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Statement of
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President,
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before the

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Committee on Commerce, Science and Transportation
United States Senate

Mr. Chairman and Members of the Subcommittee, on behalf of the nearly one thousand employees of Space Exploration Technologies (SpaceX) located in Florida, California, Texas, and elsewhere in the United States, I thank you for the opportunity to appear before you today.

SpaceX was founded by Elon Musk in 2002 because he had the foresight and firsthand knowledge of how the United States was falling behind in terms of affordable access to space. As Mike Griffin pointed out to Congress in 2003, "we desperately need much more cost effective Earth-to-LEO [low-Earth Orbit] transportation for payloads in the size range from a few thousand to a few tens of thousands of pounds. In my judgment, this is our most pressing need, for it controls a major portion of the cost of everything else that we do in space. Yet, no active US government program of which I am aware has this as its goal."

When the Bush Administration released its Vision for Exploration in 2004, the decision was made to complete the International Space Station (ISS), retire the Space Shuttle in 2010, and acquire crew and cargo services to the ISS commercially and from our international partners. In order to ensure that NASA's resources would be focused on space transportation capabilities for exploration of the Moon and Mars, the policy explicitly stated that supporting the ISS would be "separated to the maximum practical extent" from exploration missions beyond low-Earth orbit (LEO). The policy of acquiring commercial crew and cargo services to the ISS has been reaffirmed consistently by NASA, in numerous authorization bills, and Presidential national security directives.

It is important for the Committee to note, that even had all of the ambitious goals of the 2004 Vision for Space Exploration been met, this country has long been on a path to dependence on the Russians —that is if and until commercial LEO services become available. Moreover, it is a matter of policy and law that the Constellation system of Ares/Orion be developed and optimized (from a technical and operational perspective) for returning to the Moon and beyond, not for supporting the ISS. Falcon 9/Dragon, on the other hand, has been designed and optimized to replace the Russian Soyuz system with an improved US capability, and therefore is much less complex and significantly less expensive than Ares/Orion.

SpaceX is grateful for all the support this Committee has provided for commercial crew and cargo services to date. As a fast-growing, entrepreneurial, US provider of launch services competing daily for both domestic and international business, having the support of Congress and the US government is vital to our success. This is a difficult business and we have come a long way in an unprecedented period of time. One of our key customers, of course, is NASA. I am pleased to discuss the new direction that NASA has opted to take in the proposed FY 2011 budget, specifically with respect to the agency's plans to rely upon "commercial" launch providers to develop crew delivery capabilities to LEO.

I understand the skepticism that the commercial space industry can succeed at manned carriage to the ISS within a reasonable timeframe, even with the significant support from NASA and financial investment proposed in the budget. I also understand that there are concerns about the safety of commercial vehicles. Today, I will comment broadly on these issues, with a particular focus on SpaceX's capabilities, timelines, budget, and approach to safety. To begin, however, I have two answers to questions posed by this Committee – first, in response to inquiries about the timing of commercial manned carriage, I can tell you that SpaceX firmly believes that we can be ready to fly astronauts to the ISS within three years after contract award. In response to questions about safety, I can tell you that SpaceX intends to be fully compliant with any and all safety standards set by NASA and the US Government.

"Commercial Space" Continues to be the Best Approach for Servicing the ISS

As a threshold matter, it is worthwhile to discuss what it means to provide "commercial" services to NASA for cargo or crew carriage. This can be a confusing term inasmuch as NASA and other US Government agencies rely upon the private sector for launch and other space-related service. Why are those providers not considered "commercial"?

Importantly, this is not new ground being plowed. The National Space Transportation Policy and various federal statutes speak to the national imperative to develop and rely upon a commercial space sector. In fact, as early as 1991, the "US Commercial Space Policy Guidelines" (NSPD-3) were adopted, which stated in relevant part:

> "A robust commercial space sector has the potential to generate new technologies, products, markets, jobs and other economic benefits for the nation, as well as indirect benefits for national security. Commercial space sector activities are characterized by the provision of products and services such that: private capital is at risk; there are existing, or potential, nongovernmental customers for the activity; the commercial market ultimately determines the viability of the activity; and primary responsibility and management initiative for the activity resides with the private sector."

In the context of the newly proposed NASA budget, there is a distinction made between past and future plans focused on "commercial" providers – this distinction would appear to turn on the factors above, as well as the nature of the contracting mechanism. Specifically, "commercial contracts" are firm, fixed-price contracts that require a provider to name a price and stick to it. Additionally, payments are not made until the milestone associated with that payment is demonstrated as complete. This is hardly a novel concept, but in the space world, it has become an outlier.

Commercial also necessarily means a singular devotion to safety and reliability for manned spaceflight because, by the nature of the business, providers must compete primarily on that dimension. As is true with respect to commercial aviation, businesses will fail unless safety and reliability come first, regardless of price point. The need for a laser-like focus on safety and reliability becomes even more acute when commercial space companies put their own financial skin in the game, offer services on a firm-fixed price basis against competing bidders (rather than cost-plus, "no-lose" contracts), and get paid in full only if they perform.

There are those who argue that it is unacceptable to rely upon "unproven" commercial rockets for manned carriage. This begs the question: should the Ares 1 be considered "mature" or "proven" by comparison? To date, there has been one test flight of the Ares 1-X (a four-segment solid rocket booster stage, with a fifth segment mass simulator, and an upper stage simulator) and America has invested over $8 billion in Constellation. That ratio of progress to expenditure is not particularly compelling given budget realities facing NASA and the country as a whole. And the Augustine Commission agrees that, unless NASA's budget increases dramatically, to continue along this path would be "unsustainable."

The notion that "unproven commercial rockets" would carry astronauts is an unrealistic concern by the critics of the new NASA approach. Critically, there will be many cargo test and operational flights of the Falcon 9 and Dragon before any crew flights. In addition, the demand for Falcon 9 to deliver satellites is high – at this time, there are 24 total Falcon 9 flights on the manifest. Of interest is that there are 10 of our Merlin engines on each Falcon 9. This provides a factor of ten demonstration of engine performance and life with every flight. I know of no other launch system that can cite this acceleration of life demonstration of its propulsion system. This is of great benefit to the crew program as it will leverage this accelerated spaceflight heritage.

None the less, if development problems arise, there are sufficient flights to provide the opportunity to resolve any issues well in advance of astronaut transport, which stands in stark contrast to the plan for Ares 1. Separately, the Atlas and Delta vehicles, with their long-proven heritage, would actually appear to be in the front-running for manned missions. My colleagues from the United Launch Alliance will address that proposition.

Safe and reliable domestic commercial transport of cargo, spacecraft, and astronauts to low-Earth orbit (LEO) will save US taxpayers significant money that can be put towards what NASA does best – pushing the frontier and exploring beyond LEO. The work must begin now, however, if the US means to reduce Russian reliance at the current cost of $51 million per astronaut (and going up, it would appear based on recent comments by Mr. Perminov). Achieving a timely return to LEO after Shuttle retirement using domestic providers of launch services would incubate a commercial space market and enable NASA to move forward with technologies that take us beyond low-Earth orbit.

The Proposed NASA Budget

The President's FY 2011 budget request includes a much needed increase to the agency's top-line over the next five years and includes many laudable aspects such as increased investments in earth science and aeronautics, an extension and increased utilization of the International Space

Station (ISS), and sustained research and development in potentially transformative technologies that should help alleviate the impact of job losses due to the successful conclusion of the Space Shuttle program and build the foundation for 21st Century solar system exploration. The budget request for exploration systems is $4.3 billion, which is up from $3.8 billion in FY 2010.

As you are aware, the Augustine Commission reviewed NASA's plans and budget and determined, among other things, that the previous plan was unsustainable absent a multi-billion dollar increase in the NASA budget going forward and that significant multi-year delays were inevitable. Assuming that there is not going to be a large and sustained increase in the NASA budget, then alternatives must be considered. Solving the LEO transportation problem with a reliable, cost-effective, domestic solution is critical to allowing the United States to devote resources that enable NASA to move forward with technologies that take us beyond low-Earth orbit.

A key fiscal fact that appears to be lost by most detractors of the NASA budget plans is that, unless there is a massive influx of funding, you cannot both fund Constellation and extend the life of the ISS beyond 2015. The ISS is an asset for which the United States has risked much. Even according to the most conservative estimates, the US alone has spent upwards of $27 billion on the ISS (without factoring in any Space Shuttle-related costs). There appears to be universal support for extending its lifetime. Given this, and given the Augustine Commission's findings, it makes logical sense to pursue commercial alternatives for manned spaceflight capable of safely, reliably, and cost-efficiently carrying crew to the ISS.

SpaceX Progress to Date

SpaceX was founded just over seven years ago, with the overriding goal of increasing the reliability of access to space and ultimately the transport of crew. SpaceX has executed at an unprecedented pace of development and success with over 30 missions on its current manifest, over $2 billion in contracts, and a customer base that spans the civil, commercial, government and international markets.

SpaceX and NASA have a strong, enduring working relationship and history, which began in late 2005 when then Administrator Griffin established the Commercial Crew/Cargo Project, later renamed the Commercial Orbital Transportation Services (COTS) program. The competitively awarded program was established to "stimulate commercial enterprise in space with opportunities for American entrepreneurs to provide innovative, cost effective access to low-Earth orbit." At the time of the announcement, and reaffirmed in numerous Presidential policies and laws, "CEV variants [later renamed Orion] for ISS or additional International Partner capabilities are backup alternatives."

To date, SpaceX has completed 16 of 22 COTS milestones and the inaugural Falcon 9 launch vehicle is currently at SpaceX's launch complex 40 at the Cape Canaveral Air Force Station (CCAFS), where last weekend we successfully completed a full systems test, including booster ignition of the flight first stage. The completion of a successful static fire is the latest milestone on the path to first flight of the Falcon 9 which will carry a Dragon spacecraft qualification unit to orbit.

In reviewing the COTS program at Congress' request, the often critical Government Accountability Office (GAO) "found NASA's management of the COTS project has generally adhered to critical project management tools and activities and the vast majority of project expenditures were for milestone payments to COTS partners." Building on the productive working relationship established through the course of the COTS program, SpaceX has subsequently been competitively awarded 12 Commercial Resupply Service (CRS) cargo missions to the ISS and been on-ramped to the NASA Launch Services (NLS) catalog. Below is a copy of SpaceX's current manifest:

SPACEX LAUNCH MANIFEST

Customer	**Target Date***	**Vehicle**	**Launch Site**
Falcon 9 Inaugural Flight	2010	Falcon 9	Cape Canaveral
NASA COTS – Demo 1	2010	F9/Dragon	Cape Canaveral
NASA COTS – Demo 2	2010	F9/Dragon	Cape Canaveral
NASA COTS – Demo 3	2011	F9/Dragon	Cape Canaveral
Falcon 1e Inaugural Flight	2011	Falcon 1e	Kwajalein
ORBCOMM	2011-2014	Falcon 1e	Kwajalein
MDA Corp. (Canada)	2011	Falcon 9	Cape Canaveral
NASA Resupply to ISS – Flight 1	2011	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 2	2011	F9/Dragon	Cape Canaveral
DragonLab Mission 1	2012	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 3	2012	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 4	2012	F9/Dragon	Cape Canaveral
CONAE (Argentina)	2012	Falcon 9	Vandenberg**
Spacecom (Israel)	2012	Falcon 9	Cape Canaveral**
Space Systems/Loral (SS/L)	2012	Falcon 9	Cape Canaveral
DragonLab Mission 2	2013	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 5	2013	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 6	2013	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 7	2013	F9/Dragon	Cape Canaveral
CONAE (Argentina)	2013	Falcon 9	Vandenberg**
NASA Resupply to ISS – Flt 8	2014	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 9	2014	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 10	2014	F9/Dragon	Cape Canaveral
Astrium (Europe)	2014	Falcon 1e	Kwajalein
Bigelow Aerospace	2014	Falcon 9	Cape Canaveral
NASA Resupply to ISS – Flt 11	2015	F9/Dragon	Cape Canaveral
NASA Resupply to ISS – Flt 12	2015	F9/Dragon	Cape Canaveral

*Target date indicates hardware arrival at launch site

**Or Kwajalein, depending on range availability

The SpaceX benchmark objective is to increase the reliability and substantially reduce the cost to access space—ultimately by a factor of ten. To that end, SpaceX is developing a family of low-cost launch vehicles, the "Falcon" line. SpaceX is currently the only US company dedicated exclusively to developing and providing end-to-end space transportation solutions, let alone ones with improvements in both cost and reliability. This focus and our devotion to minimizing critical

external dependencies are key to cutting the Gordian knot that thus far has inhibited genuine commercialization of launch services.

SpaceX's unique approach of manufacturing a vast majority of the vehicle in-house in addition to integrating and providing launch services is changing the industry paradigm. SpaceX's Falcon 9/Dragon system offers a one-hundred percent American-made transportation solution. With nearly one thousand full-time personnel, SpaceX possesses deep expertise in propulsion, structures, avionics, safety, quality assurance, mission operations, launch, mission management and systems integration. Headquartered in Hawthorne, California, SpaceX also operates a state-of-the art test facility in Texas, the Falcon 1 launch facility in Kwajalein, the Falcon 9 launch facility in Florida, and an office in Washington, DC.

SpaceX has developed the capability to manufacture the majority of its launch vehicle and spacecraft in-house and is not dependent upon a single source for any key technology. This provides SpaceX with control (for price as well as quality and supply) over all key elements—from component manufacturing through launch operations. It also allows SpaceX designers to work directly with manufacturing located just steps away, streamlining the development process.

As evidence of the viability of this commercial model, in just over seven years, SpaceX has:

- Developed, built, tested and successfully launched the Falcon 1, which included "clean sheet" development of all propulsion, structures and avionics, fully qualifying the vehicle, ground and launch support systems, and certifying a Flight Termination System with a Federal Range. The fourth and fifth flights of Falcon 1 demonstrated repeatable success in placing payloads into intended orbits;
- Developed, built and activated (with range approval) two launch sites, including all regulatory approvals and coordination. It is worthy to note that the Kwajalein facility was designed, built and activated in less than 10 months. SpaceX has completed Space Launch Complex 40 at Cape Canaveral in Florida in preparation for the maiden Falcon 9 launch;
- Developed the major Falcon 9 subsystems to a point such that the vehicle currently sits on the pad at LC-40 in Cape Canaveral, with the maiden launch of the Falcon 9 to occur in the coming weeks;
- Completed 16 of 22 performance milestones for NASA's COTS project with the first demonstration mission scheduled for 2010; and
- Competed and won 12 operational missions to resupply cargo to the ISS and completed five reviews toward two of these missions.

The Falcon 9/Dragon System was Developed to Support Crew Delivery from Day One

SpaceX is on-track to simulate delivery of cargo to the International Space Station (ISS) within a year, and return cargo to Earth. This will be followed in mid 2011 by the first of 12 commercial cargo delivery missions to ISS under the Commercial Resupply Services (CRS) contract. Although the SpaceX Falcon 9 launch vehicle and Dragon spacecraft are initially contracted to carry only cargo, they have been designed since inception to be crew-capable with minimal augmentation. This is a logical and incremental extension of cargo transportation capabilities, especially when the cargo system includes down-cargo capability (i.e. return of payload to Earth).

Many functions and requirements for crew transportation are levied on the cargo vehicles by virtue of the fact that they must approach (and berth with) the ISS. Safety concerns for ISS crew, and prudent stewardship of the ISS itself, mandate that factors of safety, fault tolerance, air circulation, touch temperatures, sharp edges and many other "human rating" requirements be imposed on the cargo transfer vehicles. Accommodating crew involves up-rating of certain subsystems, adding crew monitoring and over-rides, and a launch escape system in case of booster failure during ascent.

SpaceX has been working closely with NASA through the Commercial Cargo and Crew Office (C3PO) office at JSC from the inception of the COTS program three years ago. The spacecraft and launch vehicle have progressed through Critical Design Review (CDR) for each of the three demonstration flights required under the COTS Space Act Agreement (SAA). At each milestone, SpaceX's designs and processes are subjected to careful, objective review by NASA through C3PO and their COTS Advisory Team of technical experts. Independent of this, the ISS program's Safety Review Panel (SRP) also review all aspects of the design that could affect the safety of the ISS and its crew. Dual-fault tolerance against critical hazards is strictly enforced, although no significant design changes have been required to-date. SpaceX will complete Phase 2 of the 3-phase SRP process this month, with the final phase scheduled for completion in late 2010. The SRP is a critical signatory to the Certificate of Flight Readiness (CoFR), a pre-requisite for the final demonstration mission which will berth with the ISS.

The augmentations required to this system in order to safely fly crew are:

- **Launch Escape System**: to provide a means for crew to safely escape from a catastrophic failure on the launch vehicle during ascent. SpaceX has identified the development of a Launch Escape System (LES) as the item requiring the longest lead time and presenting the highest technical risk;
- **Vehicle Health Monitoring System and Abort Triggers**: to continuously monitor the launch system and command the escape system if a failure is detected;
- **Life Support System**: up-grades to the existing Environmental Control System to include carbon-dioxide removal and humidity control;
- **Crew Accommodations**: including seats, pressure suits, and manual control systems;
- **Gantry Access at launch pad**: to provide nominal and emergency access for crew.

The above four items are the key, significant developments to up-rate the current cargo system to accommodate crew. A docking system development may also be required, or this could be provided by the government to maintain the broadest cross-compatibility between commercial transportation options. SpaceX can complete necessary augmentations and will be ready to fly astronauts to the ISS within three years after contract award.

Crew Safety and Human Rating

There has been significant debate over what it means for a rocket to be "man-rated." And I think it's fair to say that this term is a bit of a moving target. While NASA currently is compiling human-rating requirements to ensure astronaut safety, it has not established a certification program whereby candidate commercial vehicles will be subjected to a thorough review process focused on assuring crew safety. This said, at least with respect to SpaceX, the following facts are relevant:

SpaceX incorporated the existing NASA human rating requirements into the Falcon 9 and Dragon designs; (found in NPR 8705.2A - Human-Rating Requirements for Space Systems) and codified in the SpaceX Human-Rating Plan. This plan was presented to NASA for review as part of our first Systems Requirements Review Milestone. In May 2008 NASA released the current human rating requirements document, NPR 8705.2B, which is applicable to "crewed space systems developed by NASA", not to commercial systems. In draft form this document had an "Appendix G – Commercially Developed Space Systems" that discussed "equivalent standards", "equivalent design reviews", and participation of NASA technical authorities in design and development of new systems, or gaining their approval for existing systems. This Appendix was omitted from the released version leaving no definition for NASA human rating requirements applicable to commercial crew transportation systems.

Nevertheless, SpaceX continued to design Falcon 9 and Dragon with NASA Human-Rating standards contemplated assuming that the requirements defined for government systems such as Orion and Ares I would also apply to our vehicles. Furthermore, wherever the newer requirements were non-specific, SpaceX self-imposed the older (and in many cases more stringent) 8705.2A NASA requirements. For example, SpaceX designed its structures to meet NASA Standard 5001 Structural Design and Test Factors of Safety for Spaceflight Hardware, and SSP 30559 ISS Structural Design and Verification Requirements. Consistent with human rating standards, Falcon 9 is thereby designed to 1.4 Factor of Safety (FS) and Dragon pressurized volume and windows to 2.0 FS. Additionally, Dragon Avionics and Propulsion Systems are 2-fault tolerant to catastrophic and critical hazards. Finally, Dragon and Falcon 9 are designed to support Launch Abort System ascent and reentry loads and meet both ISS Visiting Vehicle requirements in SSP 50808 and NPR 8705.2B section 2.3.7 fault tolerance requirements. In fact, based on these requirements and available standards, the Dragon spacecraft is not expected to require any hardware modifications to the existing primary structure, propulsion, power, Command & Data Handling (C&DH), thermal control, thermal protection, communication or Entry, Descent, and Landing (EDL) subsystems. Similarly, no hardware changes are anticipated for Falcon 9 to comply with the government HRR. Both vehicles will require some additional functionality such as those listed above; however these capabilities are "keyed" into the existing design.

It is critical to note that the Falcon 9 launch vehicle is the ONLY launcher (domestic or foreign) with engine-out capability in the first stage. This feature was present on the Saturn I and the Saturn V and was leveraged to save astronaut lives in both cases.

Going forward, SpaceX will comply with any NASA-published human-rating requirements for both Dragon and Falcon 9. SpaceX looks forward to engaging with NASA to begin the Human Rating process of both these vehicles.

Current Reliance on Russian Vehicles

Though hardly news to those involved in the US civil and commercial space sectors, the following facts will likely come as a disturbing surprise to most Americans: first, from 2010 through 2017, or longer, the United States will have no human spaceflight capability unless commercial services are developed; and second, during this timeframe, Russia will wield a monopoly with respect to manned carriage to the ISS. So, while the US has toiled to build the ISS - risking lives with each Space Shuttle mission and expending significant national treasure to

construct the orbiting laboratory – we will not be able to access the ISS without paying Russia dearly for the privilege. While these facts may be new to most Americans, they certainly are not lost on the Russians, who, despite being relatively new players in the free market economy, are proving to be quite excellent capitalists.

Russia's mastery of the relationship between supply and demand has manifested itself consistently over the past decade, but no more so than in 2007, when the United States negotiated to pay $780 million to Russia to deliver cargo and 15 crew members to the space station – six astronauts in 2009, six in 2010, and three in 2011. After the Shuttle is retired, it is not apparent what price Russia may demand for rides to the American-built portion of the ISS.

Opportunities for Growth

Initial government investment, coupled with private funds, has spurred the creation of successful new industries. For example, industries such as e-commerce, commercial aviation, and entertainment were enabled by government investment in the internet, aviation infrastructure, and the satellite industry respectively.

US government investment in commercial space companies to create a safe, reliable, and cost effective human space transportation industry will enable the formation of entire new industries. Immediate beneficiaries of government incentives include commercial human space transportation providers, their suppliers, and local communities where new infrastructure is being developed to support new missions. As the human space transportation industry grows, the enterprise will extend to markets in scientific research, tourism, education, and exploration. With the maturation of systems, new industries will evolve in fields such as medicine, material science, energy, and expanded tourism.

Funds for this proposed commercial crew program will immediately create new high-tech jobs. The Commercial Spaceflight Federation estimated in 2009 that a $2.5 billion Commercial Crew Program would create 5,000 new jobs across the nation. Indirect and induced job creation is typically considered to be approximately four times this number in the wider economy. Commercial crew capability for SpaceX alone, once realized operationally, is predicted to create thousands of additional direct high-skill jobs in Florida, California, and Texas.

Mr. Chairman, thank you for your support and that of this Subcommittee. I would be pleased to respond to any questions you or the other Members of the Subcommittee may have.

GWYNNE SHOTWELL

Ms. Shotwell joined SpaceX in 2002 as Vice President of Business Development, developing SpaceX's customer base and managing strategic relations. As President, Ms. Shotwell's responsibilities include providing strategic direction to support company growth and development, as well as management of day-to-day operations at SpaceX. Her experience prior to SpaceX includes over ten years at the Aerospace Corporation where she held positions of increasing responsibility in Space Systems Engineering and Technology and Project Management. Highlights include promotion to Chief Engineer of an MLV-class Satellite program, managing a landmark study for the Federal Aviation Administration's on Commercial Space Transportation, and completing an extensive space policy analysis for NASA's future investment in space transportation. After Aerospace Corporation, Ms. Shotwell was recruited to be manager of the Space Systems Division at Microcosm, where she served on the Executive committee and directed corporate business development.

Ms. Shotwell received her Bachelor's and Master's Degree from Northwestern University in Mechanical Engineering and Applied Mathematics. She was elected statewide to the Board of Directors, California Space Authority and serves on its Executive committee. She has also served as an officer of the Space Systems Technical Committee and the local Chapter of the AIAA. She has authored papers in a wide variety of areas including standardizing spacecraft/payload interfaces, conceptual small spacecraft design, infrared signature target modeling, Space Shuttle integration, and reentry vehicle operational risks.