistic Mission Support (REALMS) contract from NASA allowing the agency more flexibility in ordering SPACEHAB services.
- February, 1997: To help eliminate the risk of reporting quarters with zero revenues and earnings losses due to no Shuttle flights in such quarter, SPACEHAB acquires the satellite processing service Astrotech Space Operations, L.P. from Northrop Grumman Corporation.
- July, 1998: To further diversify its business away from its module business, SPACEHAB acquires Johnson Engineering Corporation, a firm that trained astronauts at the Johnson Space Center.

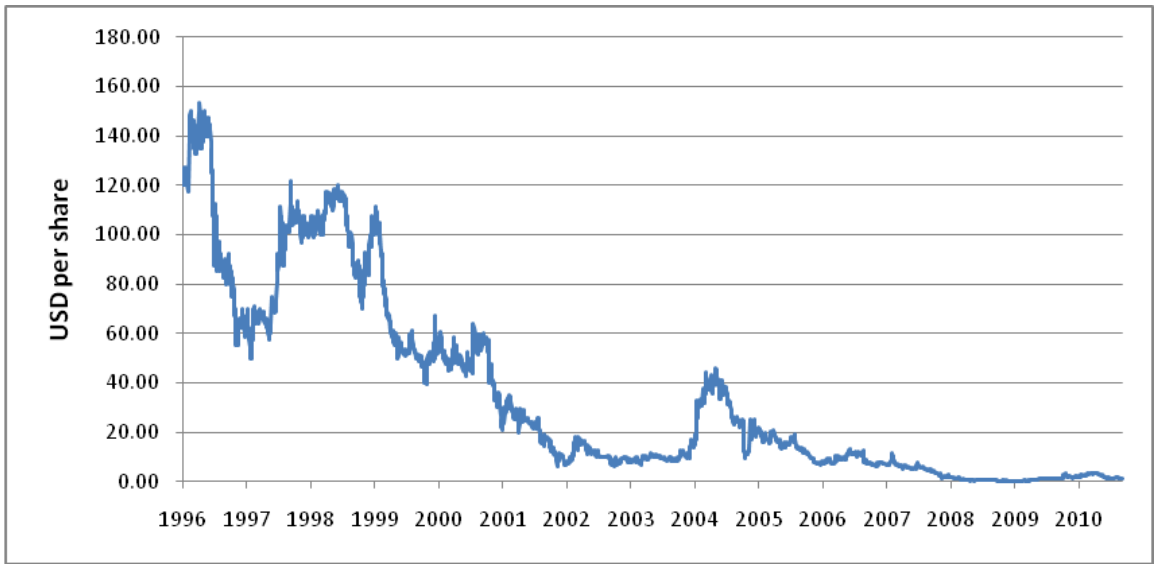
NASA or government involvement, if any: It is hard to underestimate the critical role NASA played in the life of SPACEHAB. Without NASA and the Space Shuttle there would have been no SPACEHAB business plan. For every major advance in SPACEHAB's relationship with NASA, a major financing was soon consummated.

The SPACEHAB logistics module on STS-118

Business model and business plan execution: The SPACEHAB business plan was to profit from enhancing the usability and value of the Space Shuttle to corporations, universities, research institutions and even NASA itself, by providing more affordable working space on the Space Shuttle than available from any other source. The economic business model was basically to rent up to 50 lockers per flight at $1.8 million or so per

locker and seek to cover the cost paid to NASA to carry the module (e.g. $28 million per flight with discount locker rates for NASA), plus mission costs, corporate overhead, insurance and the amortization of the roughly $150 million cost of constructing the pressurized modules.

Success or failure: SPACEHAB was certainly a successful business in that it created an important new capability for NASA at much lower cost that also benefited numerous corporate, academic and research entities. However, as we have seen with many commercial space companies the story with investors is a very mixed experience. Most investors either lost money or had very mediocre returns on their investment depending on the timing of their entry and exit points. Some of this poor return was directly related to factors under the control of NASA, such as number of missions, flight rates per year and negotiated pricing terms. The two Shuttle accidents also had profound effects on the SPACEHAB business and investor returns. In particular, the Columbia accident in January, 2003 was the first flight of SPACEHAB's double module and as it was underinsured represented a major loss of both hardware and potential future revenue. The module business never recovered from that incident and the company's great relationship with NASA was harmed by disagreements and even a law suit over SPACEHAB claims to recover its losses. This disappointing experience for investors can be seen graphically in the chart of SPACEHAB's stock price performance from its December, 1995 IPO to today where it now trades as Astrotech Corporation (ticker: ASTC). The per share prices include a 10 for 1 stock split enacted in November 29, 2007. Thus the $12 per share IPO price is shown as $120 per share.



SPACEHAB share price since IPO in December 1995

Lessons learned: The lessons learned from SPACEHAB are very applicable to any commercial space business whose fortunes are so intently linked to NASA's needs,

changing priorities, and relationship with commercial entities. Some of the most important lessons include:

1. **Loss of control over timing of business plan execution**. If NASA is your dominant customer or business plan facilitator, NASA's decisions and pace of action may very well determine the timing of your business plan execution and your ability to close necessary rounds of financing.
2. **Reliance on primary customer versus importance of service to such customer**. It is fine to create a business heavily dependent upon a major customer, in this case NASA, however, it should be based on a service or product that the customer cannot do without for a significant period of time. In this case, NASA's demand for the modules proved far less than had been expected. Microgravity research at this time was not in the critical path of anything NASA absolutely had to do. As a counter example, the COTS and CCDEV programs are to provide cargo and crew to ISS which are in the critical path of what NASA has to do and delays would have major operational and political consequences.
3. **Commercial practices and solutions can create tremendous value**. The PriceWaterhouse study showing SPACEHAB was significantly less expensive than internal NASA solutions was not well received or even believed by many at NASA. Only after numerous successful missions and years of working together were many at NASA convinced of the merits of using a commercial supplier like SPACEHAB.
4. **Because of political risk, insurance was needed to attract low cost capital.** Without the innovative work done by Lloyd's of London, SPACEHAB would not have been able to close a bank facility they had been working on for two years. With political risks, investors are likely to be uninterested in participating or seek higher equity returns than the stage of the company's development might otherwise warrant.
5. **Lumpy revenues and volatile earnings are not suitable for most private equity and public investors.** With only one to three modules being flown each year, SPACEHAB's financial results showed high revenues and good earnings in one quarter followed by zero revenues and significant losses in the next quarter. Added to this lumpiness was the fact that Shuttle launches often got delayed pushing expected business to future quarters. Even worse was the threat that an accident could eliminate all revenues for 12 or more months while the accident was being investigated. The types of investors needed to raise larger sums of money are generally not willing to put up with this lack of predictability.
6. **Delays are costly.** From founding to first flight took ten years and in that time the cost of manufacturing SPACEHAB's module more than doubled. Even taking into account inflation, this represented a painful increase in capital requirements and a more difficult challenge to create investor returns.

7. **Banks will lend against space assets.** With NASA contracts expected, SPACEHAB was able to get bank financing backed by the collateral value of its Shuttle modules and other facilities. The banks in essence believed that these assets had positive resell value in the event of a loan default. In many space applications the assets may be so specific to a particular mission that this is not the case, but where a predictable customer need can be matched to a set of assets, those assets represent potential borrowing capacity to fund development.
8. **NASA commercialization policy can impact private capital raising.** During SPACEHAB's IPO, underwriters as part of their due diligence asked NASA about its views on SPACEHAB. NASA was very positive and encouraging and even said SPACEHAB represented exactly the kind of commercial relationship it sought with industry and wished it to serve as a model for future firms. When asked if NASA could state so publicly for the IPO prospectus, they could not. Nor could NASA promise any level of guaranteed future flight rate for the SPACEHAB modules, an exclusivity period, preferential contracting, or more commercial termination provisions. The only support NASA was able to provide its poster child of commercialization was wishes for good luck.

5.2.13 XM Satellite Radio (now Sirius XM Radio, Inc.)

Founding and market opportunity: XM Satellite Radio Holdings, Inc. (XM Radio) began its corporate existence as American Mobile Radio Corporation (AMRC), a unit of American Mobile Satellite Corporation (AMSC). AMSC was established in 1988 when a consortium of entities came together to build and operate a nationwide satellite mobile communications business using a unique single license issued by the FCC.

In 1992, CD Radio (later Sirius Satellite Radio), an entrepreneurial start-up with little funding, convinced the FCC to provide licensing of spectrum for a Satellite Digital Audio Radio Service (SDARS) using S-band frequencies. Based on this development, AMSC began an internal business development effort to use its expertise in providing mobile satellite services to enter the SDARS market. AMSC appointed Lon Levin to establish AMRC and seek an FCC license. Lon Levin is generally considered the "founder" of AMRC and served as its President until 1998. Gary Parsons who served as CEO of the parent company AMSC was also instrumental in the early development of AMRC.

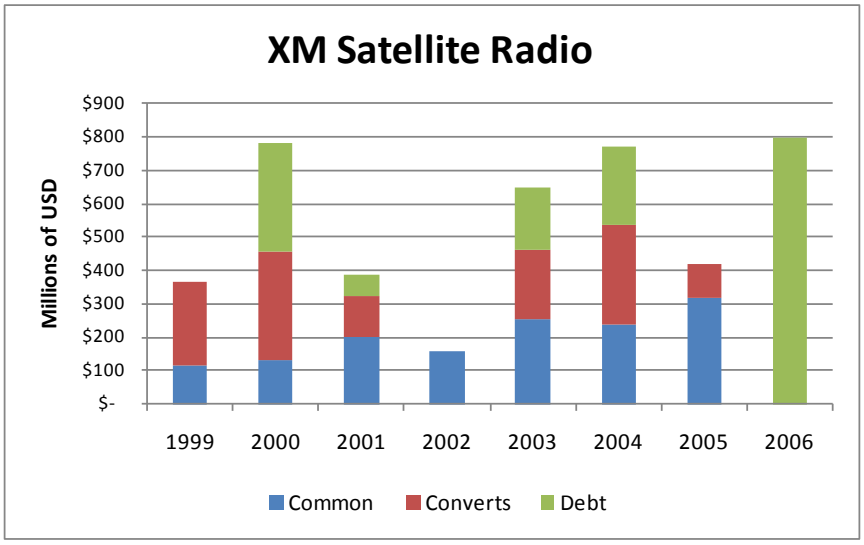
Later in 1992, AMRC decided to bring WorldSpace in as a 20% investor in part to gain access to its technology. At that time, WorldSpace, Inc. was pursuing an SDARS business plan outside the U.S. and had raised approximately $1 billion from Middle Eastern investors to launch and operate three SDARS satellites covering Africa, Asia and South America. WorldSpace was using L-band frequencies reserved in the U.S. by the U.S. Air Force and was not allowed to broadcast in the U.S. In 1997, AMRC received one of only two SDARS licenses granted by the FCC out of three applicants with CD Radio receiving the other license. An FCC mandated duopoly was thus established. In 1998, Hugh Panero joined AMRC as its new CEO and rebranded the company as XM Satellite Radio. The satellite service was officially launched on September 25, 2001.

The market opportunity was the roughly 100 million households, 200 million automotive vehicles, and 300 million people dissatisfied with AM/FM radio. Whereas television had become digital and massively multi-channel with the advent of cable and satellite television, AM/FM radio was still stuck in the analog era and most communities had only 5–20 channels with few music formats from which to choose. There were also many coverage gaps where there were few if any clear radio signals. Satellite radio offered a tired market better signal quality, more choice, ubiquitous service and the ability to listen to one's favorite channels anywhere in the U.S. Yet, on July 29, 2008, XM Satellite Radio and Sirius Satellite Radio were permitted to merge by the FCC and Department of Justice due to the continued presence of significant terrestrial radio competition and new forms of audio services such as Internet radio, iPods and MP3 players. The merger created a satellite radio monopoly named Sirius XM Radio, Inc. which today has approximately 20 million subscribers.

Risks / challenges: Despite obvious advantages over AM/FM radio, including offering largely commercial-free music, one of the key challenges to penetrating the radio market was to convince consumers to pay for something they had always received for free. There was also a need for subscribers to purchase a new radio and have it installed in their car. Many consumers balked at paying a lot of money to change out a working car radio, so retail sales through traditional consumer electronics chains were slow to take off. The auto manufacturers were also slow to factory install XM radios in their vehicles, preferring to test the market with one or a few models before rolling out to the entire fleet. There was a real chicken and egg problem. No one was going to purchase an XM radio until the service was up and running and they had gotten a free test of the service quality and few investors wanted to take the risk consumers would like the service in large enough numbers to earn a return on billions of invested dollars.

- **History of financings:** While initially incubated within AMSC, XM Radio began its stand-alone existence with a unique and powerful private financing combining several important strategic partners with several major media industry VCs. That transaction placed XM Radio on sound footing to raise the billions of dollars required to get two satellites in orbit, build out a terrestrial repeater network, create a 100-channel radio studio and market to U.S. consumers. Without the seals of approvals of these highly respected strategic and financial investors the large amount of capital needed from the general public would never have been available. A summary of key financings is provided below. Financings after 2003 are left out as the business was then in full service with fleet replacement costs largely covered.
- June 1999: $250 million Series A subordinated convertible notes sold to (i) General Motors (world's largest auto manufacturer), DirecTV (world's largest DTH company), & Clear Channel Communications (world's largest radio group), and (ii) Columbia Capital, Madison Dearborn Partners & Telcom Ventures. General Motors signs a 12-year contract to put XM radios in its cars, DirecTV agrees to add satellite radio to its direct to home video customers, Clear Channel agrees to develop or provide radio channels to the XM service and Hughes Electronics, world's largest satellite manufacturer and a subsidiary of General Motors, enters into a contract to build two satellites. XM Radio is spun out of AMSC as a stand-alone company.
- October, 1999: XM Radio goes public raising $123 million at $12/share.
- January, 2000: Follow-on public stock offering raising $128 million at $32/share and public Series B convertible preferred stock offering raising $100 million.
- March, 2000: $325 million high yield debt offering (14% senior secured notes)
- August, 2000: $235 million private placement of Series C convertible preferred stock to Honda Corporation, DirecTV, Columbia Capital, Madison Dearborn, AEA Investors, and Baron Capital. Honda agrees to put XM radios in its cars.

- March, 2001: $72 million secondary public stock offering and $121 million of public convertible subordinated notes.
- December, 2001: $66 million financing package with Boeing, including a $35 million loan and a $31 million payment deferral. Boeing had acquired Hughes Electronics and was now XM Radio's satellite manufacturer.
- December, 2001: $126 million secondary stock offering.
- January, 2003: $475 million privately placed primarily with XM Radio's existing strategic shareholders and VCs with a few new private investors. XM Radio had begun commercial service, but had not achieved cash flow breakeven and was running out of money. They also had problems affecting both satellites and needed money for replacements before performance levels impacted service. Due to this liquidity problem the company's stock plummeted to approximately $3/share. After this large infusion of fresh capital from mostly insiders, the stock rose quickly.



NASA or government involvement, if any: There was no NASA involvement, but the FCC was a determining force in the creation of the industry and impacted the evolution and "success" of the industry in several ways, including:

- Awarding only two licenses, thus limiting the amount of direct competition;
- Making the licensees pay for their spectrum (roughly $80-90 million each), thus requiring the licensees to line up significant funding based on the strength of the business cases well before commencement of satellite construction or commercial service;
- Taking 5 years to determine the rules and requirements of the licenses, thus increasing the upfront investment in securing a license and the number of years early investors had to wait to get a return on their investment;

- Treating SDARS like a subscription video service without the same public decency standards of AM/FM radio;
- Requiring both licensees to work toward inter-operable radios, something that has not happened to this day;
- Restricting the licensees' abilities to insert local programming using terrestrial repeater networks so as not to compete with local AM/FM services.

Business model and business plan execution: The satellite radio business model was premised on the basic assumption that it was:

- similar to satellite television in terms of marketing, subscriber acquisition, customer servicing, and G&A costs,
- superior to satellite television in terms of total infrastructure costs,
- inferior to satellite television in terms of average revenue per user (ARPU), and
- superior to satellite television in terms of content cost.

DirecTV and EchoStar received $40 or more per month from subscribers, but had to pay roughly 60% of that for the video content. XM and Sirius might only be able to charge $9-$12 per month, but they had lower total space segment costs and would get the music almost for free and only have to pay a little for premium content. There was even a gentlemen's agreement to never compete for content. That might have worked had the two companies entered the market at roughly the same time and with the same quality of technology and strategic partners, but with Sirius Radio behind on all counts they determined they had to compete based on content and the margin advantage satellite radio had over satellite television quickly evaporated with a flurry of high profile $100 million plus contracts for sport leagues and celebrity DJs.

Success or failure: XM Radio, now Sirius XM Radio, has to viewed as a huge success in other than financial matters. Together the two companies created an important new consumer service that is enjoyed by over 20 million subscribers in the U.S. with additional customers in Canada and the Caribbean. To get there, they developed and placed into service new digital audio technology and successfully launched and operated both GEO and elliptical orbit satellite fleets. They were also able to raise over $6 billion.

However, because neither business ever generated the strong cash flows and earnings investors expected most investors lost money on the companies. In fact, both companies experienced significant volatility in their equity and enterprise values and faced liquidity crunches and even recapitalization and bankruptcy. Most early investors were wiped out or achieved only modest returns not commensurate with the levels of risk they took on. Whether or not an investor made money on either of these firms, was more a function of entry and exit timing than on the companies' abilities to build steady value. Even in 2010, the merged Sirius XM Radio is struggling to improve its profitability at the same time the novelty and competitive advantages of satellite radio are being eroded by wireless broadband and smartphone applications.

Lessons learned: There are many lessons learned from XM Radio that seem applicable to the visionary and capital intensive new space capabilities NASA hopes to foster. Here are some of the most interesting and relevant:

1. **Power of Strategic Investor Support**. It is safe to say that without the early support of first AMSC (Hughes Electronics) and then General Motors, DirecTV, and Clear Channel, XM Radio would not have been able to convince financial and public investors to believe in a new technology that cost billions of dollars and took years before commercial service even began. Entrepreneurs should take this lesson into consideration. Without strong support from NASA or well established strategic firms (e.g. FSS companies, aerospace primes), it may be very difficult to fund capital intensive business plans. The other lesson here is that the strategic investors of XM Radio had all come to the same conclusion; that the business had to be run independently from there large and less nimble organizations.
2. **Even Two Space Competitors Can Be a Lot**. Part of the reason the FCC limited the SDARS license to only two parties was to increase the chance both would be able to raise funds and achieve enough market share to payback their investors. However, as mentioned under business plan execution, the cost model quickly exploded as competition for subscribers and proprietary content was fierce. In the end few investors made any money on SDARS.
3. **Long Development Periods Can Increase Risk of Technical Obsolescence**: In addition to lots of capital, designing, building and deploying any major space system takes years. Once in operation, it can also take additional years for the market to develop to sufficient size to cover fixed operating costs, debt servicing and amortization of infrastructure investments. That can leave only a short window before terrestrial solutions evolve to become more competitive (e.g. iPods, smartphones) or new space-based technologies are developed to start taking market share (e.g. next generation MSS systems). In this case, even a space monopoly can be difficult to make profitable if growth slows or even reverses. For capital intensive space businesses with long up front development periods, the market window needs to stay open a long time for investors to have a good chance of earning a fair return unless the profit margins are very large. For instance, if an in-orbit servicing company spends billions to develop a fleet of vehicles their business case may not close if it can be reasonably expected that once they establish the market a new competitor will enter with better technology. In space it does not always pay to be first. The followers benefit from the heavy lifting down by the pioneers.
4. **Market Studies Generally Underplay Difficulty of Penetrating New Markets**: While some early XM Radio market studies predicted 20+ million subscribers, none really addressed how long it would take and how hard it would be to gain those subscribers. Attempts were made to analyze likely price points and

subscriber acquisition costs, but not in the environment of a competitive land grab. Market studies also ignore many of the real life difficulties of getting third parties to move at an aggressive pace (e.g. XM radio fleet penetration at auto manufactures, chipset manufacturers, consumer electronic retailer promotions and shelf space). For applications like LCRATS, in-orbit servicing or in-space R&D/manufacturing, customers may be very slow to trial and then adopt the service into their everyday business practices. This can take many years and destroy expected return on investment.

5. **Management Matters, Sometimes More than Technology**: At the end of 2003, XM Radio had 1.36 million subscribers, roughly five times that of Sirius Radio. They were first to market and had a 1-2 year lead on chipset and radio technology (e.g. portable units, smaller car antennas). However, Sirius management and Board realized that the most important thing in a media business is media, not technology or a market lead. They outbid XM on the NFL content and then Howard Stern. With those two events, they won the hearts and minds of the sales clerks at consumer electronics stores and market share in new subscriber adds flipped from 60/40 to 40/60 within a year. There were of course many other factors, but Sirius had captured the momentum and ended up controlling the merged company years later despite still being the smaller entity.
6. **Government Support Needs to Be Lasting**. As XM and Sirius started taking listeners from AM/FM the National Association of Broadcasters (NAB) ramped up their lobbying efforts in Congress to make life more difficult and costly for satellite radio. They made a similar effort against Internet radio. In both cases, the NAB was successful in getting large increases in royalties imposed on these new audio services although they paid none. These increased royalties materially impacted the fragile profitability of the satellite radio companies and at a vulnerable time; delaying cash flow breakeven in some case and straining liquidity. The lesson here is that if NASA fosters a new space industry and attracts private capital through that support, the subsequent lessening or removal of that support under pressure from powerful terrestrial competitors could be highly detrimental. An analogy would be NASA providing its facilities at attractive rates and the Federal government providing tax credits and other support to build the zero-G R&D and manufacturing industry, but then changing those policies once the new industry started threatening its terrestrial competitors because of superior Congressional lobbying. In the case of satellite radio, few lobbying groups had the political clout of the broadcasters politicians need for campaigning. It will be important for the commercial space industry to have a coordinated and proactive effort on the political front. Today, while the industry appears to speak loudly and often, it is from numerous different entities with sometimes differing political agendas.

5.2.14 GeoEye (formerly ORBIMAGE & Space Imaging)

Founding and market opportunity: GeoEye Inc. was founded in 1992 as Orbital Imaging Corporation (ORBIMAGE), a division of Orbital Sciences Corporation and was spun out as a separate entity in 1997 and changed its name to GeoEye in 2006 after acquiring Space Imaging. Today, GeoEye is one of the world's two largest sellers of satellite imagery and related products and services.

The market opportunity for remote sensing and Earth imagery had already been pioneered by numerous aerial imaging firms and then by Landsat, a low resolution satellite launched by the U.S. in the 1970s, and Spot Image, a low resolution satellite launched by France in 1986. The Indian Space Research Organization launched its first remote sensing satellite in 1988. Politically, the framework for the remote sensing industry started coming together in 1986 when the United Nations issued "Principals Relating to Remote Sensing of the Earth from Outer Space" which allowed fly-overs and imaging of other nations so long as the imagery was made available to them on reasonable terms and on a non-discriminatory basis. The impetus for the founding of GeoEye and the U.S. commercial remote sensing industry was the 1992 Land Remote Sensing Policy Act which allowed private companies to enter the satellite imaging business. This act was followed in 1994 by Presidential Decision Directive 23 which further allowed U.S. companies to launch high resolution satellites. By 2002, the director of the CIA stated that it was their policy to "use U.S. commercial space imagery to the greatest extent possible" and in 2003 National Security Presidential Directive 27 stated that the "fundamental goal of U.S. commercial remote sensing policy is to advance and protect U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities."

Against this back drop of increasing government support, entrepreneurs were also developing purely commercial markets for the imagery, including for agriculture, forestry, mining, real estate, media, tourism, and many other industries. State and local governments were also market opportunities for land use planning and other applications. With this market opportunity to exploit, two other U.S. remote sensing companies were also founded in this time period: DigitalGlobe (originally Earth Watch) and Space Imaging, a company controlled largely by Lockheed Martin and Raytheon.

Risks / challenges: The key risks for GeoEye were the same major risk categories for all capital intensive and technically sophisticated commercial space projects, namely (i) technical challenges of developing, launching and operating a fleet of highly capable remote sensing satellite for the first time, (ii) raising the many hundreds of millions of dollars needed to get the company's space and ground segment into operation and fund losses until cash flow sustainability, and (iii) developing a diverse mix of commercial and government customers willing to pay sufficiently high prices for the imagery to close the

business case. There were also some political risks, especially in getting approvals to go to one meter resolution and then half meter resolution where the bulk of the market demand seemed to lie, but eventually the government was very accommodating and investors became more comfortable with the political.

The technical challenges were real, but the contractors building the space systems were the same contractors that built even higher resolution and more sophisticated national systems for the U.S. government. The technical risk was largely one of fielding high quality systems at a low enough cost to close a business case based on prices commercial customers were likely to pay for imagery. All three competitors ultimately succeeded in this regard, but not without a great deal of birthing pains.

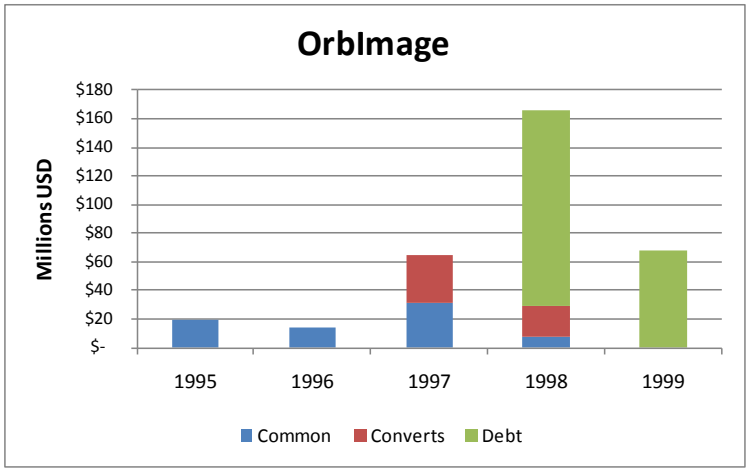
Satellite	Company	Failure date
Ikonos	Space Imaging	April 1999
Quickbird 1	EarthWatch	November 2000
OrbView 4	OrbImage	September 2001

The financing risks were high, but for the predeccesors of GeoEye: ORBIMAGE (a subsidiary of Orbital Sciences), and Space Imaging (a joint venture between Lockheed Martin and Raytheon), they were both incubated by established aerospace firms and so avoided many of the challenges of attracting start-up capital from angels and VCs. The market risks, however, were high for all competitors. Even though the concept of commercial remote sensing had strong bi-partisan Presidential support, it took some years for the intelligence community to get use to the idea of using commercial imagery sources and until GeoEye and others had one meter and then half meter systems, the demand was not high. The demand from private industry was even less developed as most industries did not even know how to use satellite imagery or what its value might be. In cases where industry was using aerial imagery, they had long standing customer relationships and the aerial imagery was often of higher resolution.

History of financings: GeoEye's initial fundings as ORBIMAGE were provided by Orbital Sciences and as Space Imaging by Lockheed Martin, Raytheon and other investors. The financing history below starts after ORBIMAGE is spun off from Orbital Sciences.

- July 1997: ORBIMAGE raises $30 million in Series A Cumulative Convertible Preferred Stock from a Crest Advisors, a New York based VC firm. This is the first institutional funding of ORBIMAGE as a standalone corporate entity. Also sells $7.3 million of the Series A Preferred to Export Development Corporation.
- August 1997: Launches OrbView-2, a one kilometer broad area color imagery satellite for scientific research, agriculture and ocean monitoring.
- February 1998: Completes a $150 million 11.625% Senior Notes offering with a 2005 maturity date. Also raises another $22.7 million in Series A Preferred.

- September 1999: IKONOS launched by Space Imaging, the world's first commercial high resolution satellite (0.82 meter panchromatic resolution & 3.2 meter multispectral resolution).
- April 1999: Issues another $75 million of 11.625% Senior Notes due 2005.
- September 2001: OrbView-4 fails to reach orbit. This failure was instrumental in forcing the company into bankruptcy.
- January 2003: Space Imaging is awarded Clearview contract by NIMA, with a minimum value of $120 million. ORBIMAGE is added in March 2004.
- June 2003: Orbview-3 launched (1 meter panchromatic and 4 meter multispectral resolution).
- December 2003: ORBIMAGE emerges from bankruptcy protection and reorganization. The Company's debt is restructured.
- September 2004: ORBIMAGE is awarded Nextview contract by NGA (formerly NIMA), with an approximate value of $500 million.
- November 2004: Raises $32.5 million in common equity at $10 per share.
- March 2005: Raises a second tranche of $32.5 million in a rights offering.
- July 2005: Completes a $250 million LIBOR plus 9.5% offering of Senior Secured Floating Rate Notes with a maturity of 2012.
- January 2006: ORBIMAGE acquires Space Imaging for $58.5 million. Gains IKONOS satellite. The consolidated company is renamed GeoEye.
- April 2007: OrbView-3 permanently out of service.
- September 2008: GeoEye-1 was launched, the most advanced commercial high resolution satellite at that time (0.41 meter panchromatic and 1.65 meter multispectral resolution).
- August 2010: Awarded $3.8 billion EnhancedView contract by NGA.



NASA or government involvement, if any: There was minimal NASA involvement, but U.S. government involvement was early, extensive and growing. Without enabling policy

there would not have been a commercial remote sensing industry and without significant financial support through government purchases of imagery the industry would most likely not have survived or at least floundered for many years.

Business model and business plan execution: The business model involved placing much higher resolution remote sensing assets in orbit than currently existed from commercial suppliers, building a supporting ground system to process the imagery, and developing customers and markets to purchase the imagery at attractive prices and in high volumes. It was truly an "if you build it they will come" proposition, but in this case there were plenty of reasons to suspect customers would come. The U.S. government by policy had stated their interest in purchasing commercial imagery and private industry was already using the less efficient aerial imagery platforms. There was a high upfront cost to get into business, but once in operation the satellites could collect massive amounts of imagery continuously and it was digital versus film based and so could be stored, transmitted and combined easily with other data sets to improve its value. The economic advantages were believed to eventually allow satellite imagery to displace the aerial imagery competitors and also create large new markets like international imagery not available to the aerial suppliers.

The business model worked in the end, but the time frame for market development was much longer than originally planned. A great deal of missionary work and hand holding had to be done to educate end users as to the value of satellite imagery and then how to use it. There was also a need to develop software and web-based tools to help non-government users more easily store, process, manipulate, combine, transmit and view imagery. In many cases, this development required specialized industry knowledge such as multispectral imagery analysis of forests or farm land.

Success or failure: Although each of the three original competitors had difficulties and set-backs, the industry as a whole developed to a point where it proved its worth to the government and many commercial customers and is now on more stable financial footing. For instance, today, in addition to the $3.8 billion 10-year EnhancedView contract, GeoEye provides roughly 100,000,000 square miles of imagery to Microsoft and Yahoo! Search engines and Google has exclusive online mapping rights to GeoEye-1 imagery.

There may still be further challenges ahead, but the value proposition has been proven and the addition of new remote sensing systems and capabilities should continue to grow the market as more and more industries and consumers embrace geospatial information in their daily lives. However, for early investors, including the founder Orbital Sciences, the results were dismal to sub-par. ORBIMAGE went through a painful reorganization that wiped out much of the initial capital.

GeoEye share price since 2004

Lessons learned: There are several lessons learned from GeoEye's experience that are applicable to NASA's effort to foster development of the commercial space industry, including:

1. **Importance of government contracts when commercial market only nascent**. Although GeoEye believed their imagery would be valuable to a wide range of private industry, the private market was not well developed. The total revenues being generated by low resolution systems like Spot Image, for instance, were not going to be enough to generate a return on the much larger investments required. It was thus essential for the government to step in as the dominant early customer to be the source of revenues to enable the large infrastructure financings and fund private market development activities. One could also argue that large government purchases in the early years were also appropriate given the control government placed on such industry factors as imaging resolution, blackout zones, customer exclusions and filtering of metadata.
2. **High risks to investors when business rests on one or two space assets**. Frequently in the commercial satellite industry, investors will require a new business to fund two satellites or at least a ground spare, so that the business plan does not die upon a launch or in-orbit failure. Given that all three remote sensing companies experienced launch or in-orbit failures, they suffered material delays in executing their business plans and investor returns were negatively impacted. If NASA plans to support the development of capital intensive space infrastructure, the business plan needs to include enough redundancy to make sure investors are protected upon a launch or in-orbit failure.
3. **Commercial markets can take far longer to develop than projected**. While there may be a nascent level of interest from private industry for a new space product or service (e.g. in-orbit servicing), the true magnitude and timing of the

development of private market demand may be very different from initial estimates. In such cases, government demand needs to be large and long enough to bridge the industry to a better mix of private industry participation.

4. **Benefits of limiting competition to two companies.** The National Geospatial-Intelligence Agency (NGA) created a competition for two contracts among the three competitors. We believe this was a realization that government support was going to need to be extensive to support the industry, but given real limits on available budget dollars it would be difficult to support three competitors with sufficient funding to allow them to deploy remote sensing satellites and run their businesses. Limiting the competitors to two instead of three thus allowed to government to maintain competition while reducing the risks that the new companies they supported would still fail. Even then, it became apparent that the ClearView contract was not going to be enough as the private market for imagery was still not large enough.
5. **Ability of commercial solutions to deliver economic value to government.** Despite the early controversy of outsourcing a traditionally government function (i.e. remote sensing) and using government contracts to support a commercial space industry the development of the commercial remote sensing industry has saved the U.S. government significant sums versus what it would have costs to use much more expensive satellite systems to collect one and half meter resolution imagery. Off-loading this easier imagery collection also freed up collection capacity on the government systems to focus on higher value tasks. As more of these commercial space case studies develop (e.g. SPACEHAB module costing one tenth of internal cost, In-Q-Tel funded technology transfers to intelligence community) it should become easier to obtain Congressional funding for new support activities.
6. **What government is willing to do to enable an important space industry and maintain global leadership matters.** Part of the success of developing the commercial remote sensing industry derived from its perceived importance to the White House and Congress. Other countries had already begun to field their own commercial remote sensing systems and it was only a matter of time before they staked out a dominant market position. The government's recognition of the importance of continuing to lead the world in this arena was a key factor in the level of support provided. There should be similar and strong arguments for having the U.S. lead in LCRATS, in-orbit servicing and other NASA priorities as well even if the development of the private industry customer base takes many years.

6 Current Support Activities

6.1 NASA Contracts

Overview: NASA contracts are conducted according to the regulations promulgated via the Federal Acquisition Regulations. These regulations include rules that are intended to foster the development of firms of several types that government policy specifies. Generally speaking, these rules apply generally to NASA and other agencies. The Small Business programs implemented within the overall NASA contracting regime consist of several programs, including the following:

- Small Business Set-Asides – Federal Acquisition Rules require NASA contracting officers to reserve small contracts and portions of larger contracts exclusively for bids from small businesses.
- 8(a) program – The Small Business Development program is designed to help small disadvantaged businesses compete in the federal contracting arena. It offers a wealth of types of assistance based on ownership of 51% or more of the enterprise by members of socially and economically disadvantaged individuals. Companies that qualify for the program can receive substantial (up to $5 million) sole source contracts through the SBA. In events where competition is used to award the contract, 8(a) firms compete with other 8(a) firms. The 8(a) program also includes mentoring programs and other support mechanisms.
- Alaska Native Corporations – ANC's are treated similarly to small businesses regardless of size.
- Veteran's Benefit Act – The Veteran's Benefit Act also provides for sole source contracts for veteran-owned small businesses.
- Price Evaluation Adjustment Credit for Small Disadvantaged Business Concerns – In competitive awards against other businesses, small disadvantaged business concerns have an adjustment applied to their bids that allows them to win contracts when they are not the low bid.
- Historically Underutilized Business Zone (HUBZone) Program – The FAR provides for a set-aside program for businesses that are based in these areas. A 10% price evaluation adjustment credit is also available to these businesses when they are involved in a competitive bid. These benefits are in cumulative with those for small disadvantaged businesses.
- Service Disabled Veteran Owned Small Business Program – The FAR provides for a set-aside program for businesses owned by such parties.

In addition to bidding advantages through sole sources and set-asides, federal agencies including NASA are encouraged to break up solicitations into opportunities that small businesses can address, encourage prime contractors to use small businesses, women owned businesses, veteran-owned businesses and disadvantaged owned businesses as subcontractors. This process includes requiring contractors to submit plans for including

such firms in their execution as subcontractors, and monitoring their success in this regard.

Notable uses and successes: Literally thousands of firms have successfully participated in contracts through the 8(a) program. From an investment perspective, the 8(a) program has been very successful at attracting seed investments from angel investors that are willing to retain ownership below the 49% maximum the program allows. This success has not generally extended to institutional investors that generally are interested in deploying greater amounts of capital than this limit and the early stage of many of these firms implies. Thus the program is very successful at helping to seed fund and then operationally fund startup firms, in most cases only one of these firms has grown significantly do they have the technical and human resources to be able to make meaningful contributions to technology programs.

Examples of successful firms that have benefitted from these programs include small satellite builder Swales, Telecommunications Systems, Arctic Slope Regional Corporation, OAO Corporation and many, many others.

Relevance to overcoming barriers: As noted above, the government programs targeted towards small and disadvantaged owned businesses have been very successful at attracting capital and talent to these businesses. While these programs are thus quite successful at their stated purpose, the benefit in terms of innovation is probably more muted. Although increasing the overall contractor pool clearly has some benefit by increasing competition, these programs otherwise provide no particular inducement to develop additional space capabilities.

More generally, however, during our interviews it was stated that the Federal Government (including but not limited to NASA) is difficult to do business with. One interviewee stated that doing business with the government is "…like doing business in China. The rules are different and there is a substantial learning curve involved with learning to compete in that world." In addition to the provisions that are intended to assist the development of small and disadvantaged businesses, which are generally helpful to those firms that qualify, the Federal Acquisition Regulations also impose substantial burdens on private sector firms that are unique to the federal contracting regime. These burdens and their associated monetary and implementation costs have been cited by several of the interviewees we have spoken to as being a disincentive for private capital to fund firms that compete in the Federal Sector, and for firms to address this market. Some of these burdens include:

- Monitoring the status of subcontractors to assist in implementation of the set-aside programs detailed above.
- Reporting executive compensation and first tier subcontractor awards

- Risk associated with the potential for drawn-out contract award protests, which may also be subject to political motivations (the Air Force aerial tanker program and EELV contract awards are emblematic).
- Multiyear contracts are subject to appropriation risk and other political risk – Because many contracts require performance over extended periods that may exceed the time range for which funds have been authorized, federal contractors are at some risk that programs may be curtailed or cancelled outright because funds are not appropriated as planned at contract inception. This can be due to change in the government's needs, political administrations or many other causes. While cancellation applies typically apply, they may not be adequate to compensate for the resources allocated to the contract and the opportunity cost assumed by pursuing the contract in the first place. During our study this also has repeatedly been cited as a primary reason companies are unwilling to compete and financiers are unwilling to fund government contractors by entrepreneurs as well as venture capitalists, angels and other funding sources.
- Contracts involving construction are subject to Davis-Bacon wage restrictions.
- Equal Employment Opportunity – Federal Contractors are required to meet additional requirements beyond those that private sector firms are required to comply with, including the following:
    - Mandatory implementation of an affirmative action plan for companies with less than 50 employees
    - Special affirmative action hiring provisions for veterans, people with disabilities and protected minorities

Also, although it is not particularly incorporated into the NASA contracting regime, the commercial value of technologies developed under NASA contracts is significantly limited though imposition of the International Traffic in Arms Regulation (ITAR). Many executives in the aerospace industry and some investors as well have indicated that that compliance with these regulations effectively reduces the potential market, and thus the potential financial returns from space investment. In turn, this serves as a powerful disincentive for private investment.

Finally, under the Federal Acquisition Rules (FAR) patents developed by contractors working on government contracts become available to the government through a royalty free license.

Options for improvement: While the political obstacles are likely to be daunting, any relief from the FAR burdens of government contracting is likely to be very helpful to companies seeking to work with NASA. In particular, industry and the financial markets are likely to respond with greater enthusiasm and accept more risk if NASA is allowed to enter into longer term commitments with more standard commercial terms on contract terminations. During our interviews, several parties indicated that the current contract termination terms place the lion's share of the risk with the bidder. As a consequence, they frequently decline to bid, or must build into their bid higher costs which are passed along to NASA.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	High
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Another strategy to increase the efficiency of contracts is to standardize procurements and use block purchases to achieve economic production runs and rates. The Department of Defense has achieved some success reducing costs through this technique.

Some of the contracting changes we would suggest are more cultural rather than by legislative means or by rulemaking. For example, we have received comments from industry participants that NASA tends to add an excessive number of ancillary requirements to RFPs that increase costs and reduce the flexibility of industry to devise innovative responses. To the extent that NASA can more frequently employ high level requirements and fixed price structures to accomplish its mission, greater efficiencies are likely to accrue. In addition, as discussed below in the "anchor tenancy" section, if NASA requirements can be altered to produce greater overlap with commercial sector requirements, significant additional savings are likely to accrue.

Finally, in response to statements from some interviewees, **NASA should consider expanded assistance to companies that may want to sell goods or services to the agency, but simply do not have the specialized government sales capabilities in-house.** NASA funded "ambassadors" that could serve as intermediaries (or perhaps "translators") both to industry and from industry connecting companies and NASA staff

and contracting officers. These ambassadors could help smaller and less experienced companies compete in the NASA contracting sector thereby expanding the number of bidders, and adding value to the taxpayer as a result. With such a program, larger government contractors could no longer rely on using the costs of keeping dedicated staff for complying with FAR as a barrier to entry. These “ambassadors” could also serve as a valuable source to the agency for feedback from industry about new or emerging capabilities and how to streamline acquisition.

6.2 Cooperative Agreement Grants

Overview: Cooperative Agreement Grants are used along with additional grant structures such as NASA Research Announcements for NASA to fund research that has substantial NASA participation. These grants are used for the principal purpose of support or economic stimulation as specified by statute. The activities must not be a NASA requirement – those activities are normally handled through NASA contracts. The types of grants employed include:

- Research Grants
- Education Grants
- Facilities Grants

These grants can be up to 3 years in duration, and the federal government gets a royalty free right to data created under the grant. The award process is competitive whenever possible. In the event the grant results in the production of new technology, the government gets the rights to that technology, unless waived. Cooperative Agreement Grants can be made in response to a competition following NASA Cooperative Agreement Notices, or alternatively parties may make unsolicited proposals just as permitted under FAR for contracts.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Notable uses and successes: Cooperative Agreements have been granted for educational projects, particularly with academic institutions looking to increase STEM participation with a focus on space and NASA's offerings. In July 2010, ESMD executed a Cooperative Agreement with The National Space Grant Foundation to encourage college students to pursue careers in STEM.

Relevance to overcoming barriers: Cooperative Agreement Grants are generally directed at specific NASA areas of interest that have been formulated without regard to commercial prospects, and that have

little direct correlation with market needs. Furthermore, because new technology invented through development under these grants vests to the federal government, there is relatively little incentive for private institutions to get involved in the program.

Options for improvement: These programs are effective at funding pure research that is responsive to NASA's mission. Rather than revamping this program, we suggest NASA focus its energies towards the other program options covered in this sector.

6.3 Funded studies

Overview: Commercial space companies generally have to pay third parties to conduct market or technical studies to provide potential investors and strategic partners with independent verification of the attractiveness and feasibility of the business opportunity. Even then, many investors are skeptical as to the true independence of the study conclusions as there could be bias in favor of the person paying for the study. Funded studies are those studies commissioned by NASA to serve as a guide to potential space markets. It serves the industry by providing relatively unbiased insight into undeveloped markets

Notable uses and successes: Significantly, the Commercial Space Transportation Study, conducted by six major US aerospace firms to investigate commercial space markets and their size and viability under different launch cost scenarios. In a different case where a study opened up a space market, Richard Garriott personally funded a study by the Russian space agency to determine the cost of providing access to space to tourists on their vehicles. This directly led to the beginnings of Space Adventure's space tourism business by providing cost certainty to the service providers.

Relevance to overcoming barriers: Studies, by their nature, tell you what a market is, but they do not change how big it is. However, to the extent they provide clarity for investors and market participants, they improve perceptions and barriers to entry. For an early stage company, it is also helpful to not bear the burden of commissioning expensive market studies.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	
CISS	
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	

Options for improvement: To the extent NASA funds and provides high quality studies to industry, it would give potential investors greater comfort that the data and conclusions are less biased toward one business plan. However, such studies may reflect NASA's own biases if due care is not taken to have them broadly focused. Such studies can also serve as a common benchmark for comparison of business plans and other third party studies. **We suggest NASA consider materially increasing its funding for such studies in the areas of its top 5 priorities.**

6.4 NASA technology demo missions

Overview: Technology demonstration missions are, as the name suggests, NASA sponsored missions designed to purposely and primarily test new or improved technologies for use on subsequent missions. Generally speaking, a technology demonstration mission can take two forms:

1) A mission where one or more subsystems (e.g. new propulsion systems, avionics, power systems) are being demonstrated in order to mature them to high (7-9) TRL levels. In some cases the mission may have a secondary scientific or functional aspect to it while in others, the mission is a mere platform to test the technologies; and
2) In certain cases, the mission is a demonstration of an advanced concept, in essence demonstrating functionality of a completely new service.

Notable uses and successes: The most notable recent NASA use of the first type of technology demo mission were those arranged by the New Millennium Program, setup in 1995 by the Office of Space Science and the Office of Earth Science and managed first by JPL and then by SMD. NMP missions were intended to provide opportunities for technology validation for a new mission every two years, based on technology needs indicated by internally developed NASA science roadmaps. Based on priorities, technology procurements would then be solicited from industry. Over the course of its history, NMP was responsible for four successfully completed missions, with one failure (the Deep Space Two Mars surface penetrators) and five cancelled missions. Notable technologies demonstrated included ion electric propulsion, concentrating solar arrays, small Li-on batteries and advanced imaging technologies.

A mission more typical of the second type of tech demonstration was the Advanced Communications Technology Satellite (ACTS), a significant activity of the NASA Space Communications Program. ACTS provided for the development and flight test of high-risk, advanced communications satellite technology using higher frequency Ka band transponders. Using multiple spot beam antennas and advanced on-board switching and processing systems, ACTS pioneered new initiatives in communications satellite technology. NASA GRC was responsible for the development, management, and operation of ACTS in conjunction with RCA Astro Space (later Lockheed Martin), TRW, Comsat and others. While ACTS did not become an operational communications satellite per se, its successful operation and demonstration of advanced concepts led to the development of subsequent high capacity satellites, such as the DIRECTV spot beam satellites that provide local stations via satellite and KaStar (later WildBlue-1) which provides satellite broadband services to consumers.

Relevance to overcoming barriers: Technology demonstration missions primarily affect technology risks to business and investment. Missions dedicated to this purpose buy

down risks to businesses while also making possible the use of new potentially cost-saving technology on commercial missions while mitigating insurance costs. Demonstrations also mitigate operational risk by generating experience and knowledgebase as well as improve perceptions on the viability and riskiness of a certain space service or technology. Demonstration missions do not significantly affect any other barrier.

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	
Technical: Launch & in-orbit operation	Moderate
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	

Options for improvement: One of the big weaknesses of technology demonstration programs is that they are "top down" programs where the government decides what technologies are worth demonstrating based largely on its own needs. If there were more commercial market driven demonstrations then they would have increased value to attracting subsequent private capital and industry participation.

For capital intensive advanced concepts where private capital cannot be successfully attracted, and thus a COTS style public – private partnership cannot be utilized to share the cost of the demonstration, we suggest a two phased approach: First, create a NASA team to survey and interface with the leading industry prospects (and other government agencies and departments) to develop a consensus plan for the key systems and capabilities to be demonstrated (within the budget allocated) in a first mission. Next, competitively award demonstration missions to the two top teams using a funded SAA. Once a plan for systems and capabilities has been finalized, as part of the competitive award process, NASA could ask bidders to include data on the marketability/commercial applicability of their proposed design. The ultimate decisions would still rest with NASA, but be based on industry input. Unlike COTS, funding of these initial technology demonstration missions would be 100% government supplied. Data would be made publicly available to all U.S. companies.

Following this first set of wholly government funded demonstrations, industry would be invited to submit proposals for their own demonstration missions with NASA providing

matching funds to those selected. This could be based on a shared cost COTS type program with funding milestones and the possibility of service contracts upon success. With private capital at risk, the chance of mismatches between what the market wants and what NASA develops would be greatly reduced. The demonstration missions should therefore be more efficiently oriented toward commercial interests. A funds matching scheme, in addition to reducing commercial risk and the magnitude of capital required, would also bestows upon chosen commercial missions the added halo of NASA approval. Data and intellectual property rights developed in these matching fund missions would go to the commercial company with licensing rights for NASA to be negotiated up front.

Regarding the demonstration of advanced in-orbit concepts such as fuel depots, servicing stations or cyclers/tugs, a key will be developing financial partnerships with an industrial team with the intent to make use of the technology to provide the demonstrated service. A major item that needs to be resolved entails the devolution of ownership and operating responsibilities. For instance, a demonstration fuel depot could conceivably continue to provide commercial fuel provisioning services well after it has been successfully demonstrated to NASA's satisfaction. At this point, an advanced concept becomes space infrastructure and NASA policy should take steps to treat it as such. Potential structures could include those similar to public-private-partnership Greenfield infrastructure projects where the infrastructure (in this case, the depot) is privately financed but NASA provides an R&D contract to support initial development.

Regarding the demonstration of less capital intensive subsystems or components, conversations with management of the New Millennium Program indicate that the demand for technology demonstration services within NASA is high, although it is unclear what price points the market for such services could sustain. **If attainable, we suggest such a service should be run commercially.** Availability of capacity for hosted payloads on (government and commercial) satellites to be launched has in recent years increased and **we suggest NASA consider purchasing this low cost capacity to address its technology demonstration needs instead of using dedicated missions of its own. Similar capacity on upcoming commercial pressurized vehicles (e.g. DragonLab) also could save NASA time and money**. To a great extent, such a program to support technology demonstration missions has much in common with an expanded FAST program which we discuss below. In such a scheme, NASA continues to subsidize the demonstration of new technologies (according to its needs), but purchases such services from a variety of commercially-available relevant platforms.

6.5 Space Act Agreements

Overview: NASA's organic statute, the National Aeronautics and Space Act of 1958 (Space Act), as amended (42 U.S.C. § 2451 et seq.), grants NASA broad discretion in the performance of its functions. Specifically, Section 203(c)(5) of the Space Act authorizes NASA:

> "to enter into and perform such contracts, leases, cooperative agreements, or *other transactions* as may be necessary in the conduct of its work and on such terms as it may deem appropriate, with any agency or instrumentality of the United States, or with any State, Territory, or possession, or with any political subdivision thereof, or with any person, firm, association, corporation, or educational institution."

Arrangements concluded under the "other transactions" authority of the Space Act are commonly referred to as Space Act Agreements (SAAs). As is evident from the language above, SAAs have wide latitude in terms of structure that can be tailored to address NASA and the industry partner's concerns. SAAs are restricted to terms of 5 years or less in most circumstances.

SAAs fall into three categories that each have their own idiosyncrasies:

- Non Reimbursable Agreements are used for projects that provide the potential for mutual benefit for both NASA and the counterparty. Under these agreements, NASA and the counterparty are each responsible for funding their own expenses. In these circumstances, because both parties are funding the effort, the output from the effort is allocated to both parties as agreed at inception. The relative contributions of the respective parties also must be fair considering the benefits that are expected.
- Reimbursable Agreements are used for projects where NASA personnel and facilities are uniquely capable of accomplishing the goals of the project and where the use of such resources is not counterproductive to NASA's overall mission. Under these agreements, the counterparty is required to reimburse NASA's actual cost for the services provided. Because the counterparty is funding the effort, it typically retains intellectual property rights and other products from the effort. In some cases, NASA forgoes part of the reimbursement in exchange for enhanced rights to these data. In other cases (e.g. Commercial Space Launch Act), statutes govern instead of NASA's general authority under the Space Act.
- Funded Agreements are used for projects where NASA funds are used to accomplish an agency mission, and only in those cases where more typical contracts that are governed by FAR, Cooperative Grants and other existing structures cannot be employed. NASA's contribution must be fair and reasonable compared to the contribution from the counterparty.

SAA structures that have been used include:

- Launch Services Agreements where NASA provides the launch services using its facilities.
- Space Station Utilization Agreements provide access to NASA's allocation of resources on the International Space Station.
- Space Systems Development Agreements provide first time entrants access to space launch services at a reduced price. These agreements are only available to domestic firms.
- Joint Endeavour Agreements provide domestic entities access to NASA facilities and services at either a reduced price in exchange for giving NASA access to the data resulting from such activities or with no exchange of funds and no quid pro quo and with each party paying for its own involvement.

SAA authority has been granted to the NASA administrator and delegated to Center Directors at a reduced funding level.

Notable uses and successes: Space Act Agreements have been used for a wide variety of occasions, including the COTS program and CCDev programs discussed elsewhere in this report. Some other noteworthy uses (particularly with respect to commercial space) have included the following:

- Non-reimbursable SAAs were executed with SpaceDev (now Sierra Nevada Corporation), t/Space, PlanetSpace, Constellation Services International and SPACEHAB in 2007 for development of systems and procedures for ferrying crew and cargo to the International Space Station. This implementation of SAAs was partially successful in that execution of the SAAs provided these firms with a measure of credibility that was helpful to an extent as they sought to capitalize their efforts. However, this benefit was limited in its overall effect as demonstrated by the record of these firms' fundraising efforts. Implementation of these SAAs was also only partially effective since only a portion of the identified milestones were successfully implemented. Subsequently, SpaceDev was able to secure $20 million in funding from NASA to continue development of Dream Chaser through a funded SAA as part of CCDev.
- Microsoft and NASA agreed to make NASA's databases available to the public through its worldwide telescope program under a non-reimbursable SAA.
- Oxantium Ventures executed a Space Act Agreement with NASA Ames Research Center to create a data exchange between them and NASA regarding emerging stage technology companies.
- In 2005, SpaceX and NASA executed a non-reimbursable SAA that predated and laid the groundwork for its successive COTS activities.

Relevance to overcoming barriers: Space Act Agreements, depending on their structure, can be very effective a helping to overcome certain investment barriers. By the legitimacy of NASA's direct involvement and commitment of resources (especially though a funded SAA, though also true for non-reimbursable SAAs) SAA's help attract private capital by allaying investor concerns about technology risk. Likewise, though the same legitimacy and the selection for the agreement itself, concerns about the amount and nature of competition are reduced.

Options for improvement: Given the repeated complaints about the burden (both in terms of costs as well as mindshare) of complying with FAR, **we suggest that expanded implementation of SAAs should be considered where practicable**. It is understood that the political environment may have limited tolerance of expanded use of SAAs as it may be viewed as an end run around FAR and other congressional authority, however, the inherent flexibility of the SAA structure creates many advantages for NASA to work more effectively with private industry on more risky endeavors**.**

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	High
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

In some cases where reimbursable SAAs have been employed where funds have been committed by commercial partners, we have heard complaints that the commercial partners have much less oversight over how their funds are expended by NASA than would be the case under normal commercial contracts. This can be alleviated through the use of more typical commercial terms in future SAAs such as:

- Defined statement of work and deliverables for NASA under the agreement
- Fixed schedule for deliverables
- Payment on normal commercial terms post receipt of deliverables

We also believe the expanded use of Reimbursable Space Act Agreements offers the potential for more efficient use of NASA facilities, benefiting both the agency and the nation. One major challenge to increasing utilization has been determining the

appropriate pricing for such facilities and services (e.g. marginal costs vs. full recovery pricing vs. market pricing). However, in most cases we believe a focus on pricing may not be necessary. For instance, **where such services and facilities may have broad market demand, but little market awareness, NASA could contract with one or more third party brokers**. The brokers would be responsible for marketing the facilities and services to private industry and for negotiating pricing above some agreed floor (e.g. marginal cost). Once NASA entered into a reimbursable SAA with the commercial customer, the broker would be paid a commission relative to the pricing negotiated. The broker is thus incentivized to maximize pricing in a way that still results in executed SAAs. **We suggest consideration of this outsourced marketing strategy for enhancing NASA facility utilization through RSAAs with private industry.**

In cases where such services are recurring on a very regular basis, we suggest NASA seriously consider privatizing such operations by leasing the facilities to a private operator using a competitive bidding process (with the understanding that the government would have preferred access).

In addition, to further encourage the greater use of underutilized NASA facilities and capabilities, we suggest NASA consider providing these services as in-kind contributions to companies pursuing capabilities it desires to support in lieu of providing cash grants, procurement contracts or other financial support. The pricing then becomes limited to an intra-NASA issue which hopefully is easier to solve if a NASA wide approach is adopted as a matter of policy. For instance, if NASA were to create an In-Q-Tel type of group it could use this type of in-kind contribution instead of cash when it made investments.

6.6 Patent License

Overview: NASA owns over 1000 patents and applications. The agency has two main methods of licensing its patents – through negotiated agreements and, more recently, through auctions. In the first case, each patent license agreement is negotiated on a case by case basis; the agency has wide latitude in patent licensing structures available including exclusive, non-exclusive or field of use licensing. Terms such as duration, application and royalties are also individually negotiated. The agency disseminates information on its patent portfolio through a variety of means, including:

- NASA Tech Briefs
- The NASA Patent Abstracts Bibliography
- NASA Field Center Technology Transfer offices
- NASA TechFinder web portal

Parties wishing to license a NASA patent are required to submit a detailed commercialization plan that includes a business plan for using the license. The plan must include the following elements:

- Products and services to be produced and markets to be served
- Financial resources required and a pro forma income statement
- A statement regarding the applicant's ability to implement the plan
- A statement regarding the fields of use for the patent
- A statement regarding the geographic regions where the patent will be used
- A description of milestones that must be achieved to complete commercialization
- Proposed royalty rates, including upfront fees and minimums
- A copy of the financial report for the applicant

Applicants are evaluated on the technical soundness of their plan, their financial soundness, the quality of the management team and the potential economic impact (both to NASA and nationally) from the licensing agreement. In the event of an award of a license, there is a 15 day public notice period during which parties may protest the action.

In the second case, NASA has arranged with Ocean Tomo, an intellectual property investment bank and brokerage, to conduct pilot auctions of certain NASA patents from two NASA centers. The intent of conducting live auction is to achieve a wider dissemination of the licensing opportunity.

NASA currently has issued an outstanding Request For Information regarding patent management services. The agency is seeking to identify no cost revenue sharing arrangements with providers that can help it more widely disseminate, utilize and monetize its patent assets. Responses are due by October 18th.

Notable uses and successes: Some of the more notable NASA patent licenses include:

- In 2008, NASA successfully auctioned a portfolio of ten patents and one application that covered methods for analyzing signals known as the Hilbert Huang Transform – the first live auction of NASA IP. Subsequently, DynaDx Corporation incorporated the technology into their biomedical analysis software. The patent auction provided very wide exposure to NASA and the sale was covered in multiple news publications.
- License of docking technology to Bigelow Aerospace (patent 6354540) that will be used in their upcoming space habitation module.

The vast majority of patent licenses entered into by NASA are for application in non-space oriented uses which are ancillary to NASA's main mission.

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	Yes

Relevance to overcoming barriers: Access to technology and obtaining patent protection for is can be a daunting challenge to startups. By accessing technology developed at NASA, and establishing exclusivity through the licensing process, early stage firms can address both technology development concerns as well as some competition concerns. By virtue of their structure, licenses are capital efficient for early stage firms that can avoid the cost of original R&D and back load royalties so that they are coincident with revenue from customers.

Options for improvement: Given the initial success of patent auctions, we suggest NASA consider expanding the practice to cover all the Centers. **We suggest that NASA also consider other proactive marketing techniques, possibly using third party brokers, to help ensure that NASA technologies available for license are made aware to prospective users of the technology.** This is particularly true of technologies developed that are applicable to areas of enhanced interest to NASA such as LCRATS.

6.7 Enhanced Use Lease

Overview: Enhanced Use leasing is a technique where underutilized real estate assets are leased to developers for extended terms (40 years or more, typically). Under terms of an enhanced use lease, payments may be made in cash, in kind, or a mixture of both. The benefits can stay with the local authority, and at NASA have been typically used for maintaining other real property assets. At present, this enhanced use lease authority is limited to two NASA centers: Kennedy Space Center and Ames Research Center.

While NASA has used reimbursable Space Act Agreements for many similar structures, the statutory authority that permits payments in kind and allows consideration to remain local are particularly attractive to NASA and thus encourage expanded use of the authority.

Notable uses and successes: NASA entered into a 40 year lease with Google, Inc. for excess real estate at NASA Ames Research Center. Google is paying $3.66 million per year initially, with customary rent escalation, and intends to construct office space, R&D facilities and a variety of amenities there for its employees and others. NASA and Google also expect to realize additional benefits from the collocation of their respective employees, along with other firms as part of NASA Research Park. Proceeds from the lease are to be targeted towards maintaining other real property at NASA Ames.

Enhanced use leases at other government facilities have been used for the construction of power generation facilities, parking lots and other infrastructure that provides added benefit to the government. While not a NASA lease program, Astrotech Corporation leases the land its facilities are located on at Vandenberg Air Force base.

Relevance to overcoming barriers: Access to real property is often essential for development and launch activities. In prior instances, SpaceX encountered difficulty with finding a launch site for Falcon I, eventually abandoning their effort to launch at Vandenberg in favor

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	
SpaceLab	Yes
Lunar/NEO	
CASPER	

of Kwajalein. According to press accounts, SpaceX spent over $7 million on preparations at Vandenberg that were eventually abandoned.

In the case of Space Launch Complex 40, a five year license from the Air Force was used that required SpaceX to pay all costs associated with refitting the pad and maintaining it for use in launch services. The Air Force also retained the rights to allow other launchers to use the complex.

Because enhanced use leases do require that the leases be provided at "market" rates, the real benefit of the program is the siting of the lease itself. As noted above, location on or proximity to NASA's range facilities are just one example where siting can be critical to the overall business case.

Options for improvement: The only change we believe is worth suggesting for this program is to consider opening up authority to enter into enhanced use leases to additional NASA centers based on existing and anticipated commercial demand and the operational suitability of NASA providing or sharing such facilities and assets with commercial lessees. However, with the additional authority under SAAs for circumstances where enhanced use leases are not appropriate, the implementation of such an extension is not critical.

6.8 CRADAs

Overview: Cooperative Research and Development Agreements (CRADAs) are used when non NASA agencies and private entities agree to collaborate with NASA on R&D for a stated purpose. CRADAs are funded individually by the respective participants, much like a non-reimbursable Space Act Agreement. Unlike the vast majority of NASA contracts, a CRADA does not need to be competitively awarded. CRADAs are used with many federal laboratories outside NASA as well. CRADAs require a specifically elaborated plan with schedule and budget specified.

Scientific and technical findings from a CRADA are exempt from Freedom of Information Act disclosure requirements for five years. IP developed during a CRADA can be retained by either partner as long as the government retains a royalty free license, and as such CRADAs represent a commercialization technique for government R&D with advantages with respect to Space Act Agreements. FAR does not apply for CRADAs.

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	High
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Notable uses and successes: CRADAs have infrequently been used within NASA due to the availability of Space Act Agreements, which offer greater flexibility. NASA's first use of a CRADA was in 2005 for Barton Medical Imaging. The CRADA structure was used because it allowed Barton to retain exclusive license in its areas of application under the CRADA structure.

Relevance to overcoming barriers: CRADA benefits are essentially identical to non-reimbursable Space Act Agreements.

Options for improvement: Given the authority that NASA has under the Space Act, no adjustment to the CRADA framework seems warranted.

6.9 SBIR/STTR

Overview: The Small Business Innovative Research and Small Technology Transfer programs implemented by NASA consist of Phase I and Phase II research grants that awarded by a competitive process. Only "small" companies with 500 or fewer employees are eligible. These research grants provide up to $100,000 (Phase I) or $600,000 (Phase II) for the development of commercially or technologically significant technology in response to NASA selected research topics. Programs are selected based on:

- Scientific/technical merit and feasibility
- Experience, qualifications and facilities
- Effectiveness of the proposed work plan
- Commercial potential and feasibility

The topics are selected based on NASA's internally assessed technology needs and are fairly broad in their scope.

Notable uses and successes: SBIR/STTR funding has been used to help found and expand a wealth of firms over its history, both through NASA as well as other federal agencies. Some of the more notable NASA success stories include:

- SEAKR Engineering used SBIR grants to develop its solid state data recorder technology. These grants included both Phase I and Phase II grants. SEAKR's technology was originally based on bubble memory, then later on flash technology and now is widely used, with over 85 units launched and in service. This technology is very low power and much more reliable than the tape recorder technology that it replaced.
- Spectrum Astro used SBIR grants to develop its orbit trajectory optimization software MATS (Multi Algorithm Trajectory System), which has been used on Solar Dynamics Observatory and is being used in planning upcoming NASA missions such as James Webb Space Telescope.
- Tecstar used SBIR grants to develop their triple-junction $GaInP_2$/GaAs space qualified solar cells with efficiency in excess of 26%, which have subsequently been used in a variety of NASA (Deep Space 1, TRACE) and commercial satellite missions.
- Digiray used SBIR grants to develop its reverse digital X-ray technology that is used to perform non-invasive inspection for manufacturing, safety, biomedical and national security applications. The technology has been widely used and has generated over $3 million in sales to date.

Relevance to overcoming barriers: SBIR/STTR grants, by virtue of being grants increase the expected return on investment for projects that they fund and the companies that

pursue them. In addition to enhancing returns (and thus making it easier for companies to reach the investment hurdle rates identified for the various investor classes, the fact that these grants are awarded through a competitive process administered by NASA gives the award itself value due to NASA's recognized expertise. Furthermore, since these awards are granted in response to topics that have been selected by NASA as being relevant to its mission, investors view these awards as providing some (albeit uncertain) revenue visibility from NASA.

However, these awards are often given in arcane areas where there is little commercial evidence of demand, and as such the awards are helpful but not sufficient in themselves to address investor concern in this area. The award amounts are often enough to do some development work that can lead to a product, but in many cases are insufficient to develop the product or service to a point where it is close enough to commercialization to attract private sector capital. In speaking to entrepreneurs and venture capitalists, on multiple occasions it was indicated to us that a "valley of death" exists between early stage companies that have been funded partially through SBIR/STTR grants but have not gotten mature enough to be able to attract institutional capital.

A second criticism of the SBIR/STTR structure is that by virtue of restricting grants to previously selected topics that are determined by NASA, the overall innovation approach becomes "top down" and may miss out on worthy technologies that could indeed be of interest to NASA but that NASA is unaware of or neglected to include in its topics for solicitation.

Lastly, NASA reports that they some times experience their own "valley of death" in that the small businesses receiving the SBIR/STTR grants from NASA's in-house technology technologists often develop their products in ways that do not meet the actual needs of NASA's mission and operational organizations.

Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Options for improvement: Our feedback from practitioners regarding SBIR/STTR has been that the program is

great for getting projects started, but that in many cases due to the small size of the grants and the inherent high risk of new technology (and thus the willingness of private capital to "finish the job") the projects become stuck at a relatively low technology readiness level. Providing a funding pathway for larger funding amounts would help address this concern. **We suggest that to bridge both "Valleys of Death", NASA consider seeking enabling legislation to add SBIR awards at the ~$2 million and ~$5 million levels and use these larger awards to better assure the technologies and products developed meet their mission needs.**

However, simply increasing the size of these grants does not address some of the other concerns we identified, nor does it address the government's legitimate concern about maximizing the efficiency of the funding it is deploying. **Therefore, we suggest that any later stage SBIR/STTR program enhancements NASA considers not be implemented as pure grants, but rather as matching programs where a specific (and perhaps, competitively determined) mix of private and public capital is deployed in projects.** In addition to levering private capital resources, the ability to attract these funds will serve as an invaluable bell weather for evaluating the true private sector interest in the technology or system being developed. Alternatively, and perhaps preferably, these matching grants could be made through an In-Q-Tel type program.

6.10 IPP Seed Fund

Overview: The IPP Partnership Seed Fund provides seed funding to address barriers and initiate cost-shared, joint-development partnerships. Moreover, it is intended to provide "bridge" funding to enable larger partnerships and development efforts to occur. Its structure encourages the leveraging of funding, resources and expertise from non-NASA partners, NASA Programs and Projects and NASA centers.

A typical seed fund award will provide $250,000 for a project over the course of one to two years, awarded through and to NASA centers. However, each proposal requires industry partners to invest an equal or greater amount into the project, with center budgets often supplementing that amount. There is no limitation in the size of the industry partner, so it is open to large and small companies as well as universities, research institutes and other government agencies.

Notable uses and successes: Over the course of 2006-2008 this program, an aggregate IPP Seed Fund of $19 million was combined with $53.8 million of other non-IPP funding, an almost 4 times leveraging of funds. This has also included funding from companies not ordinarily identified with space applications, such as Caterpillar's involvement with JSC and KSC in Lunar surface systems development. Seed funds have been applied to demonstrations of dozens of projects in all directorates, with subjects ranging from lunar habitats, improved propulsion systems and enhanced power systems to ISRU systems and life/human spaceflight support systems. Projects have involved technologies at almost all TRL levels, although most projects involved technologies with a TRL of between 2 and 5. A Seed Fund project will typically mature the technology one or two TRL tiers.

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	High
Market: Longevity	
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	High
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	High
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Relevance to overcoming barriers: As a technology development program, the IPP Seed Fund primary contribution is, like other technology development programs, to buy down technology risk for new and improved products or services. The key difference and major additional contribution is the

encouraging of partnerships and the leveraging of outside funds. This scale of funding and presence of strategic partners at an early technology development stage is often the key component to whether a technology will be carried over into further development or even into the market. Matching funds puts partners 'skin in the game' and provides additional outside talent.

Options for improvement: By all accounts, the IPP Seed Fund has been particularly successful in key metrics, notably in attracting outside funds, outside partners and in achieving TRL maturation. **We suggest NASA consider expanding the funding and use of this program.**

6.11 Centennial Challenges

Overview: Centennial Challenges is a program of incentive prizes to generate novel solutions to problems of interest to NASA and the nation. It is not a program designed to find particular solutions in a short amount of time. It is truly for problems with no consensus solution at NASA. The program seeks innovations from diverse and non-traditional sources and the challenges are open to private companies, student teams and independent inventors. The competitors are not supported by government funding and awards are only made to successful teams when the challenges are met.

In this program, NASA provides the funds for prize purses but the challenge competitions are conducted by private, non-profit organizations at no cost to NASA. The administrative cost to NASA to run these challenges has been extremely small (e.g. $10,000). The overall size of the program has also been relatively small, with approximately $15 million dedicated over the life of the program, of which just over $4 million has been awarded so far.

Notable uses and successes: Ten challenges have been instituted since the beginning of the program in 2005, four of which have concluded. All ten are described, along with their results, in the table below.

Concluded competitions		
Regolith Excavation	Robotic excavation of simulated regolith	$750,000 awarded to 3 teams. 23 teams competed.
Lunar Lander	Reusable rocket-powered vehicles	$2 million awarded to 2 teams. 4 teams competed.
Astronaut Glove	New designs in flexible pressure suit gloves	$550k awarded to 2 teams
MoonROx	Demonstrate extraction of oxygen from simulated lunar regolith	$1 million prize expired with no winners.
Existing challenges		
Power Beaming	Wireless power transmission	$900,000 awarded, $1.1 million remains
Strong Tether	Advanced materials	$2 million
Green Flight	Super-efficient, quiet and safe aircraft.	$1.65 million
Nano-Satellite Launch	Place a small satellite into orbit twice in one week	$2 million
Night Rover	Demonstrate a solar-powered exploration vehicle that operates in darkness using stored energy	$1.5 million
Sample Return Robot	Demonstrate a robot that can autonomously locate and retrieve geologic samples across varied terrains	$1.5 million

Some of the notable successes include the awards to:

- Masten Space and Armadillo Aerospace in the Lunar Lander competition, providing both with significant publicity and credibility to compete for follow-on commercial and government projects for suborbital services such as providing

the vehicles for the prospective Rocket Racing League. In return, NASA gained access to lunar landers as test beds saving development tremendous time and money. NASA also helped move forward a reusable sub-orbital rocket vehicle with the potential for future "off-the-shelf" availability for NASA's needs.

- The Regolith Excavation where [43] robotic solutions were tested for a total cost to NASA of $750,000. The value of just knowing which techniques and technologies do not work was worth far more than that small investment. This challenge was also notable in that a group of students beat out the professionals.
- The Astronaut Glove competition not only generated significantly improved glove designs, but has also generated at least two companies founded by the winning and runner-up teams to pursue commercial opportunities to market their designs (Flagsuit and Final Frontier Design). In this case, Peter Homer the winner was an individual inventor and virtually unknown to NASA.

The Challenges have also been notable for their ability to draw in talent and activity that otherwise has little to do with NASA, typically hobbyists, college students and small non-aerospace technical firms. In fact, the "front runner" does not always win.

There have also been failures. For instance, the MoonROx, Moon rocks to Oxygen, Challenge generated no takers and no team is close to solving the criteria in the Strong Tether Challenge. When a Challenge reaches the end of its stated term it is generally cancelled as the funds set aside for the winners cannot be redeployed as long as the Challenge is in effect.

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	High
Applicable to:	
LCRATS	Yes
CISS	
SpaceLab	
Lunar/NEO	Yes
CASPER	

Relevance to overcoming barriers: Although much attention focuses on the dollar value of the prize, the relatively small amounts and their once-off nature make the prizes poor financial support for any ongoing business models. To the extent that they assist a winning team, it provides that team with useful and non-dilutive seed capital to support further R&D following their victory. Otherwise, the Challenges are most useful in motivating the deployment of

large quantities of human capital (who may in turn deploy personal financial resources to support their prize bid) and in encouraging the development of improved technologies and innovative solutions. The Challenges also bring down certain market barriers by signaling to the market NASA's interest in the technology or service and change perceptions by providing a venue for high-profile demonstrations enhanced with the traditional excitement of a competition.

Options for improvement: The Challenges are very popular and effective, but criticism both internally and externally of the Challenges focuses mainly on the small number of challenges that get funded, the small size of the prizes and in some cases the scope or requirements placed on the contestants. To date, the prizes have been relatively small (never larger than $2 million). Our understanding is that the size of the Challenge budget in any given year is based largely on the amounts allocated to NASA for Challenge prizes by Congress. Multi-year prize commitments with uncertain beneficiaries are not a favorite of Congressmen and are frequently difficult to protect during budget negotiations. NASA will need many prominent success stories from the Challenge program to increase the chances for materially larger budget allocations in the future.

As to the adequacy of the prize amounts for any given challenge, we are told the prize amounts under these tight budgetary constraints are determined more by what is reasonable to attract interest than what may be necessary to even cover the costs of the winning contestants. Still, even at these modest prize levels the Centennial program has been very successful at attracting large numbers of competitors and NASA feels it has benefited greatly and cost effectively from this program.

The third issue is the question of who qualifies to compete. First of all, teams are excluded if they receive government funding for any of their business activities. Although this requirement prevents government dollars from crowding out small hobbyist teams, students and purely commercial firms, it prevents even moderate sized aerospace contractors who also have strong technical capabilities from participating in competitions. We question the wisdom of this exclusion. For example, we believe that participation by larger firms (that may have some government funding in other activities) will have two additional benefits: First, it will broaden the potential pool of talent attacking the problem, but second, and more importantly, it could help instill a more entrepreneurial culture at these larger firms with concomitant benefits across the firm. **If NASA decides to award larger prizes for larger goals, we suggest that NASA also consider altering the participation requirements to accommodate larger organizations with more significant deployable capital.** Competitions which require millions of expenditure to win are not easily won by hobbyists, students and very small firms.

If allowing firms of any size to participate as we suggest above proves problematic, a different way to address large company and government contractor participation is to create a two phased competition. In the first phase, a typical low dollar value Challenge is held and designed to achieve a diverse submission of innovative solutions from only smaller and non-traditional sources. The second phase would include the winners of the first phase plus entry by medium and larger firms to compete for much larger prizes. These larger new contenders could even partner with some of the smaller winners to further develop their innovative solutions.

An unusual, but good analogy of a very successful two stage competition structure is professional poker tournaments. “Satellite” tournaments are held with a very low entry fee (e.g. $100) with the winner receiving the $10,000 entry fee for the much larger tournament where professionals play and millions of dollars can be won. There have been many examples of unknown amateurs rising to the top after being given this low cost chance to prove their skills.

6.12 FAST

Overview: The Facilitated Access to the Space Environment for Technology Development and Training (FAST) provides opportunities for emerging technologies to perform testing in the space environment.

- Technologies that support NASA's missions but are not yet mature enough for adoption
- Technologies that might not otherwise be tested due to lack of funding:
    - Small businesses and individuals
    - Universities and research institutions
    - NASA projects in early development

FAST utilizes commercially available flight test capabilities such as the Zero Gravity Corporation aircraft for parabolic flights. The program's funds are used to purchase flight time by the week to get favorable pricing. FAST uses an open solicitation for proposals and then competitively selects winning proposals based on importance to NASA and the benefits to be gained by the testing. The selected projects and tests are then combined by FAST to maximize flight efficiency. Users of FAST not only benefit from the free flight time, but in many cases may have found testing prohibitive on their own given often tighter FAA safety restrictions for commercial services. The current focus is on testing in micro-gravity, reduced-gravity or variable-gravity conditions on parabolic aircraft flights. In the future, the FAST program may provide opportunities to test technology on suborbital and orbital flights.

Notable uses and successes: FAST is in its fourth year of operation ramping up from five projects in its first year to 19 projects in year two and then 17 projects in year three. Current funding for fiscal 2010 was reduced to approximately $500,000, enough to support four flight campaign opportunities. Users included a wide variety of teams connected to research institutes, NASA centers, universities and small companies. Projects tested a wide variety of technologies fluidics, structures, propulsion systems and advanced sensors. There are not many notable success stories, as of yet as reporting times can lag tests by a year or more and some projects require multiple flights to gather sufficient data.

Relevance to overcoming barriers: The goal of the program is to facilitate the development of space-qualified technology using facilities that NASA uniquely has access to. Currently, this involves the testing of low or no gravity condition using parabolic flights provided to NASA via a contract with Zero Gravity Corp. As these conditions are difficult to simulate on Earth (as opposed to vacuum or radiation) and access to space is expensive, it is one of the larger impediments to developing technology maturity. It is, however, only focused on one aspect of technology development and alleviates the capital requirement for tech development by only a relatively small amount. The program does not significantly alleviate any other barrier.

Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	Moderate
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	
CISS	
SpaceLab	Yes
Lunar/NEO	
CASPER	Yes

Options for improvement: Parabolic aircraft flights provide roughly 25 seconds of zero gravity. A program to facilitate affordable access to the low gravity space environment for testing of important new components and processes should eventually provide users with access to longer duration testing on suborbital and orbital platforms. To provide such longer durations, **NASA could consider additional platforms including the ISS, commercial and government satellites (through hosted payloads), commercial orbital transportation platforms (such as Dragon, Cygnus or Bigelow modules) and suborbital systems (such as the vehicles available under CRuSR). When structuring these programs, NASA can leverage its experience with FAST to preserve both the cost benefits of bundling demand and the reduced regulatory burden that the government enjoys.**

In addition to accessing platforms, **we suggest NASA consider programs that competitively award grants that consist of either excess NASA procured space launch capacity (e.g. piggyback launches), or launch capacity specifically procured for provision to industry.** This would address the purpose of providing access to space for companies that either don't need (because they have their own "platform" or bus), or alternatively are incompatible with existing platforms. **NASA could also potentially include use of NASA tracking stations and other support infrastructure.**

FAA restrictions on the use of aircraft by Zero Gravity Corp (or any other commercial operator) prevent it or any affiliate to offer the same technology demonstration aggregation service as NASA does through FAST. If NASA wishes to encourage the creation of a commercial service which offers the capabilities that FAST does then **we suggest it investigate, in conjunction with the FAA, the extent to which these restrictions can be relaxed.** In this scenario, NASA merely subsidies the use of the service for those technologies it wishes to support and outsources the administration of the program to a commercial entity.

6.13 Commercial Crew and Cargo Program Office (C3PO)

Overview: The Commercial Orbital Transportation Services (COTS) program and the Commercial Crew and Cargo Program Office (C3PO) share the goal of extending human presence in space by enabling and expanding the U.S. commercial space transportation industry. The objectives of COTS/C3PO are to:

- Implement U.S. Space Exploration policy with investments to stimulate the commercial space industry
- Facilitate U.S. private industry demonstration of cargo and crew space transportation capabilities with the goal of achieving safe, reliable, cost effective access to low-Earth orbit
- Create a market environment in which commercial space transportation services are available to Government and private sector customers

These objectives represent a significant departure from NASA's traditional approach of creating government owned and operated systems, frequently developed under cost plus contracts with the aerospace industry. The new strategy is based on fostering the development of privately owned and operated space transportation systems with NASA serving as a lead "investor" and customer of transportation services. NASA will also provide technical assistance as industry develops and demonstrates its services. However, a major difference in COTS/C3PO versus normal NASA practice is that the technical assistance is just that, "assistance," not directed design solutions or extensive technical requirements and specifications. COTS is goal driven with private industry leading the design solution, not NASA. This difference is hoped to provide NASA with acceptable, but lower cost solutions and on a timely basis. For industry, this approach allows them to develop systems which are less customized for a particular NASA mission and thus potentially capable of serving multiple commercial and government markets.

In creating COTS, NASA officials considered and debated many different mechanisms and approaches to achieve the desired results. CRADAs were considered, but found to be less flexible than a SAA and also suffered from an inability to fund the private entities directly. NASA decided to use a funded Space Act Agreement (SAA) to make the investments as this would utilize an existing funding vehicle and give NASA the structure to fund on a milestone satisfaction basis with sufficient oversight of milestone progress and achievement. It was also decided to add financial and not just technical milestones. The use of an SAA also had the added benefit, from the perspective of private investors, of not being an investment in the traditional sense of purchasing equity or debt securities. Therefore NASA's development support did not dilute the equity investments of the private companies nor create debt burdens for them to repay with interest before investors could achieve a return on their investments. Using the SAAs, however, involved the separation of the COTS development support and the award of service contracts for ISS. The service contracts would be determined by the ISS office and open

to non-COTS companies. The two COTS participants were ultimately chosen, but Planetspace, for instance, did seek a commercial cargo contract from the ISS office and complained when they were not selected.

A decision making process was also required and it was decided to use a competition as the best way to gain externally driven commercial solutions in an accelerated decision process. The Procurement Development Team (PDT) set up a very economically staffed project office and competition team. Part of the streamlining of the decision process was the ability the competition structure provided to do due diligence on proposals by meetings with the proposers versus submission of written questions and answers. An outside venture capital firm was brought in to advise NASA on the relative merits of the competing proposals business models versus technical solutions. Lastly, an independent Board was used to make the final evaluations and select the winners.

NASA officials had originally considered requesting a larger amount of funding for COTS to either support more contract awards or provide more funding per contract awardee, but ultimately decided to request $500 million from Congress for COTS which it was allocated. At this funding level, it was decided no more than two companies would be selected as to spread the financial resources any thinner would threaten the goal of providing sufficient funding support to allow the awardees to complete development.

C3PO manages COTS partnership agreements with U.S. industry totaling $500 million for commercial cargo transportation demonstrations and is investing $50 million towards commercial crew development initiatives. Additional budget for commercial crew has been requested by NASA for future years and is pending Congressional approval.

While COTS and Commercial Crew have specific purposes, the basic strategy, investment and contracting concepts could be applicable to other NASA goals, applications and mission objectives.

Notable uses and successes: So far, the COTS and Commercial Crew programs are the first applications of this new NASA strategy. The COTS program attracted numerous serious contenders from which six semi-finalists were chosen to compete for two program awards (SpaceX and RocketplaneKistler, later replaced by Orbital Sciences). The intensity of the competition for these awards and the willingness of the winners to invest considerable sums alongside NASA represent a certain degree of success. It also suggests similar COTS type programs may be equally well received in the future. The successful inaugural launch of SpaceX's Falcon 9 rocket represents a more visible and profound degree of success and probably exceeded the expectations of many at NASA and in the government.

As to failures, there was the trouble with Rocketplane Kistler (RpK) who, as an initial COTS awardee, missed its financing milestones. In hindsight, the selection process may have assigned too much credit to the $860 million previously invested in Kistler's K-1 vehicle and underestimated the difficulty RpK would have raising sufficient private capital to complete development. The K-1's reusability feature drove higher costs than an expendable rocket and with roughly the same level of COTS funding support and ISS contract potential the investment case was harder to close. At a materially higher level of COTS funding support, completion of RpK's private financing might have been possible. Still, if the strategy of commercialization is to take "baby steps" where possible then jumping to an RLV for ISS cargo delivery might have been too large a first step.

However, it is hard to fault NASA for the selection of RpK as the whole point of a COTS like program is for the government to specify the service and let industry figure out how to skin the cat. It should also be noted that the structuring of the COTS contract to include financial milestones, and to remove RPK before too much energy and funding was expended on a failing effort, is actually a NASA success that should be identified as such.

Commercial Crew is at an earlier stage, but has attracted significant interest and private capital. The fact that a COTS type program was sufficient to attain this level of industry buy-in, despite the significant technology and regulatory challenges of manned space flight, is a testament to the merits of the program's features in lowering barriers to private investment. However, there is a divergence of opinion within the space community as to the appropriateness of a COTS type contracting model for commercial crewed services. Proponents argue that the added risk of manned flights is manageable and can be funded given a COTS style support program and related service contracts. Opponents tend to argue either: (1) the manned commercial space flight market is too small and uncertain, outside of ISS missions, to support the higher funding and risk levels associated with man rating vehicles and operating with enhanced regulatory compliance requirements and liability risks, or (2) the commercial space flight industry is too immature to engage in such activities with a sufficient safety margin and too weak to sustain an inevitable failure.

As for the first argument above, while we agree developing a man-rated vehicle is significantly more challenging and risky than pure cargo delivery systems, it is not a question as to whether or not the technologies exist outside of large U.S. aerospace corporations (Soyuz proves they do), but whether or not private capital will be made available in sufficient amounts to field a fully tested capability. The availability of private capital should ultimately depend upon the visibility of the end market and investors' confidence in the management and business models being utilized to control cost and schedule while achieving desired performance. Consistent and supportive government policy can go a long way to satisfying end market visibility. As for investor confidence, if

anything, the experience to date with COTS suggests a greater than normal ability for commercial best practices to outperform or at least match traditional contracting methods and suppliers in such metrics as cost control, schedule maintenance and flight success.

The second argument above is more difficult to dismiss. There have, after all, been two catastrophic Shuttle failures despite significant expenditures on safety. No rocket-based vehicle is immune to the risk of failure and any failure causing the loss of life would have major and lengthy impacts on a commercial crew provider whether for ISS crew delivery or for space tourism. Ultimately, the secret to enhancing human flight safety is to design systems focused primarily on human transport versus other missions like satellite deployments or cargo delivery, and then to learn and improve safety based on flight test data and operational performance. Commercial Crew seems to be adopting this exact philosophy. The only real analogy we have to guide us is the development of the commercial airline industry. As with that industry, commercial crew must now take the lessons learned from the space equivalent of the barn storming, wing walking, military test pilot stage of air travel to create a "safe enough" early era of commercial spaceflight.

Relevance to overcoming barriers: Although some of the key features of the COTS program may have come about more by necessity than design, the combination of features seems to be working quite effectively. When one refers to our risk matrix, there are in fact features of the COTS program that address every risk category.

Technology Risks:

- Significant funds for technology development, manufacturing tooling and facilities
- NASA technical assistance reduces risk with no added costs
- NASA technical milestones and oversight supports private capital investment decisions
- NASA experts selection of technical solution reduces obsolescence risk as they are aware of merits and timing of competing technologies

Market Risks:

- NASA acting as major anchor tenant with billions of dollars of service contracts.
- ISS need for cargo delivery perceived strong enough to overcome normal political risks.
- ISS market is already there, does not need to develop.
- ISS market need deemed stable for at least medium term.
- ISS cargo needs and flight rate relatively well known.

Financial Risks:

- $500 million split between two companies provides meaningful reduction of capital to be raised.
- COTS milestones aligned with development program such that private capital can be staged alongside NASA funding support rather than required all up front.
- Existence of large service contracts improves private investors' ability to achieve liquidity and exit the investment, provided systems are operational.
- While material cost overruns and schedule slippage can still occur, NASA having skin in the game provides a different dynamic than a customer focused purely on technical design specifications and performance.
- Since COTS funding is in the form of a SAA and not a purchase of equity or debt, any returns on total dollars invested accrue to the private capital and the potential downside risk is limited to a smaller total private investment.

Competitive Risks:

- Limiting the ISS service contracts to two companies left both with roughly half of a very attractive market.
- COTS firms were restricted to U.S. entities thus removing the threat of competition from international firms, some of whom may have received comparable or greater support from their governments or been subject to lower levels of political, regulatory and/or liability risks.
- Limiting the COTS awards to two companies created a high barrier to competitive entry by a new participant for the foreseeable future, as any stand-alone competitor would need to achieve comparable returns for its investors on a probably larger private investment while meeting the pricing determined by the COTS companies.

Political/Regulatory Risks:

- NASA's skin-in-the-game provided some comfort to investors on political risk of policy and budget changes as did the perceived critical need for service to ISS.
- Regulatory risk involves other agencies like FAA and State Department (ITARS), but NASA involvement perceived as helpful in creating a friendly environment for commercial space flight.
- NASA does not have same degree of mission assurance and safety oversight as with a government-owned system and does not control liability and indemnification coverage requirements, but its involvement as customer and its oversight during system development is viewed as helpful versus a completely stand-alone commercial spaceflight service.

Perception Risk:

- The magnitude and continued progress of COTS is serving as an early example of NASA's commitment to relinquish control of certain space activities and to work in new ways with private industry to achieve large scale goals.

Execution Risks:

- NASA's technical due diligence and the external VCs business model due diligence on COTS contenders provided expert opinions as to the merits of the business plan and the management team's ability to successfully execute it with projected levels of capital.
- NASA technical support could be helpful in reducing temporary unavailability of necessary technical staff required to execute development program.

Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	High
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	High
Market: Size	Moderate
Market: Quality and reliability	Moderate
Market: Development timing	High
Market: Longevity	
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	High
Financial: Time to Exit	Moderate
Financial: Uncertainty	High
Financial: ROI hurdle	High
Competitive: Amount of competition	High
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	Moderate
Perception	High
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	Moderate
Applicable to:	
LCRATS	Yes
CISS	
SpaceLab	
Lunar/NEO	
CASPER	

Options for improvement: We do not have many suggestions for improving the COTS-type process other than perhaps funding a modestly larger project team to enable some effort on (a) looking at ways NASA can help develop the commercial side of the market, (b) utilizing its facilities and buying power, and (c) otherwise enhancing interfaces with relevant NASA centers and directorates. Each new project and mission at NASA could benefit from a dedicated group to systematically focus on technology sharing and finding overlaps between NASA needs and commercial solutions (i.e. Private Sector Cooperation Initiative).

There is a concern within the commercial space community and even within parts of NASA that COTS was allowed to move forward in Congress only because it was a relatively modest level of funding and did not threaten any major existing contracts with the aerospace industry. There was thus no strong push back from the aerospace industry or heavy lobbying against COTS. Commercial cargo to LEO was also a somewhat benign way to meet President Bush's 2004 directive to use commercial space "when possible" and satisfy Administrator Griffin's strong support for beginning the process of commercialization.

Other, more challenging, applications like commercial crew may have a rockier path to commercialization.

To alleviate potential discord within the space community **we suggest NASA, the Administration and Congress agree on a public policy as to what types of applications will be considered and supported for commercialization and on what time frame and how applications not currently deemed appropriate for commercialization will be periodically reviewed for consideration.** Ideally, this policy would be part of a long term technology road map supporting NASA's science and space exploration objectives.

To this end, following the Augustine Commission Report, we published an article in September, 2009 on our website (www.nearearthllc.com) suggesting one possible metric for forming these commercialization decisions. The selection process involved three considerations, but in hindsight we should really have added fourth and fifth factors as included below:

(1) Is the mission/application manned or robotic and how intense is the technology challenge?
(2) Is the mission/application far (e.g. Mars) or near (e.g. LEO)?
(3) Does the mission/application involve a deep or shallow gravity well other than escape from Earth's gravity?
(4) Are private industry and investors ready to accept appreciable levels of risk in commercialization versus cost plus government contracting?
(5) Can private industry provide such services or accomplish such missions in a manner that increases overall value to the U.S.?

7 New Initiatives

7.1 Tax Incentives

Tax incentives have been used effectively in the past by the U.S. Government (and other nations) to increase R&D investment and to promote development in industries important to the nation. We believe tax credits can be an important and taxpayer efficient tool in supporting commercial space development. However, it may be challenging to get them approved in today's challenging economic environment given tight Federal budgets. We are also concerned that having NASA seek special tax treatment for the space industry at this time could expose it to criticism that could effect Congressional deliberations on NASA's budget, especially in regard to commercialization. All proposals regarding taxes must be budget neutral and, under budgeting rules, must have offsetting increases elsewhere in the budget to pay for decreases in one area. This is where the problem may arise. Easy offsets may be hard to come by and one person's general public good is another's special interest give away.

7.1.1 Zero-G / Zero Tax, Tax Holidays & Tax Deferrals

Overview: Here we refer to programs that provide tax relief to commercial space ventures, by specifically exempting them from taxation on a permanent or temporary basis. Many ideas have been presented under the banner of Zero-G, Zero-Tax, with the goal of signaling to the market the government's interest in the development of space. Such programs would enhance financial returns by boosting after-tax income.

Relevance to overcoming barriers: The main direct effect of tax relief for space industries is to enhance the economics of investment for those projects already profitable or expected to be profitable. This makes it more directly relevant for later stage ventures which are already in the position to be paying taxes. In an indirect way, however, an announced tax policy favorable to the space industry would be a very significant signaling mechanism to the market that the government is serious about promoting space development.

Options: In our conversations with entrepreneurs and capital sources, they have repeatedly indicated that having to pay taxes is "a high class problem" that only occurs long after a venture has proven profitable. They are far more focused on lowering risks that could cause them to lose some or all of their investment. We also note that under current tax law startup loss carry-forwards provide substantial tax shielding for early stage space ventures, which are the ones that private capital is most averse to funding. Thus, any benefits from lower tax rates or tax deferrals are highly "backend loaded" and provide benefit only after carry-forwards have been exhausted. As such, we believe that even if lower tax rates, tax holiday periods and tax deferrals were constructed specifically to assist the space industry they would have little impact on attracting private capital to the types of projects most requiring government support.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	High
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	

7.1.2 Tax Credits

Overview: Tax credits are used today in a variety of industries such as alternative energy to encourage investment. These credits provide tax paying entities with tax savings that boost their financial returns. Credits that are not refundable reduce current tax liability dollar for dollar and typically carry forward to reduce future tax liabilities if they are not completely used as they accrue. Refundable tax credits result in a cash payment to the entity when it files its return. This immediate liquidity can be viewed as a form of financing to the firm.

Relevance to overcoming barriers: Tax credits mostly lower financial hurdles to attracting early stage private investment by providing investors with a tax benefit they can use in the year of investment to lower their total exposure and improve their projected returns on investment.

Options: Tax credits that are immediately usable, transferable and/or refundable have recognized value to investors in that they reduce downside risk immediately and also enhance the upside return. Implementation requires special legislation which may be difficult to achieve without easily identifiable offsets elsewhere in the Federal budget. Defining which commercial entities qualify for the tax credits can also be a challenge. **We suggest NASA consider supporting tax credit legislation with a goal of achieving a broad based program relevant to all priority commercial space applications regardless of the State or region of the qualifying company.**

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

7.1.3 Flow-through Shares

Overview: Flow-through shares (FTSs) are a tax advantaged type of common shares typically offered by publicly-traded issuers in industries involving heavy up front expenditures and risky development and exploration (sounds like commercial space). Canada allows certain corporations in the mining, oil and gas, renewable energy and energy conservation sectors to issue FTSs to help finance their exploration and project development activities. The purchaser of a flow-through share is permitted to deduct up to the amount of the original purchase price of the share against qualified expenses renounced by the issuer. Since the corporations issuing FTSs are in a non-taxable position and do not need to deduct their exploration expenses, they flow these expenses and tax deductions on to their FTS holders.

These deductions allow investors of FTSs to shelter pre-tax income in the year of the flow through and thereby provide tax benefits to investors that would otherwise go unused by the issuing corporations for many years, if ever. The use of FTSs has greatly expanded investment in these industry sectors. FTSs come in two types: (i) Regular, which has the up to 100% deduction for flowed through exploration expenses, and (ii) Super, which have all of the tax attributes of Regular FTSs plus refundable Federal tax credits. These tax credits reduce taxes payable directly versus just sheltering pre-tax income and can even result in a cash refund to the extent no taxes are otherwise owed. Canadian Provinces have also added their own tax incentives to FPSs to encourage industry development in their areas versus other Provinces. FTSs also typically involve holding periods (e.g. 18-24 months), but despite this reduced liquidity they tend to trade at a premium to normal common shares given their tax attributes.

Here is an example for an individual investor buying Super FTSs based on either British Columbia's and Ontario's Provincial tax rates.

		British Columbia	Ontario
Combined tax rate	A	43.70%	46.41%
Federal tax rate	B	29.00%	29.00%
Provincial tax rate	C	14.70%	17.41%
Federal tax credit	D	15%	15%
Provincial tax credit	E	20%	5%
Amount of investment	F	$1,000	$1,000
Less: federal tax deduction	F x B	(290)	(290)
Less: provincial tax deduction	F x C	(147)	(174)
Less: federal tax credit	G=F(1-E)xD	(120)	(143)
Less: provincial tax credit	H = E x F	(200)	(50)
Add: tax on inclusion of fed credit	G x A	52	66
Add: tax on inclusion of prov. credit	H x A	87	23
Total tax benefits		(618)	(568)
Net cost of investment		**$382**	**$432**

Relevance to overcoming barriers: As the table above highlights, the use of flow-through shares, especially the Super variety with Federal and State tax credits attached, can substantially reduce the net investment made by investors in companies experiencing heavy development expenses. Such an investor can experience a significant subsequent loss of value on the underlying equity investment and still not lose money on an after-tax basis. Another way to look at FTSs is that they enable companies to access the deeper public capital markets available to C corporations without losing the income loss flow through attributes of a limited partnership or limited liability corporation. For commercial space companies doing business as LPs or LLCs, they will already enjoy much of these flow-through tax benefits, but perhaps not the extra tax credits. In addition, many investors in private equity securities are funds or endowments set up as tax flow through investment vehicles. FTSs, therefore, work best when applied to public companies issuing shares to tax paying investors. There are not presently many pure commercial space companies that would meet that criterion, although SpaceX could be an example once it completes an initial public offering.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	Yes

Options: We believe this could be an effective support mechanism, but it is limited to more mature companies that are publicly traded and that therefore already have ample access to capital. This structure is also subject to criticism that it is a special interest giveaway, but if there is political support to treat the space industry as a national priority, as Canada does with its natural resource industry, then flow-through shares are an excellent way to attract large amounts of private capital. **For the time being, we do not think NASA needs to legislation to create pass-through shares, however, there could be a period in the future when this support mechanism deserves another look.**

7.2 Credit Programs

Credit programs, as described below, will generally not be the best or most politically expedient method for NASA to provide support to commercial space companies, especially small, early stage and risky endeavors. However, in some cases the magnitude of risk capital required to achieve desired objectives will be outside the range likely to be supported by private investors. For instance, once an in-orbit servicing capability has been successfully demonstrated, and commercial demand has strengthened, there may be a strong business case for building a commercial business. However, if the total cost of getting into operation is billions of dollars there may be no investors willing to place that amount of capital at risk for such a new business (recall that, generally speaking, the higher the perceived risk, the smaller the availability of capital and the typical investment size). In such circumstances, the only path forward, other than a purely government funded and owned solution, may be to reduce the total cost of capital for the new business by providing significant credit support. In addition to lowering the total cost of capital, the credit support also greatly reduces the level of equity investment required by private investors to more achievable levels.

For NASA and the U.S. government, credit support also has the following important advantage: while in the case of a complete failure it will generally not matter whether the government support was in the form of a grant, an equity investment, a prize, a contract for service, tax credits or credit support as the dollar value of the loss to taxpayers may be the same, in the case of a successful project the taxpayers will have expended either no funds in the case of a guarantee or limited funds in the case of a subsidized buy-down of loan terms. Thus there is little difference for failures, but great leverage for taxpayers for successes. **We believe credit support is the most efficient way to leverage tax payer dollars for large scale, capital intensive space infrastructure and reusable launch vehicle projects.**

7.2.1 Loan Guarantees

Overview: Loan guarantees have been used previously to help finance many projects of interest to the government. Under the typical structure, some entity is established by the Federal government (e.g. MARAD for ship loans, OPIC for third world development, Export-Import Bank for export) to guarantee the principal and interest payments to creditors in the event of default, essentially stepping into the company's shoes. Because of the government's AAA bond rating, this greatly lowers the borrowing cost for the guaranteed debt, which is sold to banks or other commercial entities. In exchange for providing the guarantee, the government sometimes demands a cash fee or other compensation.

It should also be noted that the provision of credit support generally involves the lender receiving a secured interest in the assets of the recipient. In the event of a substantial failure involving a restructuring of the company, the lender may call the guarantee and the government could end up owning the company or all of its assets. To the extent, the government wanted to restart the project with a new commercial entity it would be in a position to significantly influence the outcome of such restart.

In addition, government loan guarantees will be scored independently by OMB/CBO according to the overall level of perceived risk. If the risk is substantial (approaching 50%-100% risk of loss), then a loan guarantee is no better than a direct subsidy as budgeting rules must provide for maintaining the capital to cover the risk-based expected subsidy implied by the guarantee (annual risk multiplied by the magnitude of the guarantee)

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	High
Financial: Time to Exit	Moderate
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	
CASPER	

Relevance to overcoming barriers: Loan guarantees represent the purest and most intense form of credit support. They also significantly lower the cost of debt capital for companies by completely eliminating the risk of default. By lowering the cost of debt, and thus overall financing costs, they also enhance equity returns which, in turn, make equity more attractive to investors. However, given that equity holders are at the greatest risk, and this risk is

magnified by high financial leverage, this cost benefit must be balanced against their overall perception of the project's chance of success. As such, loan guarantees have the greatest effectiveness where equity investors are comfortable with the overall risk profile of the projects. This may apply more to strategic investors and a small group of experienced private equity firms rather than to typical institutional investors.

Options: Restricting loan guarantees to projects of moderate risk makes more sense from the government's perspective as it achieves greater budgetary leverage. It is also important to use discipline in providing loan guarantees to reduce the risks of embarrassing defaults that can result in political challenges to future guarantees. Further, we would suggest that the government consider extracting additional value when it agrees to provide loan guarantees. For instance, if the project is successful there should be some mechanism for the government to participate in the upside it has enabled. One way to accomplish this would be to require equity warrants (with the in-the-money value of the warrants paid to the government in cash upon exercise rather than the government receiving stock and dealing with ownership issues) from firms receiving loan guarantees. The purpose of capturing some of the potential upside is not for NASA or the Federal government to make a "profit," but to better compensate taxpayers for assuming the default risk and using such additional compensation to help secure the long-term sustainability of the loan guarantee program. In the absence of such a mechanism, the inevitable defaults any such a loan guarantee program would face could eventually drain it of its original Congressional funding. That would then require renewing Congressional approval and appropriating new funds for what would look like a failed program regardless of its successes. With such an additional funding mechanism, the loan guarantee program might eventually become self-sustaining. Lastly, we do not suggest NASA consider managing a loan guarantee program itself, but rather seek enabling legislation at the appropriate time in the future to establish something similar to the Overseas Private Investment Corporation (see below).

We also note that once a business becomes "established" the risk of default, and thus the need for the guarantee becomes greatly reduced. In this instance, "established" could refer to financial metrics such as EBITDA/debt service ratios. **When granting loan guarantees, the government may also want to require sunset clauses to the guarantees once the companies become established. This would eliminate further government exposure to a loan default should the company's prospect reverse after having achieved a level of sustainability.** Government guarantees should only be used to help companies reach self-sufficiency in their financings, not continue to provide them below market financing rates. Another similar mechanism would be to reset the loan interest rate to more market terms once companies become established. If the borrower is thereby subjected to market interest rates the government is more likely to have the loans it is guaranteeing repaid or refinanced.

7.2.2 Subsidized loans

Overview: Loan subsidies involve payment by the government of costs associated with loans sold into the private finance markets. These payments can include portions of the interest or other fees. Unlike guarantees, the potential government liability is capped at the amount of the agreed upon subsidy.

Relevance to overcoming barriers: Subsidizing loans mostly addresses the magnitude and timing of capital needs for front-loaded capital intensive projects. More directly, it also addresses the cost (e.g. interest coverage and other expenses) of a large financing as it relates to an early, pre-revenue company that would otherwise be able to service the debt at the terms presented by the capital markets at the time of financing, alleviating concerns of investors in the short term. This can be useful if there is no other alternative than to bear the financing costs for a particular group for a critical piece of unique infrastructure.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	High
Financial: Time to Exit	Moderate
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	
CASPER	

Options: Subsidized loans are simply a less complete and less costly form of credit support compared to loan guarantees. The same policy standards and benefits therefore apply only to a lesser extent. For instance, because subsidized loans involve the payment of a subsidy rather than assuming default risk, the potential loss to NASA is significantly lower. This is therefore a weaker form of credit support and may not be as effective at attracting debt capital from private lenders. We note also that loan subsidies always cost the government money, while loan guarantees that are not used cost the government nothing. Thus, and as noted in that section, loan guarantees are more appropriate for relatively less risky projects than subsidies. **We do not believe loan subsidies are very useful except for rare circumstances.**

7.2.3 Federal Financing Bank

Overview: The Federal Financing Bank (FFB) is a government corporation, created by Congress in 1973 under the general supervision of the Secretary of the Treasury. The FFB was established to centralize and reduce the cost of federal borrowing, as well as federally-assisted borrowing from the public. The FFB was also established to deal with federal budget management issues which occurred when off-budget financing flooded the government securities market with offers of a variety of government-backed securities that were competing with Treasury securities.

In essence, the FFB, which borrows from the Treasury, ensures that companies (and agencies) with guarantees are able to find financing on the market. As only the government can issue risk-free guarantees, the FFB provides a government backstop in case the private market does not lend on a government project. Examples of recent use have included financing of energy projects and utilities under Department of Energy guarantees. This method was also used by NASA when procuring the TDRSS system when it leased capacity from SPACECOM. The government paid lease payments were used to finance a federal government guaranteed loan which was procured from a federal government agency. In this instance, only the contractors were private entities.

Relevance to overcoming barriers: The FFB mechanism is similar to other credit programs, except that it eliminates the risks associated with approaching the private capital markets. This is useful during times when the credit markets are functioning at considerably less than optimal conditions.

Options: FFB is a financing backstop for projects of government priority and for which all other financing methods are either infeasible or politically unpalatable through the budget process. It is also an alternative, but very similar to, lease-to-purchase methods (see sections below). **Given the negative disposition of budgetary authorities towards using this method, especially for situations involving considerable technical and execution risks, we do not believe use of the FFB is a good option for the government as the means through which credit support would be provided to commercial space entities.**

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	High
Financial: Time to Exit	Moderate
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	
CASPER	

7.3 Alternative contracting

7.3.1 Advanced Purchase Commitments (APC)

Overview: Under an advance purchase commitment (APC) scenario, the government agrees to purchase a significant portion or even all of the capacity (at least initially) of a service or product. The APC can be achieved through a traditional contract, in some cases, and through Space Act Agreements where FAR restrictions are problematic. Ideally, APCs should be at a level that is sustained over a period long enough to partially (for dual use cases) de-risk the project enough to encourage private investment. APCs have been established in the past for space facilities (as in the case of SPACEHAB) and as part of data buys for sensing platforms (Seawifs, GeoEye, DigitalGlobe), as well as for ISS commercial cargo delivery.

APCs are viewed by the Federal government as a form of lease-purchase (see next section) albeit in reduced form and implicitly recognize the importance of non-government customers alongside the government commitments. Although it is considered a buy-now, pay-later mechanism, an APC is viewed as an effective method of reducing market uncertainty, provided technical and execution risks are addressed.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	High
Market: Development timing	Moderate
Market: Longevity	Moderate
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	

Relevance to overcoming barriers: As mentioned above, the primary barrier overcome by an APC is market risk. The commitment also serves to signal to the market NASA's support for a particular area, which greatly affects perceptions

Options: In our discussions with funding sources and entrepreneurs, revenue visibility was repeatedly cited as a strong risk factor. To the extent that NASA can serve as a major early customer for a project it can be very helpful in securing private capital. This is particularly true when there are dual use (i.e. non-NASA) applications, in which case the APC serves both NASA and commercial parties though sharing of fixed costs. **Working with industry, NASA could identify additional procurements where NASA's requirements can be structured**

together with industry to devise a product or service that can appeal to both. These requirements could then be built into standard contract requirements issued by NASA under FAR part 12. As an example, if NASA wants to procure in-orbit services for its own use, and an FSS company wants in-orbit servicing for its own use, if these uses can be reconciled by discussions between NASA and the FSS company, then NASA could consider writing its requirements so they are compatible with both uses. Then, bidders will be able to consider a larger addressable market when developing their responses and bid more aggressively, with savings that accrue to both NASA and the commercial satellite industry.

7.3.2 Lease to purchase

Overview: Lease to purchase is an alternative method of acquisition of certain assets which are intended principally for government use. In this scheme, the government prearranges fixed yearly lease payments over a certain amount of time to a private contractor for the use of a certain asset. At the end of the payment period, the government formally acquires the asset. This method promotes the private financing of certain infrastructure. Potential applications could include the construction of in-orbit fuel depots, space station modules or other space complexes. Lease to purchase is a variation of Advance Purchase Commitment, with the main difference being government ownership at the end of the lease period and predominantly government use of the asset.

Relevance to overcoming barriers: A lease to purchase program for certain space infrastructure eliminates a large number of uncertainties to the contractor, in so far as the government is guaranteeing a complete market for an asset, without regard to competition over the life of the asset. This is very favorable to a commercial enterprise focused primarily on building and selling assets versus operating a continuing service business.

Options: Lease to purchase acquisition methods are not favored by current US federal budgeting practice. In cases where government is essentially the sole user of the asset, the net present value of the outlays are always higher than an outright acquisition. We do not believe that turning to this method of acquisition would be politically palatable. Moreover, government ownership at the end of the lease period is counter to the objective of encouraging more private participation in acquiring and operating space assets. **We do not believe this mechanism makes sense for NASA.**

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	High
Market: Development timing	Moderate
Market: Longevity	High
Market: Uncertainty	High
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	High
Financial: Uncertainty	High
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	High
Competitive: Nature of competition	High
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	
CISS	Yes
SpaceLab	Yes
Lunar/NEO	
CASPER	

7.3.3 Termination liability

Overview: Investors have long been fearful of the risks inherent in relying on any one particular government program or policy on which to support a business. While the government is a large customer, and reliable insofar as its ability to pay and do so on a timely basis, it is subject to shifting policy and budgetary pressures. Many programs have been cancelled before they ever started their service or mission and even those that do commence are subject to long gaps in service (e.g. the Shuttle after the Challenger and Columbia disasters) or outright cancellation. Investors in a capital heavy infrastructure project that depends on the continued participation of the government want better assurances of future payments.

Although one way to mitigate this is the inclusion of full commercial termination fees into the contracts, insurance for termination liability and political risk may also be necessary. For instance, as a condition of establishing a credit line with Chase Manhattan, SPACEHAB needed to procure a unique insurance policy to protect against the political risk that the U.S. government would cease Shuttle operations directly or terminate the contract with SPACEHAB. It has been suggested that NASA or a related entity should establish a more systematic approach to making such insurance available, similar to the international political risk insurance provided by the Overseas Private Investment Corporation for developing-country infrastructure projects.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	

Relevance to overcoming barriers: As mentioned above, this mechanism is principally focused on reducing policy risk as well as financial uncertainty.

Options: As discussed in the contracting section above, the ability of NASA to terminate contracts, leaving contractors saddled with large stranded investments is a powerful disincentive for attracting private capital investment. Using termination terms that are commercially based, addresses this concern. **In cases where commercial termination terms cannot be utilized, we suggest NASA consider covering the costs borne by private industry to purchase political risk insurance, as it did with SPACEHAB in the 1990s.**

7.3.4 Open IDIQ advance purchase agreements

Overview: One idea that has been suggested over the years is for NASA to agree to buy a specified amount of launch services to specified orbits from the lowest cost provider that has previously satisfied a specified set of requirements. For instance, for delivery of fuel to an in-orbit fuel depot, NASA could agree to purchase launch services in a given period of time (e.g. a 5-year period) for 1,000 pounds of fuel to a certain LEO altitude from the lowest bidder which has previously successfully flown the launch vehicle to be used in two prior missions and demonstrated a robotic docking ability. The way this differs from the Advance Purchase Commitment described above is that no specific supplier is determined at the time of the commitment and no specific amounts or dates are determined outside of contractually specified ranges. Any U.S. supplier meeting the contract's requirements can qualify to provide services under the contract and receive payment upon successful delivery. This form of commitment combines some of the features of the Advance Purchase Commitment with the advantages of traditional Indefinite Delivery / Indefinite Quantity (IDIQ) contracting. The government's total commitment is capped, but it does not have to specify up front who the supplier will be.

This style of contracting already satisfies existing Federal guidelines and would require no new legislation. However, for potential bidders to feel comfortable making the up-front investments to be able to bid on these contracts they will want a high level of certainty that there will not be a policy change in the future. Legislation binding the government to honor this open advance purchase commitment at a future date is one possible solution, however, an exception would have to be granted to the Anti-Deficiency Act to obligate future Congresses. The contracts would also need to include commercial termination provisions, especially as they may cover multiple launches over many years. Perhaps a more politically feasible solution would be for government to fund termination insurance for bidders demonstrating their qualifications and making capital investments, in this way no binding legislation would be required to guarantee future purchases.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	Moderate
Market: Development timing	
Market: Longevity	
Market: Uncertainty	High
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Relevance to overcoming barriers: An open IDIQ advance purchase agreements such as described above is

another way for the government to overcome uncertainties in the market, albeit in a way that more specifically targets it goals (e.g. reduced launch costs) as opposed to contracting with a specific entity from the start. Entrepreneurs who are more hesitant to work more closely with NASA seem to prefer this approach to supporting commercial space development. NASA offers the "pot of gold" at the end of the rainbow, promises it will still be there and then stays out of the way and lets the market compete to provide the service.

Options: We believe open IDIQ advance purchase agreements could be a powerful attractor for private investment for certain NASA needs and believe such an idea merits NASA's serious consideration, provided the required legislation can be approved. In general, we would think these types of purchase agreements would be most useful for NASA needs that are: (i) certain, (ii) recurring, (iii) standard, and (iv) span a multi-year period. It would not make much sense to use this contracting structure for less certain, infrequent, specialized and short-term needs.

7.4 Venture capital / direct equity funding

Overview: Discussions with people from Red Planet Capital and In-Q-Tel suggest that there are many companies that are very unlikely to participate in SBIRS, challenges, contract competitions and other NASA programs as their entire initial target market focus may be commercial with no government market aspirations or, in some cases, they may have an aversion to seeking government contracts and never approach NASA. Therefore, without a direct investment capability, NASA will not be able to reach many of the small companies that may provide new technologies, solutions and services important to NASA achieving its objectives. A direct investing program may also be an attractive alternative for overcoming the "Valley of Death" phenomenon of the funding gap that hits small companies after their capital needs exceed SBIR type funding levels, but are still too early and small to attract significant venture capital interest. In these cases, the purpose of NASA direct investing would be to act as a seed stage VC fund to bridge this gap.

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	High
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	Moderate
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Relevance to overcoming barriers: In addition to the benefits to the entrepreneurs seeking capital, such as substantially reducing financial uncertainty, we note that existing government venture capital efforts serve as an invaluable source of information about what constitutes the cutting edge technologies being developed outside the normal government development environment. This exchange of information could potentially help NASA identify new approaches to its mission.

Options: We believe some form of direct investing by NASA is very important as part of a comprehensive plan to support commercial space, but should generally be limited to smaller investments for technology development as opposed to larger investments for funding infrastructure development.

What follows is an overview and our considered opinion on four models of VC direct equity funding that have been proposed and/or implemented within technology-focused government organizations

(1) The NASA-inspired Red Planet Capital model
(2) The CIA-inspired In-Q-Tel model
(3) The US Army-inspired Onpoint Technologies model
(4) The ESA-inspired Open Sky Technologies model

7.4.1 Red Planet Capital model

We believe that NASA restarting a venture capital arm structured similarly to Red Planet Capital (RPC) is not its best option. While RPC was inspired in part by In-Q-Tel, had many similar features and sought to act as a strategic investment vehicle for NASA, its structure was somewhat different. It was decided that RPC would use more of a traditional VC fund format with management by a general partner from outside NASA. This was problematic on several fronts, including:

- RPC could not act like a traditional VC fund – where sole investment responsibility rests with the general partner and compensation is tied to performance. Instead, just as in the case with In-Q-Tel, RPC had NASA teams at relevant centers or directorates lead technical due diligence and they had to sign off on relevance to NASA before RPC could make an investment decision. As we suspect this dynamic will need to hold for any NASA direct investments, as it should, a general partner (GP) type management structure does not seem appropriate. Management compensation needs to be based primarily on satisfying NASA's strategic and technical development goals, not financial performance of investments.
- After an investment by RPC there would be a natural desire to manage the relationship to integrate the company's development with NASA's needs, again just as with In-Q-Tel, whereas a typical VC investor would be focused on maximizing the pure economic return of the investment regardless of the desires of any one potential customer. RPC was thus expected to act in NASA's strategic interest as opposed to the interest of a pure investor. While this works fine in an In-Q-Tel type structure it does not work in a typical venture capital GP / LP structure with LPs expecting fiduciary duty to maximizing financial value. While RPC had only NASA as its sole limited partner this was really a moot point, except as it relates to GP compensation as discussed in the first bullet point. However, it is our understanding RPC was actively seeking to add more limited partners either directly to RPC or into a similar or sister fund (see below).
- RPC was not funded up front like typical VC funds. Its investment capital was to be approved under annual budgets with no guarantee as to any future funding levels. RPC was therefore uncertain as to its ability to participate in follow-on

rounds to support its portfolio companies, a very important factor in traditional VC investment decision process. If annual funding is the political reality, trying to act like a traditional VC with a GP / LP structure will be very difficult.

- Given the very small initial budget, RPC was limited in the number and size of deals it could consummate. RPC, therefore, sought to raise additional funds from private sources and approached the same universe of limited partners that invest in non-government supported venture funds. We are told this created hostility within the VC community and resulted in lobbying that may have played a part in the government's decision to cancel RPC. Even if it had not been canceled, we suspect that funding activity would have alienated much of the VC community and reduced the deal flow RPC would have seen.
- RPC was building a nice pipeline of deals when it was cancelled, but had only completed one small investment. In that investment, ROC did not act as lead investor, but there was nothing other than its limited amount of capital that prevented it from acting as the lead investor. Even where RPC did not expect to be the lead investor, it sought to play a role in valuing the company and structuring the terms of the deal. RPC also wanted to receive the same securities for its investments as its co-investing VCs. Since NASA's objectives in making direct investments are more like that of a strategic investor with more than just financial returns in mind, we do not believe it should seek to act like a traditional VC and crowd out private capital by materially influencing deal terms and participating in a head's up fashion with private capital. Leading investment rounds also generally involves taking a major if not dominant leadership position on the Board. A NASA entity should never place itself in a lead or even highly active role in terms of corporate governance. Like In-Q-Tel, it should not seek to be the lead investor or even to drive the final valuation and deal terms.

7.4.2 In-Q-Tel model

The In-Q-Tel model has proven very successful in terms of helping to secure funding for companies important to the intelligence community. Since its inception it has completed investments with over 150 different entities and, with multiple investments per entity, has completed over 450 individual transactions. An important aspect of this success is that In-Q-Tel has organized itself as a strategic investor and not a venture capital fund. It primarily seeks returns on its "missions", not financial returns on its investments (although it has gotten that too). When it was begun in 1999, it tried to position itself as a venture capital firm, but that did not work. Instead, they are now the first call of any venture capital firm seeking co-investors and technical due diligence support and inroads to the government intelligence market. In-Q-Tel contributes a good deal of their success to the large amount of deal flow they see as a result of their investor friendly structure. Here is a summary of In-Q-Tel's investment process:

- Focus on companies with commercial overlap (i.e. they don't try to create new markets) and a technology or solution that is "near ready", meaning not at the research stage, but also not available off-the-shelf (typically 6-24 months from commercial availability).
- Conducts technical due diligence through interfaces with experts at relevant agencies. VCs are very appreciative of this technical due diligence support. In-Q-Tel does its own business due diligence using its staff (not the agencies personnel), but lets the VCs lead the valuation negotiation and deal structuring. They rarely invest in a company where their business due diligence is negative, but have on occasion held their noses because of serious interest from their agency "customers". In-Q-Tel can also decide to go it alone without VC co-investors, but that is not typical.
- Enters into development agreement with the company, providing $500,000 to $3 million for non-recurring engineering to accelerate development and/or add features important to the intelligence community. VCs see this as both early revenue for the companies, as well as paid development to open up an additional market.
- In-Q-Tel receives some securities of the company, generally in the form of equity warrants to acquire stock in the company in an amount equal to 50%-60% of the development funding. The terms of the warrants are generally driven by the valuation determined in financing negotiated between the VCs and the company. In-Q-Tel, therefore, rarely holds equity shares in the companies they support or have any shareholder or Board votes. VCs like the fact that In-Q-Tel is not interfering with their ability to maximize the value of their investment and believe the dilution to their investments represented by the warrants is fair compensation for the value In-Q-Tel brings to the table.
- In-Q-Tel also negotiates a purchase or licensing agreement up front with the company setting the price upon which its end customer, the relevant intelligence agency, will buy products or services when available. However, no purchase volumes are guaranteed. The technology transfer aspects are often the hardest part of the deal, but the companies and VCs generally find the effort worthwhile in that a large, high quality customer is added.

In addition to helping companies of interest succeed, a byproduct of In-Q-Tel's efforts is that the process of reviewing funding requests and working with entrepreneurs serves as a valuable two way information exchange. For the agency, it gains valuable intelligence on the emerging state of the art that would otherwise be difficult to access. For entrepreneurs, they gain better knowledge of the potential revenue streams that the agency and other government departments could provide – and can help identify how to optimize their product/service offerings to address these markets and how to sell into those markets.

We believe a strategic investment entity structured similarly to In-Q-Tel or using In-Q-Tel itself as the outward face of NASA's strategic capital efforts are NASA's best options for direct investment. The advantage to NASA establishing a single purpose entity is primarily one of control. Supporting NASA would be the sole purpose of the entity and NASA would get 100% of the entity's focus. The advantage to outsourcing the effort to In-Q-Tel is that NASA can take advantage of their years of experience and thereby accelerate an investment program. For instance, In-Q-Tel is currently providing this service for the Department of Homeland Security and its 22 non-intelligence agencies. In-Q-Tel has also expressed to us an interest in providing this role to NASA and would like to pitch the idea to NASA senior management. The reasons for NASA to consider using In-Q-Tel versus standing up an independent capability are:

- In-Q-Tel already has multi-year relationships with hundreds of VCs, universities and research centers that source deals for them across almost every area of technology. NASA can benefit from this established network.
- In-Q-Tel has experienced staff in place for general business due diligence, back office investment managing and monitoring, and technology transfer support.
- NASA professionals would still be in charge of technical due diligence and determining the relevance of the technology or service for NASA.
- Some NASA employees could be rebadged or seconded to In-Q-Tel for interface with NASA centers, directorates and headquarters.
- Sourcing of deals from inside NASA would still work in the same way regardless of whether In-Q-Tel is used.

7.4.3 Onpoint Technologies model

Onpoint Technologies is a publicly funded, privately managed venture capital firm that is strategically focused on technologies of interest to the U.S. Army, in particular mobile power generation, storage and management. It was founded in 2003 and endowed with initial government funding of $25 million, which has been supplemented by additional appropriations over time. Onpoint is managed under contract by Arsenal Venture Partners, which also operates a broader, more seed stage VC firm (i.e. MILCOM Technologies) focused on spinoffs from government labs and contractors.

From the perspective of companies seeking investment, Onpoint looks very much like any other venture capital firm. Onpoint targets investments of $500k to $2 million either by itself or more typically as part of larger rounds as big as $40 million in conjunction with other venture capital firms or strategic investors. Onpoint is stage agnostic, but given its investment size its participation in a funding round is largely symbolic except for small early stage rounds. It can and does lead and follow in investing in rounds. To date, the firm has invested in 9 companies.

Like In-Q-Tel, Onpoint's only invests in firms that are developing dual use technologies that are applicable to its mission but also viable in commercial markets. Unlike In-Q-Tel, we believe that most of Onpoint's investments are typically in securities identical to those that other VCs participating in the round are purchasing. This reflects Onpoint's management structure, which is implemented by conventional VCs under contract. Given its similarity to Red Planet Capital, many of the same disadvantages apply. **We believe that an entity structured like Onpoint is not NASA's best option for direct investments.**

7.4.4 ESA Open Sky Technologies Fund model

The Open Sky Technologies Fund is a model established in March, 2010 by the European Space Agency to enhance ESA technology transfer to new and emerging companies which require seed or growth capital. In this model, ESA has seeded a €15 million fund specifically devoted to investing in ESA Member State-located companies which substantially use some space technology in non-space applications or which are developing satellite applications for terrestrial use. There is no indication that the fund intends to invest in space services or in technology companies intending to sell into space or aerospace markets. The fund is managed by Triangle Venture Capital Group, an established venture capital firm with additional funds focused on investing in leading edge software and physical technologies. It will source investment opportunities identified through ESA's Technology Transfer Programme Office (TTPO) and its partners.

We believe that this structure is not NASA's best option for many of the same reasons discussed regarding the Red Planet Capital model. A couple of additional key points include:

- Open Sky is primarily focused on enabling technology transfer outward to non-space businesses, which is different from NASA's interest in bringing new enabling technologies inward to its own 'customer' base.
- Open Sky is primarily focused on non-space businesses or satellite applications, which is different from NASA's interest in enabling specific space services and technologies enabling space infrastructure.
- We believe that Open Sky's function can be served with existing or improved technology transfer mechanisms combined with non-government VC investments. Government involvement in what should be a role for private capital will crowd out private capital's participation in attractive opportunities.

7.5 Government guaranteed completion bonds

Overview: A completion bond gives the government the right to step in to complete full scale development if the commercial company has failed or cannot raise sufficient capital to move forward. The government can either take full ownership and manage completion or transfer the technology to a new commercial entity to complete the development. In either case, the burden of financing completion would be on NASA and would need to be incrementally budgeted. [Note: NASA cannot own or acquire launch vehicles for missions if there is a viable commercial launch service available. It can do so for purely R&D and testing of launch technology.]

Relevance to overcoming barriers: The primary advantage of a government guaranteed completion bond program is that it allows the existence of financings where financial risks (that is, the risk that the project will need significantly more capital from existing or other investors) is greatly reduced, as the government would ensure that the excess financing would be provided by them, were the need to arise.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	High
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	
CASPER	

Options: The major advantage of a completion bond is the "March-in Right". If NASA really needs the capability being developed and on a time critical schedule, such a right can be very valuable. However, in most cases the right to march-in and complete development is gained at the worst possible time and the completion may not be economically practicable. **We doubt if there would be many scenarios where it would make sense for the government to step-in and fund completion of a non-national security need.**

7.6 Space Authority

Overview: The concept of a "Space Authority" has been discussed for many years as a potential solution for the perceived need to have a non-profit organization outside of NASA and DOD to coordinate and manage the commercial development of space for the benefit of the entire nation. Similar "authorities" have existed at the State level for many years. The most active include:

- California Space Authority (1996)
- Space Florida (2006) the merger of three Florida space entities, including the Florida Space Authority (1989)
- New Mexico Spaceport Authority (2006)
- Oklahoma Space Industry Development Authority (1999)

Traditionally, a governmental "Authority" is given the authority to issue bonds to finance, construct, own and operate general purpose infrastructure with fees from the use of such infrastructure going to service the interest and principal payments of the bonds. Prominent examples of such "authorities" include the Port Authority of New York and New Jersey, the Tennessee Valley Authority, and municipal airport authorities. In these cases Authorities have been used either because it was too expensive for any one private entity to fund the infrastructure development or there was a governmental desire to provide common use infrastructure to enhance economic development and public services. Used in this traditional meaning, an Authority is the exact opposite of what NASA should seek to create as it involves government ownership and operation of key infrastructure versus commercialization.

The space-related Authorities mentioned above tend to serve a much broader purpose, but at least in the case of New Mexico and Oklahoma were mostly centered around the creation of State owned spaceport facilities for general commercial use. For example, the Oklahoma Authority can issue revenue bonds to build infrastructure and acquire property and lease facilities in order to create a licensed commercial space port. There was also a desire to promote STEM, attract high paying jobs and enhance the economic development and diversity of the State, but this was handled largely through parallel tax credit legislation.

In the cases of Florida and California, major spaceport facilities already existed when the Authorities were formed, as did a significant space industry presence in the States. For California and Florida, the stakeholders of interest were therefore much broader than commercial space interests and included military and civil space entities and representatives. The focus for these States was on retaining and growing a broad based aerospace industry versus a more narrow focus on fostering the commercial space industry. The stated objectives of these Authorities were to "foster growth and development of a sustainable world-leading space industry in Florida" and "to retain,

grow and create California space enterprises." The activities of the Authorities are therefore more extensive than in other States and include more general support, even funding support, for space enterprises rather than a focus on spaceport infrastructure. If NASA were to create a national version of a State Space Authority, it would most likely want to base such an entity on either the Florida or California models.

Space Florida: combines the Florida Space Authority with the Florida Space Research Institute and the Florida Aerospace Finance Corporation. It is an independent special district of the State of Florida created by statute to support, assist, facilitate and/or consult on space industry-related needs for:

- Attracting, retaining, and expanding aerospace-related businesses
- Arranging financial incentives such as State guaranteed or subsidized loans and tax credits
- Providing start-up and relocation support
- Providing financial and business consulting, including consulting on business formation, relocation and venture development
- Development of targeted infrastructure
- Workforce training and placement
- Research and Development
- STEM-related innovative educational programs, summits and conferences

The California Space Authority: Serves very similar roles as Space Florida, and acts as a policy adviser to the California Secretary of Technology, Trade and Commerce. It also represents California on space issues with the international space community, the Federal government, and other State and local governments. Specific functions include:

- Pursue grants from the federal government, private businesses, foundations, or individuals, for California space enterprise activities, including, but not limited to, studies, services, infrastructure improvements and modernization, and defense transition programs.
- Identify science and technology trends that are significant to space enterprise and the state and act as a clearinghouse for space enterprise issues and information.
- Develop and implement a state strategy for applying and commercializing technology to create jobs, respond to industry changes, and foster innovation and competitiveness in space enterprise.
- Provide information regarding the development of laws, regulations, decisions, or determinations affecting the economic and employment impacts of space enterprise in California.
- Provide recommendations for appropriate state funding mechanisms and amounts to promote development of space enterprise in California, including education and workforce development.
- Provide recommendations in the form of strategic planning documents.

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	Moderate
Market: Development timing	Moderate
Market: Longevity	
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	Moderate
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

- Review applications for, and promote, the California Space Enterprise Competitive Grant Program (funded $7.5 million to date).
- Manage the California Space Infrastructure Program ($8.5 million appropriated, approximately $88 million in space infrastructure projects have been completed)

Relevance to overcoming barriers: The relevance of a Space Authority to overcoming investment barriers is largely tied to the merits of having a single organization responsible for coordinating and managing most aspects of commercial space industry support. Having a Space Authority does not create or remove any of the potential support programs and activities NASA might consider, it simply organizes them under a single roof, a "one-stop-shop" for interfacing with private industry.

Options: While we like the idea of a broadly mandated central authority to manage the commercial support process, we have reservations about the use of the "Authority" concept.

- As discussed, the traditional usage of the term "Authority" applies to government owned versus commercial owned infrastructure. Even in the broader "space authority" usage the concept has generally centered around spaceport infrastructure. Government owned infrastructure support is the opposite of what NASA is trying to accomplish with commercialization. The use of the term "Authority" could therefore cause some confusion among politicians and voters.
- Authorities have also tended to be local or regional in scope, as opposed to national, with locally driven economic goals. We wonder how politically difficult it might be to create a Space Authority at the national level focused on broadly distributed economic benefits when so many prominent States already have Authorities focused on maximizing local economic benefits.
- In addition, a broad national space authority could crowd out private industry, constrain innovation and reduce competition to the extent it gains too much

power and influence to dictate national space policy and development. Any national entity serving the purpose of managing the space commercialization process would be organized under business principles rather than operated like a government entity.

- As importantly, the magnitude of financial support required to support space commercialization at the national level suggests to us the need for a more independent funding mechanism like a government trust fund or development corporation. This entity would be set up outside of NASA (but with close cooperation and communication) with a defined commercialization mandate. To the extent a reliance on annual appropriations, whether for NASA or a new space authority, can be reduced, there will be greater confidence among private investors in the political stability of the financial support for space commercialization.

7.7 Government Trust Fund / SPIC (like OPIC)

Overview: The purpose of a government trust fund is to establish a non-profit government corporation focused on achieving a specific set of national goals, generally focused on development of a specific industry or region. The corporation serves as the interface between the trust fund and private industry. It is subject to Congressional oversight, but is given operational flexibility to form more standard commercial relationships with industry than typical government type relationships. The trust fund is established with a large up front appropriation with the potential for future augmentation, as decided by Congress. These funds are used to cover administrative costs, but mostly to fund financial support for selected projects and businesses. Financial support can come in many forms, including, among others, grants, direct equity investments, and loan guarantees.

The goal of the corporation is to provide greater assurance to businesses regarding:

- Continuity of obligated funding;
- Commitment to management and business plans;
- Security in handling proprietary and confidential information;
- Private ownership of intellectual property;
- Shared benefits of the business ventures.

There is also the important goal that the corporation creates its own funding sources by charging reasonable commercial fees for its services, investments and loan guarantees with the ultimate objective of creating a self-sustaining source of private funding.

Overseas Private Investment Corporation (OPIC)

The closest analogy we can find to a government trust fund and corporation that might work for space commercialization is the Overseas Private Investment Corporation (OPIC). Below, we display OPIC's mission statement with a version replacing the overseas developing world concept with space commercialization.

- The Overseas Private Investment Corporation's mission is to mobilize and facilitate the participation of United States private capital and skills in the economic and social development of less developed countries and areas, and countries in transition from non-market to market economies.
- The Space Private Investment Corporation's mission is to mobilize and facilitate the participation of United States private capital and skills in the commercial development of space in transition from non-market to market based economic drivers.

The major similarity between OPIC and SPIC is the U.S. government's desire to foster growth and achieve economic benefits in a region in transition that private investors

find too risky for many needed investments. OPIC seeks to bridge this transitioning period by engaging in three core activities to support private investors:

1. Financing: provides medium and longer term financial support through direct loans and loan guarantees, subject to private equity investment representing 25% to 40% of total capital. OPIC charges a fee for these financings and screens opportunities to back credible management teams with good industry track records and sound business plans.
2. Insurance: provides international political risk insurance backed by U.S. government guarantee as well as engaging in co-insurance and re-insurance with private insurance carriers to increase coverage capacity for large projects. OPIC charges commercial fees for its insurance coverage.
3. Investment: invests in private equity funds dedicated to OPIC's developing world objectives through long term loans guaranteed by the U.S. government and sold to U.S. investors. Loans are typically 10-12 years in maturity and can be for amounts up to one third of the value of the equity capital committed to the private equity fund. OPIC is paid a fee for these investments and receives a small profit participation in the fund.

According to OPIC's website: "OPIC-supported funds are among the largest providers of private equity capital to emerging markets. Since the inception of its investment funds program in 1987, OPIC's funding commitments (as of FY 2009) have totaled $3.6 billion to more than 50 private equity funds. These funds in turn have invested $4.6 billion in over 470 privately-owned and managed companies, the vast majority of which are small and medium-sized entities, located across 53 developing countries that are eligible for OPIC support. The beneficial impact of OPIC's credit support of funds that invest in companies is significantly greater than the amount of capital that OPIC contributes directly to the funds: private equity direct investment creates a multiplier effect as new capital attracts additional investment and financing in companies." This magnitude of private investment is exactly what is needed for space commercialization.

OPIC also bases its support on additional criteria important to the U.S. such as: (i) U.S. control of supported entities; (ii) private sector involvement in financing; (iii) the project not being in a prohibited category; (iv) effect on U.S. jobs; (v) environmental impacts; and (vi) worker rights standards. SPIC would have a similar set of criteria such as, NASA's and the U.S. government's space commercialization priorities, job creation, STEM support, technological innovation, and international diplomatic relations.

Relevance to overcoming barriers: The example of OPIC provides a good roadmap for what the U.S. government can achieve in promoting large scale private investment in difficult markets for long term economic and societal benefits. The relevance of such a government trust fund and corporation to space commercialization is two-fold: (1) it

creates an independent entity to coordinate and manage much of the larger scale financial support, and (2) it creates a more politically sustainable funding source. However, we do not see an entity like SPIC as the be all and end all of space commercialization support. Its relevance is primarily for the "big ticket" projects versus earlier stage technology development and flight demonstrations. These less mature projects may be better managed with closer links to technical expertise within NASA.

Something similar to this was attempted in the 96th Congress (H.R. 2337). It was called the Space Industrialization Corporation (SIC), but was never enacted. SIC was designed to use Congressionally appropriated funds to make direct equity investments in private space companies to "promote, encourage and assist in the development of new products, processes and industries using the properties of the space environment." The legislation was contemplated during the euphoria of the early Space Shuttle days and looking forward to the capabilities of ISS. We think large scale equity investments from a government trust fund are politically unlikely and would compete directly with private sources of capital (see Red Planet Capital discussion). We believe other support mechanisms, such as those used by OPIC, that reduce risk to encourage private capital investments are more appropriate and sustainable politically. SIC is not the right model.

Options: We believe there is an important role for a government trust fund / corporation in space commercialization if it is designed like OPIC and focused on large scale financial support for more mature projects. For instance, we believe it is the preferred vehicle for providing credit support and loan guarantees.

A corporation like SPIC also provides the ability to charge fees and capture benefits of successful commercialization to cover the annual operating costs of the corporation and reduce the need for further annual appropriations. That way, any new requests for Congressional funding could be based upon demonstrated success. A corporation like SPIC would, of course, run the risk of defaults on the loans they make or guarantee, but having an organization like SPIC could provide the

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	High
Financial: Time to Exit	
Financial: Uncertainty	High
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	

government with focused expertise to make such decisions where credit support is a desired mechanism to support commercial space. The broader than purely financial criteria of SPIC could also increase political and public support.

A corporation like SPIC would also be an independent center of excellence for providing an interface between NASA, the private investment community and the developers of significant space infrastructure. Fully implemented, it would have the resources to source, evaluate, finance and oversee the development of large-scale space infrastructure developments with the backing of NASA's technical resources and expertise. We consider this an enhanced version of an In-Q-Tel type entity, where the organization takes on tasks beyond early stage strategic investment in technology companies and takes a pro-active role in large, capital intensive projects such as spaceport developments, on-orbit fuel depots, enhanced orbital microgravity facilities and privately operated telecom infrastructure beyond Earth orbit.

If something like SPIC could be established, it would be our preferred option of how to provide loan guarantees and other forms of credit support.

7.8 Super SBIR (e.g. Army's Fast Track Phase II SBIR)

Overview: The Department of Defense has implemented several programs that enhance the SBIR. The Fast Track program provides interim funding of up to $50,000 between Phase I and Phase II SBIRs and puts companies on an accelerated track for consideration of phase II funding. The more interesting program is the enhanced SBIR, which uses a matching fund strategy, similar to what we have suggested as an option for improving NASA's SBIRs, albeit at a lower overall funding level ($500,000). We believe the blending of public and private capital provides benefits to both parties, particularly at levels that can span the funding "Valley of Death".

Investor Risks	Focus
Technical: Developing new technologies	High
Technical: Manufacturing difficulty	Moderate
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	High
Market: Size	
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Relevance to overcoming barriers: While SBIR grants are demonstrably helpful in encouraging innovation, they often produce technology at TRLs that are too removed from the market to attract private capital. The use of larger SBIR grants can move select projects that are of relevance to NASA's mission to higher TRLs. At these higher TRLs, the risk to investors is lower and the funding to complete development is lower, making private investment more attractive.

Options: See SBIR section above for our options and suggestions.

7.9 Super Challenges

Overview: NASA's experience with competitions has been very successful despite extremely modest budgets for prizes versus the tasks required of contestants. We think there is a great opportunity for NASA to achieve similar results for larger tasks by offering commensurately larger prizes. If a $10 million X-PRIZE can inspire a Burt Rutan and Paul Allen to fund Scaled Composites and then upon award attract a Virgin Galactic strategic partner and ultimately $280 million of additional private capital from Aabar Investments for 32% of the company, a $875 million valuation in less than five years from award of the prize, then what might a $100 million or a $1 billion prize accomplish?

The difficulty appears to be the unpopularity of competitions within Congress and the requirement for the prize funds to count against NASA's budget in the year the contest is announced regardless of the probability of an ultimate winner. Making the prize awards far larger will most likely just make Congressional funding that much more difficult. The only way to lessen the budget impact is to get legislation that allows for annual OMB/CBO scoring of the probability and timing of award of the prize. This scoring would be based on NASA and perhaps third party assessments. For instance, if the assessment was that there was a 50% probability the $100 million prize would be won in five years or later and scoring specified a 10% annual discount rate, then the scoring for the first year of the competition would be $31 million. Without such scoring flexibility, it is highly unlikely NASA would even want to utilize truly large scale prizes, in example a billion dollars, because they would begin to represent a very material percentage of its total budget.

Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	High
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	Moderate
Market: Size	Moderate
Market: Quality and reliability	Moderate
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	High
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	

Relevance to overcoming barriers: The barriers overcome by Super Challenges are similar to those overcome by the current, smaller Challenges (see Section 6.11) although at a significant scale, a much larger Challenge will serve to reduce other barriers, such as the difficulties presented by manufacturing

and in-orbit operations. Large Challenges will inevitably focus on much grander challenges with greater difficulties but also more relevant to ongoing commercial service and operation in the space environment. They will also likely engage the energies of larger commercial entities, focusing their considerable resources on the presented task.

Options: We believe competitions can be an excellent way to spur competition and inspire innovation. The key question is for what applications will Super Competitions work? Extremely capital intensive development and space infrastructure projects costing hundreds of millions or billions of dollars will most likely be outside the scope of endeavors supportable by Super Prizes. Given the costs of competing at this level, we believe that private capital will generally not want to accept the large financial downside of losing the competition. However, technology development projects materially larger than typical Centennial Challenges costing perhaps tens of millions or a hundred million dollars to compete may be within the scope of Super Challenges. For instance, NASA's recent BAA in support of the GLXP XPRIZE competition could have been accomplished as a $30 million Super Challenge.

Another interesting alternative is to have NASA create Super Challenges managed by independent non-profit organizations which could attract tax-deductible donations to add to the prize pools. Donations could build up over time and earn interest until the prize was won. NASA's portion of the prize would be funded only upon success. This mixed public – private contest has the advantage of gaining the marketing flexibility of non-governmental organizations promoting the prizes and even seeking commercial sponsors.

We believe NASA should consider using the Super Challenge concept either as the second phase of a two phase challenge as described under Centennial Challenges or as a separate challenge conducted in coordination with private non-profit sponsors where matching private funds are involved.

7.10 Customer #1 Procurement Program

Overview: The idea of a customer #1 procurement program is that in space, no customer wants to be first. To help overcome this barrier, NASA could devise a program to specifically enlarge the pool of flight proven hardware. This program could be structured so that a specific pool of funds was available to NASA for the express purpose of acquiring unqualified flight hardware and testing it for future integration into planned missions.

Program Characteristic	Technology Demonstration	Customer #1
Technical challenge / cost	High, $10 - $150 million	Moderate, $5 - $50 million
Eligibility	Crosscutting benefits desired	NASA / commercial only
Mission infusion	Capable of rapid infusion	On technology roadmap
Demonstrations	System level only	Individual components

In cases where it can be done safely, this could be as a redundant operational unit in a satellite (e.g. an attitude sensor) where a conventional primary unit was used, as a hosted payload, or in high risk cases (i.e. where the new device could potentially harm the mission) on a dedicated validation mission used to validate large amounts of hardware. This program is a natural extension to the Technology Flight Demonstration program already run by the Office of Chief Technologist and is in effect a broadening of the applicability and loosening of the qualifications for such demonstrations. Above is a summary of how this program would differ from the current technology demonstration program.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	High
Market: Longevity	
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	Yes

Relevance to overcoming barriers: In many cases, we have spoken to entrepreneurs that have raised the TRL for their product/service as far as possible in the terrestrial setting, but need to be "space qualified" to gain market acceptance. By procuring a single flight article (i.e. serial #1) and placing it in an environment where it can prove itself in space under realistic flight like conditions (either as a primarily or redundant system, potentially as a hosted payload where appropriate, depending on risk) NASA

can significantly enlarge the pool of flight proven components, software and systems – with competitive benefits to the agency and commercial users alike.

Options: We believe the customer #1 concept has merit if implemented through a competitive bid process open to all where only systems and components that have not yet been space qualified are allowed to compete. NASA could then select the most technically sound and cost efficient solutions for procurement. The incremental cost to NASA for such a program would be limited since in many cases the items would need to be procured in the future anyway.

7.11 Stimulus Grants

Overview: Stimulus grants are outside the control of NASA, but we believe a persuasive case could be made to Congress and the public for allocating a material portion of any future stimulus packages (if any) to stimulate job creation in STEM and in particular the nationally important aerospace industry. The focus is too often centered on construction jobs to build infrastructure like roads, railways and airports. The jobs of the future our nation needs to stay competitive globally are not the blue collar construction jobs and very little new technology that can be reapplied in the future is developed in such programs – making any benefit short lived. Aerospace is one of the few remaining industries where the U.S. leads the world, but that lead is narrowing. Stimulus funds to support the aerospace industry would most likely flow through NASA and a few other agencies (e.g. NOAA, FAA, DARPA).

Relevance to overcoming barriers: The relevance is strictly one of having public funds available to make grants to accelerate development. The utilization of those funds would most likely flow through one of the other support programs described herein.

Options: As NASA cannot publicly advocate for such stimulus funds, it is difficult to formulate a suggestion and it may be a moot point anyway. **What we do believe makes sense is for NASA to work closely with the Department of Education to address the nation's serious STEM education problems.**

7.12 New COTS style programs

Overview: The object here is not to create a new support mechanism, but simply to reuse the structure utilized for COTS, especially when combined with the follow-on ISS service contracts. We are strong supporters of the COTS-style support structure as it addresses so many key barriers to private investment and reduces risk in an efficient risk sharing manner. The one critique we would add is for future COTS-style programs to have imbedded as part of the process, the selection process for the service contracts such that satisfaction of some advanced program milestone guarantees selection for at least some meaningful percentage of available service contracts.

Relevance to overcoming barriers: The investment barriers overcome by a new COTS-style are similar to the existing COTS program as managed by Commercial Crew and Cargo Program Office (C3PO). See Section 6.13 for an overview of that program.

Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	High
Technical: Obsolescence	Moderate
Technical: Launch & in-orbit operation	High
Market: Size	Moderate
Market: Quality and reliability	Moderate
Market: Development timing	High
Market: Longevity	
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	High
Financial: Time to Exit	Moderate
Financial: Uncertainty	High
Financial: ROI hurdle	High
Competitive: Amount of competition	High
Competitive: Nature of competition	Moderate
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	Moderate
Perception	High
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	Moderate
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	
Lunar/NEO	Yes
CASPER	

Options: We believe new COTS style programs could be particularly powerful in supporting significant technology development and space infrastructure projects where the development funding and potential service contracts provide enough inducement to close a business case and attract sufficient amounts of private capital to fund the balance of the project. Examples of potential uses include the various applications under in-orbit servicing where a capability has to be developed, demonstrated in space and then operated as a service business. At some point, when basic technology development has reached a higher level, LCRATS developers may also benefit from this support mechanism.

7.13 Free Flight Challenge

Overview: One of the "space truisms" that we have encountered is that "only if the cost of access to space were reduced" a thriving private commercial space industry would emerge. However, the experimental data to support this claim is limited – that is the demand curve for space access has to date only been determined at the high price points typical of space flight.

We envision that this program would consist of opportunities for free flights to space that would be given away to applicants via a competitive process. This can be thought of as an extension of the existing FAST program. In addition to FAST, we also understand CRuSR intends to offer such flight opportunities and the Space Operations Mission Directorate is planning a similar program focused on cubesats. We believe free flight challenges may have broader applicability within the NASA community, especially for applicants seeking to fly new (i.e. previously unflown) operational systems that provide a commercial service of interest to NASA. Selection factors could include the scale of potential benefits to NASA and other customers, potential revenues for the business, number of jobs the business can create, novelty or other factors. In many cases, the free flight will be available as extra capacity on a flight already procured by NASA. In some limited circumstances, NASA may choose to purchase new launch capacity to accommodate one or more free flight challenge winners.

Investor Risks	Focus
Technical: Developing new technologies	Moderate
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	High
Market: Size	
Market: Quality and reliability	
Market: Development timing	Moderate
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	High
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	
Competitive: Barriers to entry	Moderate
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	Moderate
Execution / Operating: Availability of talent	Moderate
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	

This program is intended for two purposes: first, to access real empirical data as to what new applications emerge for space when the cost of reaching orbit falls essentially to zero. The second purpose is to encourage the development of new space ventures that find raising the capital to access space to be prohibitive.

Relevance to overcoming barriers: Many writers have speculated that "if only we can get the cost of space access down to such and such" then new space industries will take off. Likewise, private investors have lamented that without proven demand, they are unwilling to risk the very large sums

likely to be necessary to drive down the recurring costs of space access. This program is intended to address the "chicken and egg" nature of the problem by providing essentially free access to space and calling the entrepreneur's bluff. At worst, it is likely to lead to the development of new technologies and business models that provide real value to consumers. At best, it could produce the proof of demand needed to attract private capital to make LCRATS a reality.

Options: We believe a "Free Flight Challenge" program where NASA would give away, via a competitive process, opportunities for payloads to fly in space has sufficient merit to justify NASA's serious consideration. The opportunities could include hosted payloads, spare capacity on launches that had already been procured or even dedicated flights that were specifically procured for the purpose of award under this program.

7.14 Non-monetary government considerations

Overview: The granting of valuable spectrum licenses and scarce orbital slots has been a very effective way for the government to help attract private capital to fund new commercial satellite industries such as satellite broadcasting, direct-to-home satellite television, satellite radio and a variety of mobile satellite services. In each case, the government has been able to use access to these intangible, but enabling assets as a gating mechanism to control the quality of the service providers and the level of competition. For instance, licensees generally have to meet certain satellite manufacturing milestones and launch dates as well as post multi-million dollar bonds. In some cases, the intangible government controlled assets have even been auctioned and for tens or hundreds of millions of dollars. In turn, possession of such intangible assets has proven to be a critical requirement for companies seeking to raise substantial private capital.

For the commercial space applications of interest to NASA, the intangible assets may involve more than just spectrum related licenses. The key factor is that they be important in establishing valuable property rights necessary to create reasonable barriers to competitive entry. They should not, however, be used to overly restrict competition, just to provide the licensee or property owner with enough collateral value to raise funds and create a sustainable business. Examples of potential intangible assets within the government's control include:

- Up and downlink frequencies for spacecraft performing new missions and applications;
- Operating licenses for servicing U.S. space assets in orbit;
- Long-term leases of launch or other NASA facilities;
- Long-term leases of ISS laboratory capacity or rack space; and
- Property rights or rights to excavate and remove materials from celestial bodies (e.g. Moon, asteroids).

Some of these intangible assets will involve other agencies such as regulatory bodies such as the FCC and FAA and others involving property rights may only be achievable with new international treaties. However, it is our opinion that no major new program of exploration and eventually settlement and commerce can be efficiently achieved without the creation of property rights. The New World was explored and settled largely by the granting or claiming of large tracts of land. The U.S. railway system was built largely off of massive grants of land from the U.S. government to railroad owners. It was these land grants more than the initial cash flows generated by the immature railroad industry that supported the bonds issued to finance the construction of the railroads. Even the airline industry, whose development often serves as a good analogy for the emerging commercial space industry, depended on the creation of new intangible assets for its success. Some of the most valuable assets held by airlines are their airport gates,

takeoff and landing slots and air routes, all created by pieces of papers from government bodies.

Relevance to overcoming barriers: To the extent that the granting of non-monetary considerations increases a market for those considerations, then it reduces that market risk. However, the most powerful effect of granting these rights may by providing market participants to accrue valuable asset coverage for their business. Moreover, in the long run, the perception of a 'gold rush' and the making of fortunes based on space assets may be the most effective way to change perceptions on opportunities in space.

Options: It is crucial in the coming decades that the issue of property rights in space be addressed; hopefully in a peaceful and international manner. Otherwise the pace of private investment needed to truly open up the "final frontier" will be unnecessarily delayed. While this is not a near term need to support NASA's current priorities, it will become increasing important as bigger private investments are required. What should not be allowed to happen is to treat Space like the continent of Antarctica or to allow an international situation like the contested rights to the arctic sea floor develop. There is a tremendous future opportunity to commercially develop Space outside Earth orbit and, for commercial development, investors and industry need property rights. **We suggest NASA consider commencing a formal internal process for forming its policy recommendations for the Administration and Congress.**

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	Moderate
Competitive: Nature of competition	
Competitive: Barriers to entry	High
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	
Perception	High
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	
CISS	
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	

In the near term, we suggest NASA consider other intangible assets of value it can create to provide collateral and scarcity value for attracting capital and creating barriers to entry. One example is to competitively offer or bid long term rights to ISS rack space for micro-gravity experiments (i.e. like airport gates for airlines). Similarly, you could also offer contractual rights to future scheduled cargo and crewed flights to ISS (i.e. like take-off slot for airlines).

7.15 Regulatory holiday

Overview: The removal or streamlining of government regulations for immature industry sectors has been known to promote growth and innovation within those industries. This is particularly useful where the standard regulatory regime is viewed as too burdensome for a sector composed primarily of startups or growth companies which cannot sustain the overhead necessary to comply with the regulations. It is also useful where the regulations are a direct impediment to activities which are core to this new growing industry (e.g. FAA flight clearances for suborbital vehicles), but where relaxing or removing them does not significantly endanger public health, safety and security. Most proposals for regulatory holidays for the space industry involve export control and waivers for liabilities for certain passenger duty of care responsibilities.

Relevance to overcoming barriers: The most direct effect of a regulatory holiday would, of course, be the reduction of the regulatory uncertainty associated with starting and operating any space business. We also believe that certain targeted reforms or relaxations will also reduce barriers to growing market size, either through cost reductions or reducing the red tape required of customers (e.g. passengers on commercial space vehicles).

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	Moderate
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	High
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

Options: Although NASA is not a regulatory agency, it can reach out to other US government regulatory agencies to seek regulatory relief in a couple of areas important to fostering growth and investment in commercial space.

First, in export control, **NASA could back industry and participate more publicly in the recent process to loosen ITAR restrictions.** The State Department is currently reviewing certain Categories of the Munitions List to reclassify or remove items on this list. Space components and systems on the Munitions List are expected to be reviewed in the upcoming months. **NASA could request, from its contractors and other relevant space participants, feedback on key items**

that, while not believed to be a national security concern, are critical to facilitating space commerce and then support the removal of such items from the munitions list. This could include loosening restrictions on systems such as suborbital spacecraft and servicing spacecraft. We believe this will effectively reduce regulatory risks and enhance the market for new space technologies and systems.

Second, we suggest NASA consider approaching the FAA regarding a process to modify regulations which govern the operation of commercial parabolic aircraft flights and how such regulations can evolve to allow private industry to match the abilities and capabilities of NASA-operated parabolic flights. This could be part of a larger process designed to create workable regulations for future commercial manned suborbital and orbital spacecraft.

7.16 Alternative budgeting

Overview: Under an alternative budgeting regime, Congress could appropriate funding for programs that match the time frame for the development cycles of these programs. Proposals have ranged from two year budget cycles, essentially appropriating a single budget for each elected Congress, to longer term, five-year budgeting for specific programs or sections of the Federal budget.

Relevance to overcoming barriers: The major advantage of eliminating budget uncertainty overall is that it increases the certainty on the overall direction of American space policy over a longer term. This is important for new businesses that seek to offer ancillary services related to a NASA program or policy direction (e.g. offering commercial lunar transportation logistics services based on a budgetary plan and administration policy to develop the lunar surface), project risk is reduced. Moreover, the increased longevity and decreased uncertainty of the government market increases the propensity of private capital to invest.

Options: While we believe that industry would appreciate the greater market certainty and revenue visibility provided by multi-year budgeting on the Congressional level, the effect on investment decisions for projects which depend on NASA as a primary customer would be marginal unless the budget period is similar to typical investment horizons (5 to 7 years). We are unsure how politically palatable this is, either as a part of overall US federal budgeting reforms or as a measure specifically designed for NASA, and since the benefits of greater revenue visibility must be weighed against the drawbacks in the loss in budgetary flexibility. **Thus, we do not believe this is an option worth NASA pursuing.** multi-year support can be better addressed through some of the other mechanisms discussed herein.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	
Market: Quality and reliability	High
Market: Development timing	
Market: Longevity	Moderate
Market: Uncertainty	Moderate
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	Yes
CISS	Yes
SpaceLab	Yes
Lunar/NEO	Yes
CASPER	Yes

7.17 Space access lotteries

Overview: The basic concept, as we understand it, is to use a nationwide lottery to raise public interest and perhaps money by offering one or more trips to space (e.g. ISS). This is an intriguing idea although it may be very difficult to pull off in practice and may be better handled by private ventures rather than government. The trip itself has considerable commercial value as has been demonstrated by recent space "tourists" paying roughly $30 million to go on a Soyuz spacecraft to the ISS. There should be considerable public interest and lots of publicity generated. Some tricky issues to consider include what restrictions to place on the winner, for instance: (i) health, (ii) age, (iii) citizenship, and (iv) past criminal record. A winner may also change their mind out of fear or wish to sell their ride to the highest bidder. It could be a much more complicated lottery than the typical "dollar and a dream" variety where you know the winner will take the money.

Relevance to overcoming barriers: NASA's participation in a space access lottery would principally serve to expand the market for space access upon the invested costs of its existing space facilities. To an extent, this also accelerates the development of the market and enhances perceptions. Additionally, the participation of the wider public in space access could be an excellent way of encouraging STEM education participation and attracting talent to space enterprises.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	Moderate
Market: Quality and reliability	
Market: Development timing	Moderate
Market: Longevity	
Market: Uncertainty	
Financial: Magnitude of capital required	
Financial: Timing of capital needs	
Financial: Time to Exit	
Financial: Uncertainty	
Financial: ROI hurdle	
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	
Political / Regulatory: Regulatory compliance	
Political / Regulatory: Treaties & indemnification	
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	Moderate
Applicable to:	
LCRATS	
CISS	
SpaceLab	
Lunar/NEO	
CASPER	Yes

Options: We do not think NASA should attempt to run any such lottery program. However, NASA could consider contributing seats it purchases on commercial vehicles and granting access to ISS and letting private groups run a lottery program. If NASA were to make this expenditure, what we think would make more sense is to have some or all of the winners chosen by public voting as opposed to a lottery style ticket purchase. Voting would be accomplished through online means, phone calls and text messaging as is done with American Idol, America's Got Talent and other contests. Specific categories for winners can then be chosen to maximize publicity for space travel and contestants can opt out if

nominated. Examples of categories for high profile individuals include: (i) actors, (ii) entertainers (e.g. singers, musicians), (iii) sports figures, and (iv) politicians. Trips should also be reserved for non-celebrities with categories such as (i) teachers, (ii) scientists/engineers, and (iii) space enthusiasts. For the non-celebrities the selection process should be something beyond random choice. Examples would include: (i) essay contests, (ii) computerized tests, (iii) YouTube clips, and (iv) a space boot camp. The overall concept is to maximize both public interest and public involvement with a blend of high profile individuals and Main Street America. Examples of companies that might be selected to run various contests include: (i) ESPN for sports figures, (ii) Sirius XM Satellite Radio for entertainers, (iii) C-SPAN for politicians, (iv) Teachers in Space for teachers, (v) Scientific American for scientists. It should be easy to find interested parties with great media access and web presences to run these competitions. But, again despite interest within NASA to consider such lotteries, we think they are best left entirely to the private sector, with perhaps encouragement and an authorizing mandate from NASA.

7.18 Bounties on orbital debris

Overview: The idea of targeted challenges or bounties on specific pieces of debris or unused spacecraft has been proposed as a solution to solving the fundamental issue of commercial orbital debris removal, that is, lack of economic incentive for private operators. The bounty model partially solves this problem by providing economic rewards for removing debris such that it becomes profitable for a private enterprise to engage in an ongoing debris removal business. This solution avoids specifying technical solutions to the debris problem and instead makes it a matter of competition where private enterprise delivers on solutions and is only paid once completion of each task is completed and verified.

Aside from significant liability and treaty issues regarding access and ownership of to third-party space assets, the major issues surrounding the establishment of debris bounties system concern the bodies that would oversee and finance the system. Suggestions for oversight bodies have included national space agencies, international bodies (such as UN COPOUS or the Inter-Agency Space Debris Coordination Committee) or consortiums of satellite operators or insurance underwriters. Fees charged to satellite operators on a per-satellite or per-kilograms basis has been suggested as a method of financing a bounty system that avoids recourse to taxpayer funds.

Investor Risks	Focus
Technical: Developing new technologies	
Technical: Manufacturing difficulty	
Technical: Obsolescence	
Technical: Launch & in-orbit operation	
Market: Size	High
Market: Quality and reliability	High
Market: Development timing	High
Market: Longevity	Moderate
Market: Uncertainty	High
Financial: Magnitude of capital required	Moderate
Financial: Timing of capital needs	Moderate
Financial: Time to Exit	
Financial: Uncertainty	Moderate
Financial: ROI hurdle	Moderate
Competitive: Amount of competition	
Competitive: Nature of competition	
Competitive: Barriers to entry	
Political / Regulatory: Policy & budgets	High
Political / Regulatory: Regulatory compliance	Moderate
Political / Regulatory: Treaties & indemnification	High
Perception	Moderate
Execution / Operating: Management quality	
Execution / Operating: Availability of talent	
Applicable to:	
LCRATS	
CISS	Yes
SpaceLab	
Lunar/NEO	
CASPER	

Relevance to overcoming barriers: Bounties create a clear and visible market for a service where once there was none, at least none that was clear enough or actionable enough for a commercial service to pursue it. Moreover, international agreement on the necessity of addressing the issues of debris through commercial services will serve to reduce the regulatory and international treaty and liability risks that are inherent in this problem, whether international parties agree to bounties or some other mechanism.

Options: We believe the bounty model for dealing with orbital debris is a very innovative and economically effective model and would enhance the addressable market for in-orbit

servicing solutions. However, verification, liability and treaty issues would need to be resolved as well as a means of shared funding. For the most part, these issues will need to be tackled at the international level as numerous other parties (including other national space agencies, commercial satellite operators and other US government agencies) have significant, if not greater, stakes in resolving debris issues. **If NASA wishes to advance this solution, the first step may be for NASA to propose it to relevant international organizations and publicly support it at industry forums.**

Secondly, we believe NASA could stimulate this discussion by proposing a limited challenge, starting with a single, publicly identified, piece of debris. This piece of debris should be one that was originally launched and developed under the auspices of NASA or DOD for which the U.S. government can release participants of any liability issues (resulting from sending a spacecraft to touch or service it). An award would be issued to the first U.S. party that can demonstrate that it has moved the piece of debris to a specified orbit. It would be particularly helpful if that debris is in geostationary orbit, which would make participation in the challenge of particular interest to parties already planning to develop in-orbit servicing missions for commercial geostationary satellites. **We believe NASA should study this concept and identify debris removal candidates and then seriously consider taking steps to initiate a limited challenge program.**