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Prepared Statement of
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Committee on Commerce, Science and Transportation
United States Senate

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear today to express my views on commercial space capabilities. I have an abiding interest in the subject, and I appear before you without any interest to pull my punches. My background as a NASA program analyst for some thirty years gave me some insight about the NASA side of the issue. After my retirement, I have worked occasionally as a consultant to contractors doing business with NASA. However, I lack the intimate familiarity with the contractor side of the government-contractor relationship that only time spent in that environment can afford. This limitation should be accordingly noted, and I apologize to all concerned in the commercial space community if, inadvertently, I poorly articulate your case.

My remarks focus on the intended use of U.S. commercial space capabilities to address U.S. Governmental responsibilities under the international partnership agreement for the International Space Station. The impetus for this policy proposal was provided by the Augustine Committee's findings last year, which recommended "the development of a relatively simpler launcher and capsule designed only as a low-Earth orbit crew taxi." The costs for this development were estimated to be lower than those associated with the development of the Ares 1 launcher and the Orion spacecraft. As a commercial venture, the Committee envisioned that "at least some commercial capital must be at risk." The Committee report notes that it heard "many argue that economic efficiencies could be found by striking a better balance between the legitimate need for a NASA quality assurance and safety process on one hand, and allowing industry to execute design and development efficiently on the other." Moreover, the Committee raised the prospect that "some development costs, and a larger fraction of operating costs of a commercial crew service to low-Earth orbit could be amortized over other markets and customers."

At the outset, let me state that I do not doubt the technical ability of commercial or "commercial-like" enterprises to supply cargo and crew services for the International Space Station (ISS). Launch vehicles and spacecraft that provide cargo and crew services are already servicing the ISS. Indeed, the Russian vehicles operate in a "commercial-like" manner, with proving both cargo and crew for a price to all who can afford the bill, including some particularly hardy and wealthy private citizens. The international partnership takes full advantage of the reliability and safety of the Progress spacecraft to carry cargo; just recently, two new spacecraft became available to carry cargo, the Ariane Transfer Vehicle and Japanese HTV. The Soyuz carries crew to the ISS and returns them to Earth, and does so satisfactorily enough the U.S. Government deemed it acceptable a number of years ago to retire the Space Shuttle by 2010 and allow a lengthy period of time when no alternate U.S.-sourced mode of crew transportation would be available until the advent of the Orion spacecraft and its launcher, the Ares I.

With the proposed cancellation of the Constellation program, the current Administration has proffered the substitution of the Orion, an advanced U.S. crew capsule, with the concept advocated by the Augustine Committee, a U.S.-sourced "commercial" crew delivery and return system. This new system is said to be "a simple spacecraft with a simple mission" that by being commercially developed for the ISS mission will allow NASA to focus on the more challenging beyond-LEO missions of the future. The budget estimate for the cost to the U.S. over the next five years for this effort is $6 billion, a figure close enough to the Augustine Committee's finding that the program "can be viable with a $5 billion stimulus from NASA."

The concept of a U.S.-sourced simple spacecraft to address ISS mission needs is attractive to those who find it untenable for political reasons that the U.S. pay Russia for Soyuz launch services or for program "robustness" reasons, a reliance on a single mode for crew access. Some commentators worry that the Russians will hold us "hostage" and raise the prices for the Soyuz or that the U.S.-Russian relationship will sour. The political argument is, in my way of thinking, disingenuous. The program robustness concern is not, but there is no good immediate answer to the problem it raises. Both are clearly subject to the countering punch that the barn door was open previously (post-Columbia), is soon to be open again, and will remain open for a number of years. U.S.-sourced payloads are already launched on non U.S. –sourced launchers. Although there is some merit to the trade deficit issue, sending U.S. funds abroad to buy foreign goods and services is common practice, and the amounts sent to Russia are relatively trivial in that larger context. So, the balance of payments argument is weak. Those who obviously lack trust in the Russian entities conveniently ignore the interdependent nature of the U.S.-Russian relationship that has been in existence and will be for a number of years, for as long as the ISS is operable.

Why attempt to close the barn door at some point in the future? Is there is a concern that the crew/cargo delivery products made in Russia will develop quality defects that will escape detection and cause ISS service outages? Even if that is a real problem looming on the horizon, and I would not dismiss it as an unreasonable postulate, we are confronted with the fact that an alternative to the Soyuz for crew delivery will not be available for some years to come. If it is deemed an urgent problem requiring quick attention, the current commercial transportation service program proposition most assuredly is not an effective counter. A cynic might argue that the U.S. manufacturers could more speedily acquire the rights to produce the Soyuz spacecraft and launcher in the U.S., using build to print manufacturing and U.S. safety and mission assurance processes. Given the willingness of U.S. rocket engine manufacturers to procure Russian-sourced engines and purchase co-production rights, I wouldn't want to argue that there is no precedent for this and accordingly this is an untenable concept.

Some have argued that we should ignore the arguments of the Augustine Committee and return to the program plan for Constellation. The availability of funding for executing this plan is a matter for the Congress and Administration to decide, so I will not opine on its feasibility. However, I will acknowledge that I was a fan of the original argument for Ares I and Orion. The program plan was based on the "leapfrog" logic. Effectively, this stemmed from a finding that there was little merit in producing a Soyuz wannabe. Hence, U.S. Government investment would be better spent for a more complex, capable design. The Orion and Ares I would receive the design maturation benefit for both spacecraft and launcher from undertaking LEO missions to the ISS, and then the additional incremental investment—for a better-outfitted Orion and the Ares V-- would build on that experience to go to beyond-LEO missions. The problem the Bush Administration had with the plan was its affordability, unless the Shuttle expenditures could be ended, thus avoiding a further $3 billion per year increase to the projected NASA budget increases already envisioned in the outyears. Although there was some modicum of interest in a U.S.-sourced commercial cargo delivery solution, and funds were allocated to begin early work on it, there was no hesitation about relying on the Soyuz for crew delivery and return. As events have proven, the combination of funding constraints within NASA and normal technical challenges have led to a slip in the probability of an early Orion crewed mission to ISS by 2015. I don't know if the Augustine Committee was correct in assessing that the probable first ISS use date would be 2017, but clearly the Committee could argue cogently from past experience.

I have no quarrel with the findings of the Augustine Committee about the need for increased funding to support the logic of the original argument, or its findings that there was a great need for additional investments in research and technology required for beyond-LEO voyages. There were substantial defects in the logic of the program and budget plan NASA was saddled with by the Administration. **However I believe the nexus of their argument for developing a U.S.-sourced "commercial transport service" is grounded in their belief that there is a commercial space growth opportunity -- in addition to LEO flights of crew and cargo to ISS -- that can be seized by a U.S.-sourced commercial venture. This prospect will materialize only if the U.S. Government puts up the money and commits to a commercial transport service to meet its responsibilities under the ISS partnership agreement.**

I agree that there is sound logic behind the logical proposition that if (a) the U.S. Government underwrites the bulk of the development costs and "makes the market" by committing to an annual crew delivery quota, then (b) the marginal costs -- for increasing the spacecraft and launcher production rate and address operational requirements – could form the basis for a price-competitive market penetration. To follow the logic, the increased utilization of the launcher would lead to a drop in the unit cost (and increase in competitiveness, and ultimately profit margin) for the launch manufacturer. The crew spacecraft carrier would enjoy a high consumer confidence level due to NASA and FAA's involvement in its "man-rating," and additional spacecraft could be produced at marginal costs to carry (for example) tourists, all because U.S. Government funds financed the basic spacecraft production capability. It is essential for this proposition to succeed that the spacecraft be simple, yet safe, and that the U.S. governmental mission requirements be constrained in scope to avoid higher unit production costs for bells and whistles.

I also agree that the development costs for the crew capsule will clearly be less than required to execute the more complex, capable design for Orion. The annual funding increment required to be disbursed from the Treasury will be comparatively less, an especially important consideration given the priority assigned to civil space and aeronautics programs in the federal budget. And, for those who favor beyond-LEO voyages, the Administration proposes Congress agree to allocate a portion of the

NASA budget would be applied to research and technology development to address those needs. I am an ardent fan of this investment proposal.

Why should there be any doubt on the part of Congress that this commercial transportation services venture will result in an appropriate return on the investment both to U.S. taxpayers and private investors?

One important reason for caution is the uncertainty as to the useful service life of the new crew and cargo service spacecraft. After the retirement of the Space Shuttle, the sustainment of the ISS as a viable spacecraft is a major undertaking, presenting future maintenance, repair, and enhancement uncertainties that could impact its useful life, whether that is to 2020 or even 2028. A major uncertainty is the ability to respond to game-changing events onboard the ISS, such as crew evacuation and return to Earth, or an extended period of minimal operational capability because necessary repairs cannot be accomplished by applying available on-orbit spares, or where the orbital replacement unit required for the repair exceeds the volume or lift capacity of cargo supply vehicles.

Another uncertainty is whether the participating nations will allocate the necessary future funds to respond to future ISS operational requirements, particularly if technical or programmatic events require an unanticipated spike in funding requirements. How long will the ISS last as a mission-capable spacecraft? How long will the international partners be willing to keep operating it? This is a critical issue for private investors because the commercial model assumes the revenue stream provided by the U.S. Government is lengthy enough to ensure the profit potential from the expansion of the LEO tourist trade, the key to their receiving an adequate return on their investment.

Putting aside the engineering challenge of sustaining the ISS, we should not assume the investment community dismisses out of hand the possibility of a change in the international partners' willingness to support ISS operations over an extended period of time. I highlight this point because our nearly five decades of human spaceflight illustrate the waxing and waning priorities of governmental entities engaged in human spaceflight. And, I don't mean just the U.S. federal government, but also the priorities of the other ISS partners: the Federal Government of Russia, the nations supporting the European Space Agency, the Government of Japan, or the Government of Canada. To that mix, there are many others who are or will be involved in future human spaceflight, most notably the governments of China and India, and in a collective sense the United Nations. The changes in priorities over time have been driven, in my opinion, predominately by these governments assigning greater or lesser value to how its human spaceflight program contributed to national security objectives.[1]

[1] The oldest case in point is the U.S. response to the Sputnik launch and follow-on launches of cosmonauts. More recently, I am not alone in suggesting that the U.S. involvement in the International Space Station's development survived in 1993 largely due to our national security interest in keeping Russian scientists and engineers off breadlines. The Bush Administration's lack of interest in planning budgetary resources to sustain U.S. participation in ISS beyond 2015 can be viewed as an indication of the priority it assigned to ISS.

Although the development of the ISS and its initial years of operations have promoted collaborative engagement with our former adversaries and economic competitors, the future expected return on investment for the ISS on national security grounds is uncertain. (That could change, of course, if the international partnership expanded to take in the People's Republic of China and other nations, thus increasing the value to the U.S. for remaining in this collaborative engagement and a higher priority in the U.S. federal budget.) The arguments on other grounds – economic, and research returns for instance -- for continuing to invest in the international partnership are good, but not as compelling as the national security argument as reasons for governments to stay committed.

What assurance should a prospective investor take from the historical record of governmental investments in risky ventures that would lead them to invest funds in a collaborative government and industry "commercial" venture without an insurance policy? And, would he be able to recover his investment and his foregone opportunity costs? Who would provide that insurance? And, from the federal government's point of view, how would including costs of insurance impact the total program costs? From my experience, I have difficulty believing that our government will make an enduring commitment to provide whatever level of resources is necessary to "make the market" and ensure an adequate return on investment for U.S. commercial suppliers of cargo and crew services. It is conceivable that the Executive and Legislative branches might agree to appropriate sufficient funding guarantees that would mitigate the investment risk. However, I would not dismiss the possibility that other nations and their commercial entities would view the U.S. Government's underwriting of the investment risk as creating the potential for an unlevel playing field in the competition for non-governmental flights, such as space tourism. I would expect them to argue that the U.S. firms' pricing must include some factor related to governmental investment cost recovery. If this is viewed by the investment community as a real threat, the financial attractiveness of the commercial venture would be further diminished and require an offsetting remedy.

The Augustine Committee "estimated that the cost to NASA of creating an incentive for industry to develop the commercial transport capability for crew…of between $2 billion and $2.5 billion." Another component of their total program cost estimate is the provision by NASA to bidders of a "suitable version of an existing booster with a demonstrated track record of successful flight." The fraction of the launch vehicle design, development, test and evaluation costs that would be borne by NASA was estimated to be another $3 billion. Based on material available from NASA and public sources, the $ 3 billion would cover the unique costs of "man-rating" the launch vehicle and associated infrastructure investments. The Augustine Committee also looked back to an historical analogy, the Gemini program, and reviewed its program costs, applied GDP-inflator corrections. They believed the result -- $2.5 billion to 3.0 billion, in 2009 dollars -- provides a sanity check on their total program cost to NASA of $5 billion. I cannot comment on the credibility of these estimates, given my lack of access information to the detailed cost estimating and financing assumptions used. However, I can provide this Committee with some thoughts based on my extensive experience with program cost and schedule estimates, the interaction with funding constraints, and the unique complications introduced by the lack of failure tolerance in the human spaceflight arena.

First and perhaps foremost, human spaceflight activities are fanatical about attention to detail and documentation of processes and products, through the phases of the hardware/software design engineering, manufacturing phase, and test and evaluation phases. The designs have to be robust, with as much margin as possible to handle off-nominal conditions with margin remaining. Changes in designs are subjected to rigorous, time-consuming reviews. The close coupling of hardware and software functionality in current vehicle designs requires an integrated analysis to ensure changes do not introduce unintended consequences. Every manufacturing discrepancy is scrutinized, and "use-as-is" buyoffs of blemished hardware are extremely low. Hardware and software are subjected to exacting tests. Unanticipated test results are reason enough to redo the large performance simulation models that engineers use to establish the anticipated vehicle response to environments. Care is taken in every possible fashion to mitigate the physical stress of ascent and descent loads and other stressful conditions on the human crew member. The high acceleration forces allowed for cargo transport to orbit are not acceptable for humans. Meetings are recorded and documented, decisions are not made in haste, and caution rules the day. Every aspect of the process, from raw material acquisition to finished product, is certified. "Off the shelf" products, designed for different environments and built to less exacting standards, are not incorporated without rigorous certification. <u>Everything is apprised with an eye to whether it would meet a post-failure review board's excoriating analysis.</u> As Gene Kranz famously said, "failure is not an option." Nonetheless, in human spaceflight, systems are designed to be sufficiently robust that there is a remedy to failure for almost every system. The "fail-operational, fail-operational, fail-safe" philosophy is incorporated wherever feasible.

How much will a human-rated crew spacecraft and launcher cost? Should the Committee accept the Augustine Committee's use of Gemini as an analogy as appropriate. Or, was the environment so different in the early 1960's that the cost comparison is only of limited value? We certainly know that today's world of avionics and hardware/software integration is lightyears different. I confess that I am not the person with the level of detailed knowledge required to provide this Committee with an assessment of the appropriateness of the analogy. Perhaps General Stafford, a Gemini crew member, can provide some insight. I would note the historical literature suggests that the cost and schedule baselines for Gemini cited by the Augustine Committee need to be placed in context, and used – if at all – only as adding a limited value to the discussion.

Having noted my limitations on the subject, I would point the Committee's attention to several Gemini attributes that give me concern about the analogy's appropriateness. First, I doubt that current program planners would accept the risk taken by the Gemini program designers to have only ejection seats for the three person crew. (No emergency escape rocket was provided for the crew capsule in the event of a failure of the Titan II.) Although General Stafford is far more informed than I am, I will hazard my opinion that the likelihood was small that the crew would survive a failure of the launch system during all but the first seconds of the ascent. That said, it is important to understand that the Titan II design had one really good feature for crew safety; it used a storable hypergolic liquid propellant. This gave it a much lower explosive potential than the Titan I, Redstone, Atlas and Saturn boosters. The design is also inherently less costly. The propellant, plumbing, tankage and engines of a storable hypergolic fueled vehicle permit increased design and manufacturing tolerances, and less hazardous launch site environments than do launchers using liquid oxygen and (particularly) liquid hydrogen.

A second point from the Gemini literature indicates that the schedule (39 months) and cost-estimate ($2.5-3.0 billion) analogies cited by the Augustine Committee need further research to determine their appropriateness. For example, the literature points out that "man-rating the Titan ICBM required minimal changes to the basic Titan II. Changes were made in the interest of pilot safety (e.g., system redundancies); some modifications were also necessary to ready the basic ICBM to accept the Gemini payload."[2] The literature does not indicate whether a separate production line was established at the Martin Company to produce the twelve man-rated vehicles, and how that impacted costs, favorably or unfavorably . The literature does indicate that the 39 month development period for Gemini cited by the Augustine Committee does not take into account the development schedule funded by the Air Force prior to NASA's selection. Specifically, the Air Force, building on the experience with the Titan ICBM, awarded a contract in June 1960 to the Martin Company for the Titan II ICBM development. Although the first Titan II ICBM R&D flight took place in March 1962, NASA had selected the Titan II, appropriately man-rated, as the vehicle of choice for Gemini in the Fall of 1961. The program had its development issues to overcome, although not an inordinate number of them. However, NASA maintained a fallback position to use the Saturn I until second state combustion instability problems were solved (jointly by the Air Force and NASA in the Spring of 1963) and a series of successful Titan II test flights occurred in late 1963. (It is unclear from the Gemini literature whether the costs incurred by the Air Force in support of the Titan II man-rating were funded by NASA.) The first Gemini qualification launch occurred in April 1984, a second qualification launch (for spacecraft qualification) occurred in January 1965, and the first Gemini crew was launched in March 1965. Twelve (12) Gemini launches in total were flown by NASA, ten of them with crew. All successful.

The Committee may also wish to examine more carefully the arguments of advocates for the commercial crew and cargo launch services proposition to the effect that benefits would accrue to the global price competition environment for existing launch vehicles (such as the Atlas V) by increasing the launch rate and thus achieving lower per unit costs. This is an argument that requires careful explication of assumptions before undue credence is given. As I noted above, the human spaceflight environment is inherently costly due to its exceedingly low tolerance of any risk and demand for exhaustive levels of documentation throughout the engineering, manufacturing, test and launch environments. Economies of scale in production environments are realized when the same processes and products are used throughout. These economies are minimized if, for instance, commercial and government customers find the increased costs of man-rated processes to be overkill. Separate production lines are a possible outcome. That is not to say there are not savings from the distribution of facility support, indirect, and overhead costs across a broader user base. There are, but the savings are insignificant unless the relatively fixed costs of engineering, manufacturing, and supply chain management are very high proportionately to the production rate.

[2] Source: NASA Historical Data Book, volume II, p. 84

I also worry about the credibility of the arguments put forth to the Augustine Committee and included in the report that a "better balance [can be struck] between the legitimate need for a NASA quality assurance and safety process on one hand, and allowing industry to execute design and development efficiently on the other." My experience with NASA is somewhat dated, given my departure from the agency in 2003, but I had many occasions during my tenure to listen to contractors complain about time-consuming and documentation-laden NASA reviews. Time is money, of course, and an unduly lengthy review process before a decision is rendered by NASA impedes the timely accomplishment of work. But complaints often arise when the government-contractor relationship is damaged, and the contractor believes NASA staff --civil service and support contractors-- do not participate as collaborators, with a sense of shared urgency. Most frequently I found the argument was about broken promises and the need for more money. NASA program managers are not welcomed with open arms by their management when they return from discussions with contractors who need more money than the budget affords. NASA program managers often find that the contractor has different priorities when it comes to assigning the "best and brightest" to their programs. And, the same is true of NASA priorities, which change over time, again as a reflection of NASA managers striving to stretch resources across programs to meet emergent problems.

The procurement environment for cost-reimbursement contracts is inherently adversarial, of course, because NASA's abiding interest is (or should be) ensuring the public's money is expended effectively, with as much accountability as possible, and in compliance with the law and procurement regulations. Among those legal and regulatory constraints are those which address socio-economic objectives, national security objectives (e.g., ITAR), financial management (Prompt Payment Act, etc.) and identification of liability. Compliance with these constraints adds costs to the contract, and reduce the contractor's flexibility.

However, the Augustine Committee's report language caused me to wonder if those who pressed the "excessive oversight" argument understood the burden placed on the government officials who must address the "insurance" responsibilities of the government. To simply state the matter, NASA does not take out an insurance policy from Lloyd's to cover the consequences of failure. These consequences include not only the out-of-pocket costs but the consequent damages to program objectives. Instead, the government "self-insures." This avoids the expenditure of public funds to pay the premiums on the insurance policy provided by a private concern. However, the concomitant responsibility placed on government officials is to assure the taxpayers that they have been diligent in reducing the probability of loss of lives, hardware, and mission accomplishment. NASA officials agree to take constructive delivery of hardware and software from contractors, and sign on the dotted line. NASA officials consent to the launch and accept the liability for failure. Hence, processes must be designed to protect against those consequences, with their scope consistent with the amount of potential loss. Smaller consequences receive less attention than larger ones. Over the course of years, we have adjusted our oversight/insight insurance plans to fit the environment of acceptable risk. After the Challenger and Columbia disasters, the hang-them-high environment led to a lower risk tolerance throughout the human spaceflight community. The costs incurred by NASA for the self-insurance policy went up accordingly. Over time, with demonstrated successes, a sense of higher confidence and trust builds up.

But, the trust must be earned. The oversight and engagement levels of NASA in the commercial transportation service venture cannot start out low, in my estimation, because the trust has not yet been earned. However, as success accrues, the levels will diminish to what NASA and FAA officials agree is required to fulfill their insurance responsibilities.

In closing, let me note that during my thirty years in NASA as a program analyst, cost estimator, budget formulator and Comptroller, I became all too familiar with the internal U.S. Government debates about how much of the scarce federal budget resources should be allocated to meet the needs of mounting human spaceflight programs. I was a member of the supporting cast to the NASA Administrators for many of those years when they met with the members and staff of this Subcommittee to explain and advocate for the Administration's priorities. As representatives of the Executive Branch, we were not here to express our personal and professional views of the wisdom of those policies and priorities. Your challenge was then and is now difficult: how to discern the wisdom of the Administration's program and budget plans, not only in regard to civilian government space activities, but also within the larger context of public policy across the federal government.

Thank you for the opportunity to testify.