Mission Assurance—A Key Part of Space Vehicle Launch Mission Success

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Recent years have shown unprecedented levels of launch success for both Air Force and National Reconnaissance Office (NRO) missions. In order to achieve these results, many people and organizations have employed processes and worked in a disciplined and collaborative fashion to ensure every aspect of the mission has been examined, every scenario has been considered, and every risk has been understood, accepted, or mitigated before a multi-million dollar launch vehicle ignites, carrying a billion dollar payload. This collection of activities over the lifecycle of a space vehicle development program and through launch is called mission assurance.

Like in other national security space agencies, mission assurance is a key part of ensuring mission success for Air Force and NRO launches. All launches involve integrating the activities of one organization with another, whether those organizations are both internal to the Air Force or between the Air Force and the NRO. The mission assurance process allows the disparate organizations involved in the lifecycle of a program to speak in a common language with a common framework about different aspects of a mission. With mission assurance, program offices use a structured, disciplined, and layered verification process that requires rigorous analysis by subject-matter experts on every aspect of a mission to ensure all risks are known. Requiring programs to go through this process ensures that no rock is left unturned before launch. Mission assurance gives us the highest level of confidence to proceed with launch and ultimately ensures the best opportunity for mission success.

The Need for Strong Space Vehicle Mission Assurance Practices

In the late 1990s, the US launch industry suffered five major failures, including three Titan IV vehicles, losing Air Force and NRO payloads totaling over $3 billion. As a result of these failures, the president asked the secretary of defense to examine the failures and provide a report on the causes and corrective actions being taken to prevent their recurrence. The resulting Broad Area Review (BAR) of space launch, chaired by former US Air Force Chief of Staff, General Larry D. Welch, retired, was completed in November 1999. Three follow-up reviews were conducted through 2003.

The series of BAR reports were critical of existing mission assurance processes, as modified during a period of acquisition reform in the early 1990s. The BAR recommended changes to strengthen those processes by returning to earlier methods to prevent future failures. The BAR recommended incorporating several key features, such as clear accountability, strengthened systems engineering, process discipline, independent reviews, and government involvement in the mission assurance process.

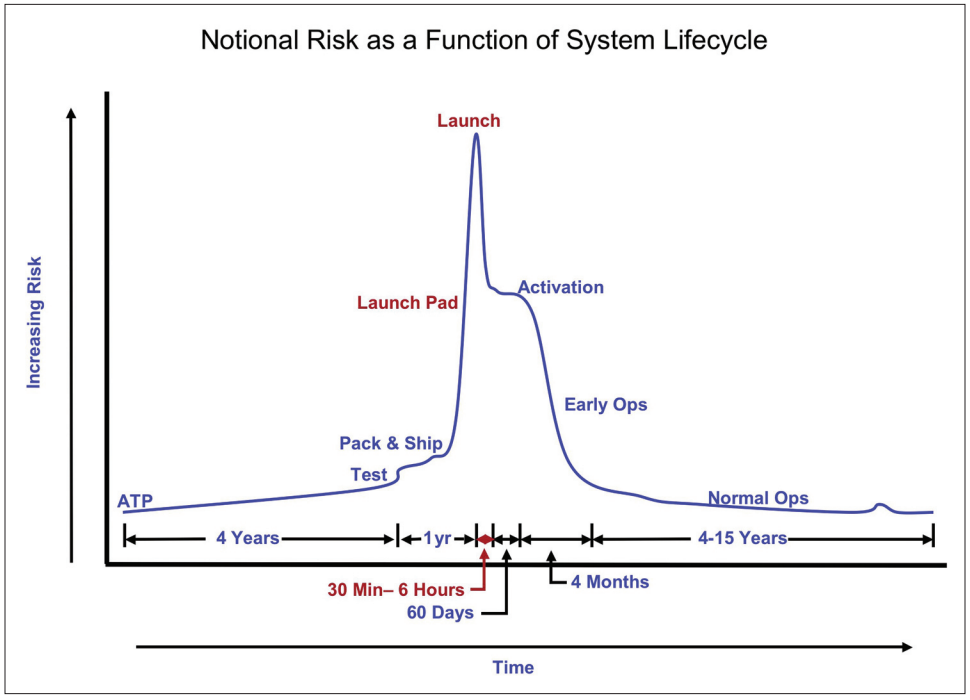

Figure 1. This notional chart shows that launch often is the greatest risk to any space system over its entire lifecycle.

Beyond the specific launch failures of the 1990s, mission assurance is a mandatory process that lays the foundation for successful launches. Each launch offers one—and only one—chance at mission success. There are no unconstrained post-launch orbital corrections, and there are no de-orbits of spacecraft to fix faulty wiring. There is no pre-launch flight testing; there is no second chance for success. We must ensure that every launch places a satellite in the correct orbit and that once there, the satellite performs flawlessly. Because of this, we continuously incorporate the lessons of the BAR into the Evolved Expendable Launch Vehicle program that provides the Delta IV and Atlas V space launch vehicles.

Defining Mission Assurance

Mission assurance is both a process and a culture that must be adhered to by all individuals involved with launch. As a process, mission assurance is an iterative,

continuous, technical, and management activity employed over the entire lifecycle of a launch system to achieve confidence in mission success. Mission assurance includes a disciplined application of systems engineering, risk management, quality assurance, and program management principles. Mission assurance is performed by a partnership of both contractor and government, beginning at concept design and continuing through launch operations and post-flight analysis.

The launch mission assurance process consists of three primary elements. The first two, system design assurance and operational mission assurance, together demonstrate that the fully-integrated launch vehicle and its payload have been reviewed, all known technical issues have been assessed and resolved, residual launch risks have been satisfactorily assessed and accepted or mitigated, and confidence in launch mission success is acceptable. This process requires an in-depth review and validation of the launch system design, launch system manufacture and preparation, launch site processing, payload integration and mission design, and flight and ground hardware, software, and interfaces. These two elements result in a design certification and launch readiness verification.

Third, independent space vehicle mission assurance includes additional technical assessments of the system design to increase confidence that no issue has been missed or incorrectly dispositioned during the certification and verification processes. This process represents a third set of eyes to ensure the contractor and program office's technical and quality assurance processes have been adequately performed and all significant mission risks have been independently assessed.

Both the Air Force and NRO are doing this routinely and systematically. The Air Force, through the Space and Missile Systems Center (SMC), has its Independent Readiness Review Team. The NRO, through its Office of Space Launch, has its Mission Assurance Team. Both organizations perform mission assurance checks and readiness assessments as independent arms of their respective commanders.

Carrying out these structured and disciplined mission assurance processes is critical to mission success. But equally important is maintaining a culture of mission assurance. The way of doing the business of mission assurance requires strict attention to detail, rigorous analysis of issues, and a commitment to 100 percent mission success. Each individual must assume personal accountability and responsibilities both to perform successfully their part of the mission and to work collaboratively with others to ensure the process functions as a whole. This culture is revalidated periodically and passed along as experienced personnel depart and new individuals and teams step in. In addition, mission assurance is incorporated into various training classes and certification programs.

Though we have had an impressive string of successful launch performance in recent years, we must never become complacent with our successes. The culture of mission assurance requires recognition, acceptance, and continual awareness that each launch is unique and poses new and different integration challenges. While no two launches are the same, the process is. The mission assurance processes for the next launch must be carried out with the same rigor and focus as those for the last launch. We are only as good as our last launch.

Key Features of Space Vehicle Launch Mission Assurance

Procurement strategy. The first key feature of space vehicle launch mission assurance is the current "Buy 3" strategy for launch procurement that makes industry a full partner in the mission assurance process. Largely a result of the BAR, "Buy 3" expands upon and normalizes the mission assurance features that were added to earlier buy strategies. Unlike the "Buy 1" and "Buy 2" strategies, which were both for commercial fixed price contracts, "Buy 3" separates procurement into two components—one a fixed price and the other a cost-plus contract.

The fixed price portion of the contract is for the launch service—buying the hardware and touch labor associated with each individual launch, plus a mission success incentive. The cost-plus portion of the contract is to maintain launch capabilities for mission assurance—the workforce, facilities, and data sharing required to perform integration and launch, handle contingencies, and reach agreement—not just consensus—when issues arise. An award fee plan tied to this portion of the contract ensures that launch providers will maintain key mission assurance capabilities, irrespective of launch demands and timelines, and continue to perform quality work.

Unlike "Buy 1" and "Buy 2," with "Buy 3" mission assurance is no longer procured on an as-needed launch basis. Instead, industry has become a full partner in mission assurance because they are incentivized to maintain sound mission assurance capabilities across launches. This procurement strategy provides assured US access to space and ensures that launch vehicle providers maintain the infrastructure and expertise to deliver mission success.

Clear accountability. One of the key recommendations of the BAR was to de-fragment the accountability for spaceflight worthiness and launch. At the time the BAR was conducted, there was no single entity responsible for understanding and tracking the pedigree of a launch vehicle from design to delivery of a spacecraft on orbit.

Adopting the BAR recommendations, Air Force Space Command Instruction (AFSPCI) 10-1208, *Spacelift Operations,* and its lower level SMC Instruction 63-1201, assign overall responsibility to the commander of the SMC (SMC/CC) for delivering systems to orbit. These instructions implement Air Force Policy Directive 10-12, *Space,* Air Force Instruction (AFI) 10-1201, *Space Operations,* and AFI 10-1211, *Space Launch Operations*.

Together, these documents establish Air Force Space Command (AFSPC) roles and responsibilities relating to spacelift operations. The SMC/CC is responsible for certifying spaceflight worthiness approximately one to two weeks prior to launch. Concentrating this authority and accountability in the SMC/CC ensures that the certifying individual gains insight throughout the development of the satellite-launch vehicle system to make the certification with confidence.

Once that certification is made, equally important are clear roles and responsibilities between developers and launch operators in the final weeks before launch. AFSPCI 10-1208 and AFSPCI 21-202v2, *Missile Maintenance Management,* outline

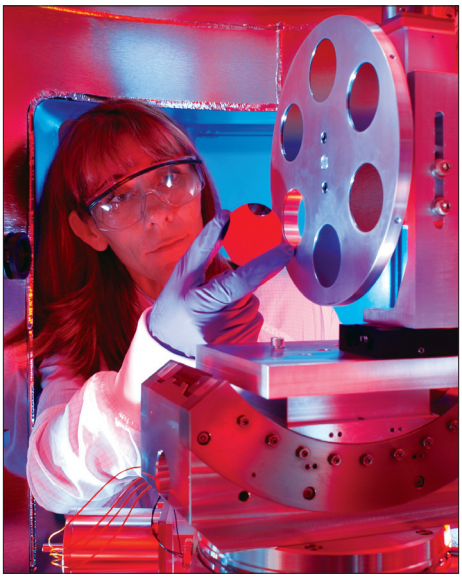

Figure 2. The Aerospace Corporation has a long history of developing tools, models, data, analysis, and testing capabilities to support mission assurance for both the Air Force and National Reconnaissance Office.

the interdependent responsibilities of the developers and acquirers at SMC or NRO and the launch operators at the 14th Air Force. Clarifying how these two organizations interact up to and on the day of launch assigns clear responsibility and accountability to ensure that nothing is overlooked due to confusion over roles and responsibilities.

One key individual in the final weeks between certification and launch is the mission director. Once spaceflight worthiness certification is made, the mission director is responsible for ensuring that flight worthiness is maintained all the way through the remaining operations, including countdown and launch. The mission director, under SMC authority for Air Force payloads and NRO authority for NRO payloads, is the overall mission team lead in establishing the focus for mission assurance and mission success.

Continuity and independent verification. The Aerospace Corporation, a dedicated Federally Funded Research and Development Center supporting both SMC and NRO, plays a key organizational and technical role in providing mission assurance.

First, The Aerospace Corporation provides the critical role of technical continuity for SMC and NRO. Though active duty military personnel rotate frequently through launch and system program offices, Aerospace employees can remain with programs through most or all of a development cycle.

In addition, The Aerospace Corporation maintains a depth of independent technical capabilities to analyze potential issues and render assessments on spaceflight worthiness. The Aerospace Corporation has a long history of developing tools, models, data, analysis, and testing capabilities. These processes and tools have been validated many times over through The Aerospace Corporation's ongoing support of all major Air Force space programs. Aerospace facilities, employees, and processes together create a level of technical expertise that has, many times over, been called on to determine whether a particular issue will result in mission failure. This technical depth and excellence is a critical component to mission assurance and final launch certification.

Finally, the fact that the same Aerospace organization, personnel, and processes support both SMC and NRO ensures a bedrock foundation for those missions requiring partnership between SMC and NRO.

Review process. The final key feature of the space vehicle launch mission assurance process is the series of extensive reviews, both those leading to the spaceflight worthiness certification and go/no-go decision for launch and the post-flight data reviews conducted after launch.

The three major reviews preceding every launch are the Mission Readiness Review (MRR), Flight Readiness Review (FRR), and Launch Readiness Review (LRR). These critical reviews are in addition to the many reviews that the program office, contractors, and The Aerospace Corporation conduct throughout the design, development, and integration process.

The first critical review, the MRR, evaluates the flight hardware, launch and support facilities, range and orbital operations, and readiness and training of the operating personnel. The purpose is to determine whether all elements of the launch system are ready to accept the payload and proceed toward launch. Successful completion typically results in a "consent-to-ship" the payload to the launch site, five or six months prior to launch.

The second critical review, the FRR, focuses on launch vehicle, spacecraft, range and satellite control network readiness status; impacts from previous missions; open technical issues; and the launch mission assurance verification process. The purpose of the FRR is to ensure all stakeholders, including the system program office, launch program office, The Aerospace Corporation, prime contractors, and SMC/CC agree that the launch stack is spaceflight worthy and ready to begin final launch operations, one to two weeks before launch. The FRR results in the SMC/CC making the spaceflight worthiness certification based on the recommendation of the mission director and the senior representatives of the launch team.

The final critical review, the LRR, ensures that all elements of

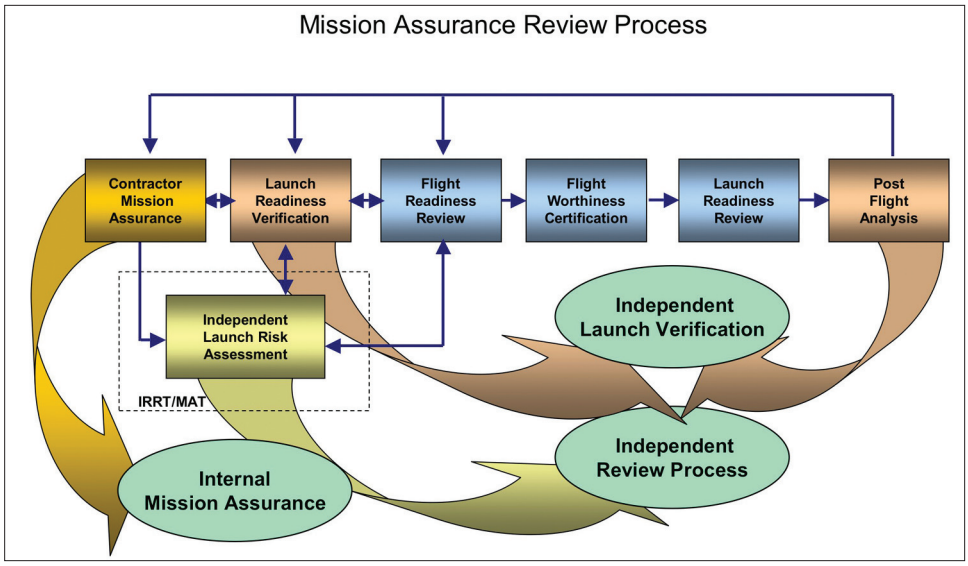

Figure 3. Pre- and post-flight reviews ensure checks and balances in the mission assurance process.

the launch system are operationally ready to support the launch. Typically conducted the day before launch, the LRR results in a final determination to enter the launch countdown. The spacelift commander (SLCC), as the launch decision authority under the direction of the commander of AFSPC, chairs the LRR and calls for the launch site, range safety, and range operations go/no-go determinations for launch. During day of launch operations, the SLCC makes the "clear to launch" statement following the mission director's final "go for launch" decision. This decision is based on the mission teams' assessment of the integrated launch vehicle and spacecraft stack.

Following launch, formal post-flight reviews are conducted by both The Aerospace Corporation and the launch vehicle provider for each mission. The post-flight analysis assesses any anomalies for a given flight, as well as any specified investigations in the event of a mission failure or mishap. Output products from each review, post-flight analysis, and lessons learned are assessed for impact on subsequent missions and the launch vehicle fleet as a whole. These reviews ensure that maximum value can be carried over from the lessons of one launch to the next.

This extensive and exhaustive review results in more than 2,000 individual items being certified before launch, as well as many more areas examined in the weeks and months following. This attention to detail, from the bottom up, across every aspect of the mission, and through several different individuals and teams, is a critical component of mission assurance.

Mission Assurance Works

There are many examples of how the rigorous mission assurance process has detected and corrected issues that would have caused launch failures if left uncorrected.

In one example, an engine bearing failed several acceptance test firings, raising concerns over its reliability. Technical experts at The Aerospace Corporation analyzed test data and bearing design, manufacture, and materials. They concluded that the probable cause of the failure was a change to a lower-strength material for the bearing. They also concluded that low pressure in the turbopump gearbox during the initial test firing of the engine contributed to the failures.

Based on these findings, new criteria were established for bearing acceptance and for the initial hot fire test run. Engines scheduled to fly were screened using these criteria, and where required, the bearing was changed. Additionally, the turbopump gearbox pressure requirement has become a standard screening criterion for Air Force engines and provides added engine reliability.

Detecting this issue during testing shows that the many reviews, tests, and certifications are critical for mission assurance. The ability to examine the issue and identify its root cause demonstrates the necessity of the technical expertise of The Aerospace Corporation and their partnership with the Air Force and NRO. Incorporating the findings of these analyses into the overall verification means the mission assurance process will forever remember this issue and ensure that the same conditions do not place future missions at risk.

Strengthening Launch Mission Assurance for the Future

A hallmark of mission assurance is striving for continuous improvement. Each mission and each launch teaches us one more thing about risk mitigation and technical excellence for spaceflight. Continuing the mission assurance process, consciously identifying successful and unsuccessful practices, and incorporating new developments will strengthen the mission success ratio.

As the space vehicle launch mission assurance process itself is improved, we also must share successful practices across our space enterprise. One existing example of this is the annual Mission Assurance Forum. This forum brings together stakeholders from industry and government across the space vehicle enterprise to describe and baseline current processes, share lessons learned, and disseminate best practices. Increased interactions between the Air Force, NRO, NASA, Missile Defense Agency, United Launch Alliance, prime contractors, and others result in increased cross-pollination and increased mission success for all types of US space assets.

Conclusion

In the almost decade since the costly failures of the late 1990s, SMC and the NRO have adopted a "back-to-basics" approach to mission assurance. This refocused mind-set has permeated the national security space community and is manifested in a culture of assuring each mission is flightready and flightworthy. From the SMC/CC down, each individual involved in contributing to the mission feels accountable for thoroughly resolving every issue and assuring 100 percent mission success.

These revitalized initiatives will increase the credibility of the space vehicle acquisition community, strengthen partnerships between the Air Force, NRO, and the other national security space agencies, and deliver the world's best space capabilities to our joint warfighters and the nation.

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Major General Pawlikowski has served in a variety of technical management, leadership, and staff positions in the Air Force. Previous assignments include vice commander, Space and Missile Systems Center, Los Angeles AFB, California, and commander, Military Satellite Communications Systems Wing, Space and Missile Systems Center, Los Angeles AFB, California. She was selected for promotion to major general in March 2008.