Written Statement of

Mr. Daniel L. Dumbacher
Executive Director
American Institute of Aeronautics and Astronautics (AIAA)

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

"Keeping Our Sights on Mars Part 3:
A Status Update and Review of NASA's Artemis Initiative"

March 1, 2022

Introduction

Chairman Beyer, Ranking Member Babin, and distinguished members of the subcommittee, I want to thank you for the opportunity to speak to you today about complex space systems engineering, especially as it relates to NASA's Artemis initiative. As a former NASA program manager, I have led several major NASA programs, including systems in service today, and the establishment of the Space Launch System (SLS) and Orion programs. I currently serve as the executive director of the American Institute of Aeronautics and Astronautics (AIAA), the world's largest aerospace technical society with nearly 30,000 individual members. I am here representing the interests of our nation's aerospace professional community.

Over the span of my 33-year career at NASA, I participated in several major space hardware development and operational programs. I personally understand the opportunities and challenges presented by planning, designing, building, testing, and operating space systems, particularly when human lives are at stake. The harsh realities of developing and flying space systems for humans require exacting engineering, our best talent, and persistence. This is risky business.

Today's aerospace industry recognizes the need for developing and fielding systems at a more rapid pace. In the past, human space exploration set its own schedule, with the notable exception of the Apollo program that was driven to succeed by a presidential imperative. The Apollo program established the approach of large-scale systems engineering and program management that are widely used across today's aerospace industry. Now in the 21st century, with significant achievement in space systems programs accomplished via the Space Shuttle and International Space Station (ISS) programs, new capabilities have been developed and continue to be developed by the commercial space industry, along with the government capability.

Recently, AIAA held its annual AIAA SciTech Forum, the world's largest event for aerospace research, development, and technology. The weeklong event's theme was "Enabling Sustainability Through Aerospace Technology." During the opening plenary session, Brigadier General Leon Johnson, USAF (Ret.), addressed sustainability from an end users' perspective. He candidly spoke about our need to move faster, doing so at a pace to keep our technological edge over our peer and near-peer competitors. General Johnson made the very apt comparison of China behaving like Netflix and the United States like Blockbuster, or China as Amazon and the United States like Barnes and Noble. I believe his point is valuable to consider in this testimony – we must develop new space systems at the increasing pace of innovation, so we are not overtaken by other spacefaring competitors.

In the Apollo era, we felt a sense of urgency and used a "can do" approach that accelerated us from a presidential mandate to a moon landing in less than 10 years. Unfortunately, that urgency is lacking today. NASA is not presently positioned to move faster. A new way of thinking is required.

The speed of innovation is increasing, and the aerospace community recognizes the necessity for improvement. There are several important factors needed to capitalize on the rapidly evolving capabilities in the aerospace sector, including:

1. A clear strategy and focus for what is to be accomplished, why it is important, with consistency over time.
2. A clear systems engineering approach, serving as the glue to bring the program elements together. The program elements must operate together and independently within defined constraints.
3. A greater tolerance for risk at certain points in program development, assuring safety and balancing schedule, and cost.
4. The development and growth of a talented workforce who will make the strategies a reality.

The Need for Clear Strategy

First and foremost, an organization needs an overarching, clear, communicable, and stable strategy. Such a strategy must describe goals and objectives, and define the program elements needed to achieve the objectives. This strategy establishes and communicates the "why" so that the "what" and the "how" can be developed and accomplished. The "what" and "how" are performed through the space systems engineering effort. A well-developed strategy establishes the framework for the program elements to be developed in concert with the integrated whole and to operate safely while achieving the goals and objectives.

For example, the SLS, Orion, and Exploration Ground Systems planned to return humans to the moon and explore beyond flow from the strategy developed at NASA via the Human Exploration Framework Team in the 2010 time frame. Doug Cooke, as a witness before this subcommittee in September 2019, eloquently explained the strategy behind cancelling the Constellation Program and moving in a new direction. The analysis established the program elements needed to accomplish the overarching objective of returning to the moon to stay, and eventually exploring beyond the moon to Mars, in terms of safety, mission reliability, schedule, and overall systems cost. Within this strategy the systems engineering approach was initiated and the acquisition approaches were developed. Additionally, a clear, understood strategy builds the case with external stakeholders (Congress, Executive Branch, industry, academia) for their support in funding and participation.

Mike Griffin and Jim French, in their book *Space Vehicle Design, Second Edition* (AIAA, 2005), define space systems engineering as the "… art and science of developing an operable system capable of meeting mission requirements within imposed constraints including (but not restricted to) mass, cost, and schedule." I will explicitly add the additional requirements of *safety* and *risk* to this definition. These requirements and constraints become the driving decision criteria for the multitude of decisions to be made in the development and execution of the overarching strategy.

Space activities by their nature are highly complex. They require high precision, high performance, and extreme reliability and safety, and must be operable within the mass, cost, and schedule constraints. This requires a highly integrated space systems engineering effort to deliver the strategic objectives, while assuring the needed elements physically operate together. Success demands a clear understanding of what is to be accomplished, an ability to objectively assess options within the framework of the strategy, and a decision process that works toward what is best to achieve the strategic objectives.

Complexity increases as we move further into the space environment, sustainably returning to the moon and exploring Mars and beyond. Today, the commercial space enterprise also adds a level of capability, economic opportunity, and potential to carry out the strategic objectives with less cost and more speed. This increases the need for clear strategic direction, as the recently released NASA Aerospace Safety Advisory Panel report correctly identifies.

The Need for a Systems Engineering Approach

As the program elements are defined and cost and schedule estimates are developed to achieve the strategy, the following criteria are required:

1. An overall understanding of how all the pieces of the program fit together,
2. An understanding of how the system will operate and tolerate malfunctions and failures, and
3. The establishment of options and backup plans to address risks and potential problem areas, with on ramps for new technologies and capabilities.

Such a systems engineering effort requires highly interactive teams with clear decision criteria and risk acceptance decision processes and authority. This effort must be very intentional, understood, and clear. A piecemeal, uncoordinated approach is doomed to failure. Therefore, management must be expert in systems engineering, analysis and integration with clear reporting authority throughout the program elements. The necessary integration from the lowest to the highest levels must be driven to success; it cannot be expected to just happen.

For the various and essential program elements to successfully operate together, the acquisition models and selections must be coordinated within the framework of the overarching strategy. These cannot be driven by ‘favored status’ for one acquisition approach or another. Rather, the various acquisition models to be applied to the multiple program elements must include the needed information sharing, clearly understood and consistent decision criteria, and clear decision authority based upon program interfaces and impact to

strategic objectives. Acquisition decisions must be made to assure the strategy figures of merit (safety, performance, mission reliability, schedule, and total cost) are accomplished.

The Need for Risk Tolerance

With these complex endeavors comes known and unknown risks. Program leaders must continually evaluate the overall progress, risk posture, and potential external forces. This will necessitate backup plans, options, and risk mitigation plans to address potential influences and outcomes. Everyone on the team must remain curious and challenge the status quo to assure success of the overarching strategy, and verify risk is understood and addressed.

Understandably, no one organization or entity can execute the strategy alone. Undertakings, such as the Artemis Program, require the best talent and capabilities from across the existing and rapidly developing industry base, government leadership, and academic research. All of this must be integrated and ultimately work together. Therefore, the various program elements and their acquisition models must be coordinated and integrated with shared information, clear leadership and decision authority. Importantly, the necessary risk assessments across the interfaces and within the program elements are critical to success of the strategy. We must remember that a large-scale team effort is necessary to ensure all aspects are considered and thought through. Moreover, the final analysis must include a clear decision authority. The appropriate level official must own the decision-making authority on risk acceptance and interface trades to meet safety, cost, and schedule requirements. This does not necessarily mean pushing all decisions on risk to the most senior level official, which can slow progress unnecessarily.

Clearly, the technical community is key to accomplishing the strategic objectives. It is essential that the technical community address all the strategic requirements. Safety is a clear requirement to accomplish the strategic objectives; we must be able to get the astronauts safely to the moon and safely return them home to their families. Technical performance can be balanced with schedule and cost. Recognizing that safety, technical performance, cost, and schedule are all interrelated is key to strategic success. We must constantly be in search of how to improve safety, and assuring safety is not negatively impacted by performance, cost, or schedule decisions. This risk acceptance must be done at the appropriate levels for the stage of the program lifecycle.

The Need for a Talented Workforce

I would be remiss if I did not address the workforce needed to make the strategy a reality. After all, it is all about the people who make it happen.

Space exploration is a long-term endeavor and therefore requires a broader view of the needed workforce. The workforce employed by companies, government labs, and academia is ever evolving and changing. Career journeys will be built upon strategy, and mission and consistency of strategy is key to enabling the best and brightest to commit to careers in the space enterprise. People will need to grow and learn new skills as those before them move through their own career and personal journeys.

We must continue to expand, grow, and enhance the talents of the workforce through inclusivity, capitalize on the various perspectives of our diverse demographic communities, and, most importantly, continue to build a community where everyone is treated with respect and as equals with different perspectives and talents.

We must encourage team leaders, at all levels and especially the most senior levels, to remain vigilant and totally focused on executing and accomplishing the established strategy. It is easy to lose focus in the day-to-day tyranny of the urgent. Experience has taught us well that the successful organizations are laser focused on accomplishing their respective strategy and assuring the team has the tools and resources necessary to be successful. Discipline is key, along with the team's ability to speak truth to power, identifying problems and potential solutions, and moving forward once decisions are made.

We must also allow the workforce to test to failure, giving us an understanding of the limits of our designs. Allowing people to seize opportunities for rapid learning and accept risks will benefit the mission and strategy, as well as their personal growth. While we cannot fail when astronauts' lives or the safety of our teammates is at risk, our tendency to avoid all risk at all cost and all times must be tempered with the need to learn and grow our workforce, to understand the limits of our designs and operations, and to learn rapidly from a test in place of analytical perfection.

Conclusion

In summary, it is my expert opinion that there are four crucial elements required for successful complex space endeavors:

1. A clear and understood strategy is absolutely critical. The strategy underpins all decisions moving forward and must remain the clear focus of the entire team – from senior leaders to the skilled individuals building the hardware.
2. We are building a complex system of systems; the clarity of "why", "what", and "how" establishes both the framework and the foundation for success. The systems engineering and integration is the glue that brings all the elements together for safe operation. It must be treated with respect, be clear in its implementation, and be

adhered to with a team discipline. In addition, the acquisition decisions must be made in the context of the executable, understood strategy. We must be adaptable to incorporating emerging capabilities and opportunities for the long-term evolution and sustainability of the overarching strategy.

3. Ensuring safety, delivering technical performance, achieving cost targets, and meeting schedules are possible as a balanced approach to achieving strategic success. Throughout the program lifecycle, risk acceptance must be managed at the appropriate level to remain in balance with the other elements.
4. We must continue to expand, grow, and enhance the talents of the aerospace workforce. An intense focus on diversity, equity, and inclusion will benefit our innovation and further our pursuits. We must push our talented teams to test their ideas and learn from their failures as a vital component of space programs.

This process will take courage, require hard decisions, clear communication, and focused leadership. We can do it, we have done it, and the generations to follow demand that we do it for their future and those that will follow them. AIAA stands ready to support and further this all-important human venture.

Thank you once again for allowing me to address this body and to share my experiences as a former NASA program manager. I would also like to thank this Committee for its continued support of our nation's space program. I look forward to answering any related questions.