



Written Statement of

**Dr. Sandra Magnus
Executive Director**

American Institute of Aeronautics and Astronautics

**Subcommittee on Space
Committee on Science, Space, and Technology
United States House of Representatives**

“An Update on NASA Exploration Systems Development”

November 9, 2017

Chairman Babin, Ranking Member Bera, and distinguished members of the Subcommittee, I want to thank you for the opportunity to address you today concerning our nation’s space program and its trajectory. My last testimony before the full committee was in February 2014, and many of the points I made then I will reiterate today. I will also highlight changes and/or progress that have been made and the potential that is unfolding before us.

EM-1 and its attendant schedule are major milestones for our nation’s space program, and I would not understate its importance. However, I would posit that the larger purpose of today’s hearing is to examine the current state of our human spaceflight program and comment on its progress and direction. I believe that we are on the brink of an exciting new phase in human spaceflight. For the last decade or so numerous companies, including those working with and

directly supported by NASA, such as Boeing, SpaceX, Lockheed Martin, Sierra Nevada, and Orbital ATK, as well as those privately funded, such as Virgin Galactic and Blue Origin, have been working very hard to develop and operate the next generation of vehicles to send cargo and humans from U.S. soil into space. The different vehicles will have the ability to launch humans and cargo into suborbital trajectories, to low Earth orbit, and beyond low Earth orbit to the moon and to Mars. Each and every program has had its technical and management challenges and its setbacks. Each and every company has risen to these challenges, tackled problems, created solutions, and thus, incrementally, step by step, made progress toward their respective first flights. Some of the cargo vehicles are already operational. The next two to three years will be very exciting as the crewed vehicles will start flying. To the public it will seem as if suddenly, overnight, a whole new phase of the U.S. space program will have been initiated. But as those of us in the industry and in this room know, our space program has been steadily, determinedly working on the tools and capabilities to achieve these goals.

Indeed for those of us here today and the many who work diligently across our country in the space industry, we know the hard work, planning, dedication, and commitment required to execute a successful human spaceflight program. We know that sending humans into space is hard. That despite numerous decades of experience in this endeavor the exercise of launching humans out of the Earth's gravity well into the challenging environment of space continues to be anything but straightforward. Progress in human spaceflight is measured not in days or weeks, but in months and years. Every human spaceflight program in development or operation today, whether it is driven by governmental or private motivations, is advancing steadily, but they will still encounter technical, management, and operational challenges. I make these statements not to imply that the industry is at risk, but, alternatively, to highlight the steady, committed, and talented community that is determined to succeed and will succeed in keeping America engaged and at the forefront of what is possible in space.

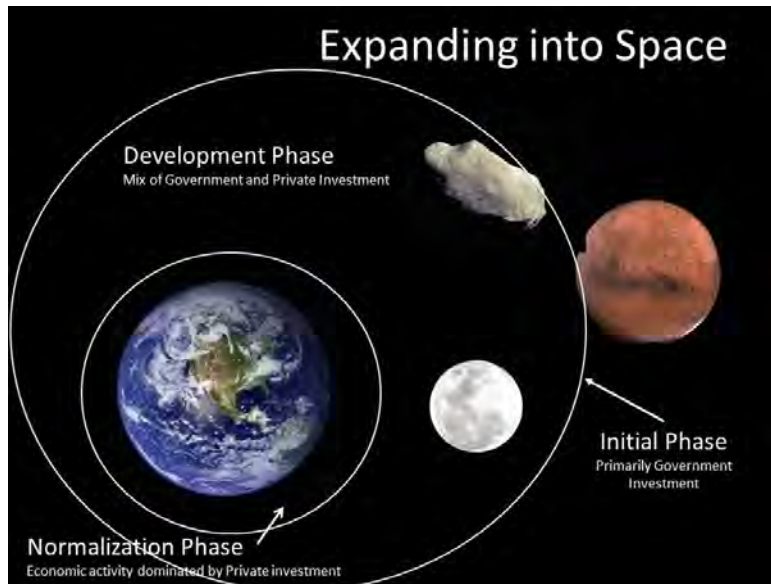
The idea of "what is possible in space" has been in transition over the last decade or so. As I have mentioned in my previous testimony and in other venues, after 60 years of government investment and activities in space we have reached the point where the private sector is able to leverage the accumulated technological developments, operational experience, and management knowledge to create and execute plans for engagement in and economic development of space. In concert with and because of this expanded private interest, NASA has been able to extend its ambitions beyond low Earth orbit and outward toward the moon and Mars.

Times of transition and change are chaotic: norms are challenged, creative energy and new ideas enter the paradigm, and what has been a well-understood landscape seems to be

constantly shifting. During such a dynamic phase I find it useful to take a step back and examine the situation from some distance to better understand possible trajectories, motivations, and outcomes. There is a model that I like to use to describe the ecosystem that is today's U.S. human spaceflight program.

I would like to refer to Figure 1. As illustrated in the figure, imagine a bubble or balloon, centered on the Earth, slowly expanding outward. The expanding surface represents the outward expansion of human activity. Putting aside our trips to the moon in the Apollo era, for the last forty years the surface of the bubble has expanded to low Earth orbit and has remained there. During this period government-directed investment and government-led missions, which were the driving force behind the expansion of human activity to low Earth orbit, led to an accumulation of experience, technology, and knowledge about operating in this environment.

Figure 1



Outward Expansion of Human Space Activity

Now many decades later we are at the point where private industry has become interested in engaging more proactively in the open space—between the Earth's surface and the surface of the bubble. As these activities initiate and mature, it creates stability and a foundation upon which the surface of the bubble of human activity can expand yet further, for example, beyond low Earth orbit. Similar to the initial expansion into low Earth orbit, further expansion beyond it will be driven by government-derived goals and investments. Because of the increasing engagement by industry in the open space created by the expansion's surface, currently stationed at low Earth orbit, NASA can now begin to disengage as the main investor in low Earth orbit. In doing so, government can take advantage of the options that are created due to the

maturation of the private sector and evolution in the industrial base. So, in summary, human activity is moving outward from the Earth with government leading the outermost expansion and private enterprise evolving to provide stability and sustainability in government's wake. While this is a simplistic model, it helps create a framework for us to establish a strategic approach to human spaceflight. I might note that this model is applicable to civil space and commercial development but not national security-related activity in space, which will remain the purview of government.

This is a model that, in some form or another, many in the industry espouse even if it is not described as an expanding bubble as I have illustrated in Figure 1. Indeed I believe NASA is attempting to create a framework based on this model, but I would argue that it is difficult for it to achieve this vision comprehensively as a single agency, outside of a larger, more nationally comprehensive view of what the United States is and should be doing in space.

Before I expand on this further, I would like to address why the government, with its goals and investments, is and should be (for the time being) the driver for the expansion of human engagement in space. I think it is important to note that true exploration is occurring at the leading edge of the bubble. As we expand human reach further into the solar system away from Earth, new technologies require development, new operational paradigms require testing, and potentially even new program management techniques will need to be established. Any one of these areas alone can be high risk and all require investment, and there is no clear understanding of how much investment will be necessary to be successful. In addition, the return on that investment is unknown or highly uncertain at best. The government is the natural investor and developer in such a scenario—it is not driven by profit motives, but has other concerns. I would add that it is quite possible that in the future companies may be driven to conduct exploration missions outside of a government framework and government investment; I would argue, though, that based on where we are today the business case and profit motive for such activity is still solidifying.

Even though, for the reasons I just articulated, the government has an important role in driving human expansion into space, by no means does that mean that it does so alone and absent partnership with industry. How the government defines and executes those partnerships is the critical strategic question that we struggle with today. Answering this question clearly and thoughtfully is vital. With a truly long-term and integrated strategic plan, government investment can be leveraged to meet its goals in ways that address the maturation of U.S. industry's capabilities in space as well as the development of a non-government-based economic sphere off of the planet. The identification of an effective strategy requires that two key questions must be addressed:

1. What are the technologies, knowledge, and experience base that the government wants to have available for broad dissemination to industry fifty years from now?

2. What are the capabilities and services that the government, for a myriad of reasons, and private industry, driven by their own motives, are interested in developing that can potentially sustain viable space-based businesses after leveraging initial government investment?

With regard to the first question about broad dissemination in the future it is worth noting that Elon Musk has talked about the importance of several publications on rocketry and rocket propulsion, knowledge funded by government investment during the Apollo era, that were the genesis of SpaceX. That is just one example of how the innovations occurring today in the space sector were incubated by decades of government-sponsored research and development (R&D). So, consequently, we have to think about the investments that the government is making in R&D today and project into the future how the results of that investment will enable the next wave of innovation. I believe it is necessary to address this question on a national level from the viewpoint of not only what technologies the U.S. space industry can benefit from, but also from the lens of identifying what technologies are critical for the United States to maintain or take a lead in globally. The answer to this question will help guide R&D investment and spending, as well as shape partnerships.

Regarding the second question about private industry developing capabilities and services that the government can leverage, I would like to illustrate the success of the commercial cargo program. Because the contracted companies were able to apply decades of NASA technology and know-how, they demonstrated the ability to develop and operate a reliable cargo delivery service, freeing NASA from the need to focus on this effort. While only the U.S. government still primarily uses these systems, the companies have the ability to provide these services in the future to other customers. Going forward NASA has to decide where it is appropriate to develop similar partnerships. The question should be addressed from both an economic viewpoint as well as an industrial base/national security lens; the government has many different goals driving decisions. The approach taken in addressing this question will help guide mission architectures, partnerships, acquisition strategies, and, to a certain extent, the types of international collaborations in which we might engage. Done correctly, this second question should begin to be addressed by the NASA Human Exploration Roadmap due to Congress in December 2017.

Through the National Space Council we, as a nation, have an opportunity to address these questions and others. The Council, as it is structured, has the ability to work across government

to create and integrate a comprehensive national space strategy and then to implement it effectively. I can imagine four main pillars that might inform a national strategy: continuing exploration beyond low Earth orbit, creating an economic sphere in low Earth orbit, national security, and driving and influencing the “norms” for engagement in space for humanity. A government-wide effort is required. The Council touched on this at its first meeting, for example, when discussing the topics of rules, regulations, policies, and enabling laws that might influence space activities. All of these issues encompass the supporting infrastructure that is vital for the success of a framework based on the model I have described. The Council strategically answering these key questions will allow several decisions related to NASA to come into focus—decisions about where NASA (and other government agencies) should invest in technology and capability, decisions about how to help industry establish an independent economic base in space while simultaneously pursuing NASA’s mission to expand human presence outward, and decisions about NASA’s role in leading or establishing international collaborations for exploration.

Given such clarity there is no reason why a framework cannot be crafted that can send us to the moon, Mars, and beyond, while supporting and nurturing private economic activity in space. From the framework, missions can then be designed in the context of the broader strategy that advance humans into the solar system while developing the capabilities and experience-base of U.S. industry.

I would like to pause here to emphasize an important point; one that many of us in the space industry have emphasized time and time again. The United States needs a comprehensive national space strategy accompanied by a continuous long-term commitment for its execution. It should be crafted such that it allows us to leverage our resources for the maximum benefit of achieving all goals identified. I repeat, because this is critical, to be successful in our space endeavors it is imperative that we commit, as a nation, with a constancy of purpose for the long term—it is the nature of the space business that it takes time, patience, and constant purpose to make advancements.

Crafting such a strategy, while complex, is possible. It is complex because any strategy has to take into account the constraints of our governance structures, general politics, and our tendency as human beings toward short-term thinking.

A committed long-term strategy is necessary but not, by itself, enough to ensure the success of the U.S. space program. To be effective and produce the desired results, sufficient resources need to be allocated to implement the plan. This is something that NASA has been challenged by in the past and continues to be challenged by today. When I joined the agency in 1996, NASA

received approximately 7/10ths of a penny for every tax dollar paid. Today, in 2017, the agency receives approximately 5/10ths of a penny for every tax dollar paid. This is despite the fact that the number, breadth, and complexity of programs has increased in that same time frame. I applaud NASA for working diligently to cut costs, streamline processes, and identify new ways of doing things that has allowed it to manage to this point in time.

However, fundamentally, NASA faces constraints on how efficient and streamlined it can become as its budget shrinks; it has limited control on the expense side of its budget. The politics of the situation give it no freedom to adjust overhead, either facilities or civil workforce, whether in size or skill set, as well as in some cases, the management of task assignments around the agency. To execute a long-term strategic U.S. space program in a constrained budget environment effectively and successfully, NASA must be given the ability to make decisions and take action in these areas. Without that freedom, an increasing portion of NASA's shrinking budgets will go to maintaining the agency as an institution and not to successfully executing its programs. The model I described earlier depends on both a healthy government effort and a strategically husbanded and growing industrial base. With a budget allocation of only 5/10ths of a penny per tax dollar, ignoring this dynamic and expecting lofty achievements cripples our collective (both government and industry) efforts to succeed now and in the future.

I would also like to take a moment to address one other critical aspect of resource allocation. Clearly having adequate resources is imperative, but equally vital is the phasing and consistency of the flow of those resources. Developing space hardware is complex and technologically challenging. As stated earlier, every program in existence today, regardless of whether it is primarily government funded or completely privately funded, and regardless of acquisition approach, has had to face, and likely will face again, technical, manufacturing, and operational challenges. What we do is hard. Period. Uncertain and improperly phased budgets as a result of lack of clarity in funding timelines add extra management challenges that drive inefficiencies, ultimately affect schedules, and drive decisions that trade off engineering design versus operational complexity. I saw this dynamic at work in the early days of the International Space Station program. Flatline budgeting—an approach that did not take into account the changing funding needs during different phases of development programs—and uncertainty in funding levels—affected engineering decisions that resulted in driving operational costs higher in the long term. A program with an optimized multiyear and appropriately phased budget can absorb more initially expensive engineering designs knowing that the result will provide lower operational costs and hence overall net savings over the life of the program. The current budgeting process, including the regular usage of continuing resolutions, threat of government shutdowns, and lack of a stable budgetary environment, prohibits this kind of comprehensive trade space to be used. With a budget allocation of only 5/10th of a penny per tax dollar,

introducing flexibility and constancy into the budgeting process is another lever that will allow NASA to optimize program execution, regardless of the acquisition methodology being employed.

We are living in a time of transition as we redefine how humans engage in space. Many decades of government investment and experience have produced a dynamic in private industry that is driving a new approach to human spaceflight. We have to consider carefully how we manage and drive change while continuing to explore and expand our technology and knowledge. Now, more than ever, the nation must commit to a bold strategy that provides multiyear stability and that is adequately resourced.

This transition started about ten years ago, and I suspect that it will continue for another ten years or so as we figure out what the next “small step for mankind” looks like. It is a grand experiment, and we are forging the path and writing the rules as we go. We have a unique opportunity at the moment, but to take full advantage of that opportunity it is imperative that we establish a strategy that will guide our efforts. The strategy cannot be so constrained that it will stifle the energy and innovation, but must have enough structure to ensure coherency in direction. We still have a lot to learn; some of our lessons are going to be difficult and painful. We have to be prepared to meet those challenges and promise ourselves that we will persevere. Above all, we must remain committed, strategic, and flexible. And we must also provide sufficient resources to progress along our journey.

The transition that is occurring as we evolve to the next phase of how humans engage in space is a goal that we have been pursuing for many decades. How we choose to guide, nurture, and define our expanding human presence and outward exploration of space will determine our country’s role in the next century. The roots of our nation lie in exploration, expansion, and economic development; from the arrival of the first immigrants and settlers at the founding of our nation to the westward expansion across the continent, we have faced the challenges, forged new paths, and overcome all obstacles. As we expand into space, the next frontier, I am confident we can tap into that same spirit and energy. I know the passion and dedication of the people in our industry, and I know their ingenuity and determination to succeed. I know that our national leaders, no matter which branch of government or party affiliation, understand the importance of space for the future of our country. I do not know how we can fail if we apply our minds and energies toward success.

Again, thank you for the opportunity to address this body and thank you for your continued support of our nation’s space program. I look forward to answering any questions you may have for me in this regard.