

ORS-5 System Acquisition Successes and Regrets

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ABSTRACT

In August 2017, the Operationally Responsive Space (ORS) Office launched its first operational system since ORS-1. The ORS-5 (SensorSat) satellite developed in response to a 2013 United States Strategic Command (USSTRATCOM) urgent need for space situational awareness. Developed by MIT Lincoln Labs (MITLL) the ORS-5 satellite's cost was less than \$50 million. It served as a pathfinder for small satellite technology and procurement, was the first to operate on the Multi-Mission Satellite Operations Center 2.1 (MMSOC 2.1) ground system, and was the first commercially licensed Department of Defense (DoD) launch. The entire mission, to include the Minotaur IV launch vehicle, was under \$100 million.

In order to meet the principles of affordability combined with rapid timelines, ORS-5 relied heavily on streamlining defense acquisition processes and documentation, exercising a series of increasing fidelity demonstrations to rapidly assess and incorporate lessons learned, and accepting a higher risk profile to achieve success. Although ORS-5 was a lower cost system with a higher risk profile, the stakeholder community initially expected the same standards and risk profiles typical of larger, longer programs. As an operational prototype, ORS-5 provides key information to the warfighter enabling more exquisite satellite systems to utilize their full capabilities. ORS-5 demonstrated operational prototypes can meet requirements and provide value to the warfighter.

This paper documents the successes and regrets associated with acquiring this class of space vehicle and recommends how to apply lessons learned from ORS-5 towards future rapid prototype missions.

INTRODUCTION

Founded in 2007, the Operationally Responsive Space (ORS) Office was renamed the Space Rapid Capabilities Office (SpRCO) at the end of 2017. Part of the office's congressionally mandated mission is *"to contribute to the development of low-cost, rapid reaction payloads, busses, launch, and launch control capabilities in order to fulfill joint military operational requirements for on-demand space support and reconstitution."* In order to bind program costs and still meet rapid timelines, the Office executes its programs under a design-to-cost philosophy using threshold requirements rather than designing to objective requirements typical for national security space system developments. Under a congressional exemption to the Joint Capability Integration and Development System (JCIDS) used to develop and approve requirements, United States Strategic Command (USSTRATCOM) validates the SpRCO mission requirements. The resulting requirements documents focus on threshold

requirements and are typically less than five pages--much shorter than traditional programs. This experience in developing low cost systems and providing viable operational capability was key to the success of the ORS-5 space situational awareness mission.

Started in 2014, the ORS-5 mission was in response to a USSTRATCOM-identified urgent need for space-based situational awareness. The entire mission consisting of the space vehicle, launch service, and ground system, cost under \$100 million. Massachusetts Institute of Technology Lincoln Laboratory (MITLL) built the ORS-5 SensorSat space vehicle. It was MITLL's first satellite development in over 14 years. The Office purchased a commercial launch service from Orbital-ATK using the Minotaur IV launch vehicle. The Minotaur IV had a long history of successful launches but this would be the first from Cape Canaveral. The satellite would operate on the

Space and Missile Systems Center (SMC) Advanced Systems and Development Directorate's (SMC/AD) new Multi Mission Satellite Operations Center version 2.1 (MMSOC 2.1). A planned evolution from a previous ground system, MMSOC 2.1 was capable of operating a wide variety of spacecraft at one time and was the foundation for AFSPC's Enterprise Ground Services concept. Operations began using the MMSOC 2.1 at the RDT&E Support Complex (RSC) at Kirtland AFB and then transferred to the MMSOC 2.1 system at Schriever AFB. During the early phase of operations, a combination of contractors at the RSC and 1 Space Operations Squadron (1SOPS) personnel from Schriever AFB operated the satellite with full transition to 1SOPS at Schriever AFB prior to operational test and evaluation (OT&E). This was the first time 1SOPS operated a prototype system so soon after launch.

Launched on August 25, 2017, the ORS-5 mission currently provides tipping and cueing information to space warfighters at the Joint Space Operations Center in Vandenberg AFB, California.

SPACE VEHICLE

The space vehicle, developed and built by MITLL, was awarded and launched in under 3 years. Key to meeting this timeline was focusing on a stable set of threshold systems requirements, making appropriate system design trades, managing technical risk with government oversight, and using a build-up test approach. The results of the satellite development would be a highly integrated spacecraft and built to Class "C" standards with a three-year design life. (Please refer to DoD HDBK 343 for definitions of Class C.)

SpRCO programs are exempt by law from the standard DoD requirements validation process known as JCIDS. Under JCIDS, the Joint Requirements Oversight Council approves program requirements. Requirements approval can take as long as two years. Instead, USSTRATCOM approves SpRCO program requirements. The Secretary of the Air Force, as Chair of the ORS Executive Committee, approved the ORS-5 program on February 25, 2014. USSTRATCOM approved the requirements on June 10, 2014. It was a relatively short requirements document (4 pages) with nineteen clear, concise requirements. Those requirements remained stable throughout the years of development. Even though there were requests for modifications by other stakeholders, the program office held strong to the initial requirements set. Keeping to the USSTRATCOM-validated performance parameters reduced the potential for cost overruns and increased development time.

Even with threshold requirements, system development was not without difficulty. The developer had issues with components from subcontractors. The components required design and performance trades. As an example, the team had to make a decision on the design of the focal plane lens construction. This decision would either increase focal plane development timelines or add risk to the integration of the focal plane. The decision was to take more time in the focal plane design and development in order to reduce the integration risk. By making smart trades to ensure ease of manufacturing and integration at the cost of small performance parameters, the ORS-5 program preserved integration and launch timelines.

While managing some risks through hardware design, others required a different approach. Early program reviews of MITLL ORS-5 design identified critical weaknesses in flight software development. In response, the SpRCO established an independent flight software review. The resulting approach reduced risk by instituting a series of external and internal peer reviews, embedding program office personnel at the site, and integrating appropriate software builds with increasing fidelity hardware system capability demonstrations. This early focus led to large dividends later in the program as the flight software team became a strong portion of the effort. Unfortunately, they were in high demand by both the space vehicle and ground development activities. Based on cost trades, MITLL opted to keep the team small. The benefit resulted in efficiencies. The streamlined team worked quickly through challenges in order to meet hardware integration timelines. However, the small size of the team often meant a function was one person deep. As the program got closer to launch, unplanned software drops and increasing time demands to support ground system integration and test caused schedule delays.

Pathfinders were key in reducing technical and schedule risk during the development, integration, and test of the vehicle. MITLL employed a robust buildup concept and design architecture throughout spacecraft development. On the path to the final flight vehicle, MITLL developed a spacecraft representative FlatSat and an Engineering Design Unit (EDU).

The FlatSat was a high-fidelity representation of the flight vehicle laid out on a table. The FlatSat used flight-representative spacecraft hardware including the avionics subsystem to represent form and function of the flight vehicle as opposed to using flight simulators. Using the FlatSat, the contractor thoroughly tested subsystems and the flight software without impacting the schedule of the EDU or flight hardware. This approach yielded high confidence when introducing

new software builds to the EDU and flight units. With ORS-5 satellite now in operations, the team continues to use the FlatSat to test software changes before uploading to the operational spacecraft.

MITLL treated their EDU like flight hardware using a “test like you fly” mentality for assembly, integration and test. The EDU was a pathfinder to verify primary structure assembly techniques. Once assembled, the EDU served as the test article to produce the test-verified finite element model taking the flight vehicle out of the coupled loads analysis schedule. Removing the flight vehicle from the critical path allowed for parallel work and risk reduction activities without risking final flight hardware. MITLL also put the EDU through a full environmental test campaign to find issues early in the program. Lessons learned from testing the EDU refined assembly and test procedures for the flight hardware. This led to a highly successful and streamlined flight unit environmental test campaign. The approach was a culture shift for the government technical oversight team; it led to some resistance and uneasiness. The government’s primary concern was additional schedule margin consumed in the EDU test phase was better spent on the flight unit test campaign. With only one data point, an accurate assessment of such a strong emphasis on EDU testing is difficult, but it is worthwhile to explore further.

Successes:

- Stable requirements baseline ensured developers stayed on track
- Pathfinders for the integration and test campaign were instrumental to maintain schedule
- The Engineering Design Unit was key in identifying issues in spacecraft design
- FlatSat allowed quick mitigation of flight software discrepancies and user interface issues

LAUNCH VEHICLE

The launch vehicle was perhaps the least difficult part of the effort, but the team discovered new challenges during the weeks and days leading to launch. Given the small size of the SpRCO, the Office decided to purchase a commercial launch service to leverage industry best practices with respect to vehicle development and mission assurance. However, launching a Minotaur IV for the first time at the Cape from a launch pad not used in almost 20 years and the associated range impacts added its own issues.

The SpRCO purchased a commercial service from Orbital ATK. To get the spacecraft to the appropriate

orbit and inclination, the Minotaur IV launched from Cape Canaveral. The contract was firm fixed price (FFP), low cost (\$23.6M), with a 4 month launch window starting 15 May 2017. Orbital ATK was responsible for range safety, scheduling and operations, procuring a Federal Aviation Administration (FAA) commercial launch license, and launch vehicle mission assurance. Since this was a launch service, government-unique mission assurance was minimized to the maximum extent possible. The SpRCO spent another \$5M for the refurbished ICBM motors and associated mission assurance.

This mission was the first Minotaur IV launch from Cape Canaveral on a launch complex unused since January 1999. As the first Minotaur IV launch from Cape Canaveral, new challenges faced the launch team. For example, Orbital-ATK had to revise procedures to operate at the Cape. In addition, 45th Space Wing range and safety personnel were unfamiliar with the Minotaur series with the extra variation of it being a commercial launch service. To mitigate these challenges, Orbital-ATK and the SMC launch management team (SMC/LEX) conducted a pathfinder mission in February 2017. The mission consisted of shipping a simulated launch vehicle and motors from Vandenberg AFB to the Cape and simulating stacking the stages of the vehicle. They used the pathfinder to refine vehicle stacking, launch and safety procedures as well as assess any potential issues with the logistics of bringing the vehicle onto the range.

The launch complex, LC-46, had not been used in nearly 20 years and required extensive refurbishment to support the ORS-5 satellite launch. Space Florida, an organization created by Florida’s Department of Transportation to expand and develop its space industry, managed the overhaul of the state-owned site. LC-46 needed a great deal of work to overcome corrosion issues, upgrade electrical systems, and improve communication networks. Space Florida successfully managed the effort from beginning to end. However, neither Space Florida nor the program office had funds to add lightning protection at the site.

Given that the launch was to be in August, lightning was highly likely. There was sufficient protection on the mobile service tower, but once it rolled back, exposing the launch vehicle, no protection remained. All options for temporary lightning protection were too expensive. To mitigate the lightning protection issue, the team conceived a plan to roll the pad over the launch vehicle during times when lightning was close to the area. The team extensively practiced the procedures during the February 2017 pathfinder with 45th Space Wing Safety personnel observing. Using the pathfinder

results, the launch integration team developed the requisite procedures. However, a month prior to launch, the 45 Space Wing levied additional lightning mitigation safety measures. Individuals working on the pad had to evacuate when lightning warnings occurred.

Florida weather affected both stacking and day of launch operations. Once stacking began, multiple delays to integration occurred due to lightning warnings. In order to minimize the impacts to the launch vehicle processing timeline, the launch integration team worked in the very early morning hours when chances for lightning were lowest. By being flexible with work hours and with support from the entire team, the launch vehicle successfully processed and delivered on time. Lightning continued to be an issue on the day of launch with multiple storms in the area. The evacuation distances made it challenging to get back to the pad to complete final pre-launch steps.

Lightning protection was not the only concern. Despite the February 2017 pathfinder and regular range operations working group meetings addressing a number of issues for this first time launch, engagements with 45 Space Wing personnel in the days prior made it clear that there were some gaps in understanding the Minotaur IV requirements. The range setup needed to be adapted for the launch pad (cameras to confirm pad liftoff and other obscure corrections). This was not identified until days before launch. Incorrectly interpreted interface documents delayed reviews. The range, launch and program office teams persevered. After a short lightning-free window, they were able to roll back the tower in less than 15 minutes and launch on 26 August 2017.

Successes:

- On time launch at low cost
- Flexible and motivated team allowed for launch vehicle processing outside of normal work hours
- Team overcame last minute obstacles in order to ensure an on-time launch

Regrets:

- Better communication with launch range could have mitigated lightning and interface issues
- Roles/responsibilities between program office, contractors, range, safety were not well defined
- Needed to bring in 45 Launch Group to act as a liaison to the range and safety office

- Lightning protection system would have reduced launch vehicle processing risks

GROUND SYSTEM

In the excitement of launch, we have a tendency to forget that launch is only the prologue. The story begins when the ground talks to the satellite for the first time and after testing, sends data to the warfighter. Ground systems can be just as challenging as the space vehicle when it comes to development. In the early days of the then-ORS Office, ORS worked with SMC Space Development and Test Wing (so named at the time) on the first instantiation of the Multi-Mission Space Operations Center at Kirtland and Schriever AFB for ORS-1 flight operations. Based on the success of that effort, the SpRCO continued its partnership with the now known as SMC/AD. ORS-5 was the first mission to operate on the new MMSOC 2.1 ground system. Operations started at Kirtland's RSC and transferred to SOC-11 at Schriever AFB. MMSOC 2.1 was the first version to use NASA Ames's Goddard Mission Service Evolution Center (GMSEC) service bus, designed to integrate software applications and services onto a common platform for all missions to use. ORS-5 utilized the Neptune Tracking Telemetry and Control (TT&C) platform, developed by Space Ground System Solutions (SGSS) for the Naval Research Laboratory, with the Optical Processing Architecture at Lincoln (OPAL) mission unique software created by MITLL. While MMSOC 2.1 leveraged earlier MMSOC developments, schedule and development risk was still moderate due to necessary hardware and software changes.

By February 2017, MMSOC 2.1 development was well underway, but the pending launch coupled with the start of the operations training campaign increased pressure on the ground systems development team. Since development was in progress, interface documents were immature and constantly changing. Both Neptune and OPAL were already in use by other missions, but the uniqueness of MMSOC 2.1 made integrating the systems a challenge. Any time there was a flight software change on OPAL (which occurred three times from February through May 2017) there was a waterfall effect changing how Neptune ingested the data in turn changing how MMSOC 2.1 processed the data.

Integration and testing changes was no trivial matter. The MMSOC 2.1 build out at the RSC required the developers to integrate and test each software drop sequentially through three suites. It began with the development/integration suite, followed by the test suite, and finally the operational suite. Information assurance accreditation purposes drove this methodology. Each suite added new layers of cyber

protection causing configuration changes with each suite. Thus, passing one suite did not mean clear sailing through the subsequent suites. The integration team had to trouble-shoot issues at each level. In some cases, cyber protection layers locked out entire functions adding even more time to the tight integration schedule. Sending MMSOC 2.1 laptops to the software developers and installing a long line from MITLL to the RSC mitigated it to some extent. The teams used telecons when needed, but they were a poor substitute. Key mission members from SGSS and MITLL had to sit, in person, side by side with the MMSOC 2.1 developers to work through various deficiencies. As mentioned in the space vehicle section, this was challenging because the teams were small and did not always have the needed availability.

Scheduled for a March 2017 Factory Capability Test, MMSOC 2.1 was still in the middle of development and in the final stages of integration. The purpose of the Factory Compatibility Test was to prove MMSOC 2.1 could command the spacecraft through an air gap via the Air Force Satellite Control Network. While not an ideal time for the test, the program office accepted the additional risk to meet schedule constraints. A van simulating the Air Force Satellite Control Network deployed to MITLL near Hanscom Air Force Base in Massachusetts. There were some initial challenges with the test van set up. The contract was new, and documentation changeover was still in progress. At over two weeks, the test took longer than expected, but it provided useful discovery. MMSOC 2.1 could not command ORS-5. Root cause investigation revealed an incompatibility issue with a MMSOC 2.1 subsystem. The fix was a software change. Unfortunately, the schedule constraint still existed, and the AFSCN simulator van was not available in time. The SpRCO ORS-5 team developed an alternate test procedure. In May 2017, a team member piped recorded spacecraft data through the Eastern Vehicle Checkout Facility (EVCF) at Cape Canaveral to check commanding from MMSOC. While test fidelity decreased, it confirmed commanding, and the program office gained the necessary confirmation to ship the spacecraft to the launch integration facility.

Development on MMSOC 2.1 continued after shipment of the vehicle, as the system demonstrated signs of instability. Reboots of the system were common until the development team burned down solutions to various problems. This high pace of development and test activity continued until two weeks prior to launch. At that point, the system was stable and successfully supported the 26 August launch.

Successes:

- Alternate FCT approach allowed a commanding test to meet schedule constraints
- MMSOC 2.1 developments on ORS-5 set the success for future Air Force spacecraft missions

Regrets:

- Concurrent development on all software platforms increased timelines for integration
- Small, geographically separated software teams not often available for integration activities
- Not streamlining integration through the RSC suites
- Long-line requirements and process not fully understood by all stakeholders

OPERATIONS

At program inception, the 3rd Space Experimentation Squadron (3SES) was to operate the ORS-5 mission at SAFB. This organization has a heritage of accepting new “one-off” missions and adapting to various operational challenges. Program plans included 3SES developing all training products and procedures and conducting all exercises and rehearsals necessary for Launch and Early Orbit (L&EO) and day to day operations rather than contractors. Because the mission supported space situational awareness, AFSPC A2/3/6 proposed re-assigning ORS-5 to 1SOPS who operated similar missions. Leaders from AFSPC, 50th Space Wing, SpRCO, and SMC/AD discussed the pros and cons of the reassignment. Unfortunately, the team did not fully assess the secondary impacts: training, operating culture, and ground system build-out. Unlike 3SES, 1SOPS was not accustomed to operating prototype systems right after launch. They did not have sufficient personnel or experience to develop the training materials or train their initial cadre. In addition, they were used to a longer, more detailed training campaign and had little experience with developmental ground systems. Finally, the original plan for Schriever AFB was to leverage earlier version MMSOC hardware, wiring, and facility space at 3SES. These would no longer be available. All of these factors would have schedule, cost, and stakeholder impacts.

Training began in February 2017, but the developmental ground system was unavailable to present any semblance of a user interface. Operators scheduled training exercises every other month; many cancelled due to system unavailability. Continued developmental delays and training impacts led to a

growing operator distrust of the system. At the request of 1SOPS, the SpRCO funded contractor operators from the RSC (Space Test and Engineering Contract [STEC]) to develop training materials and operating procedures. STEC also supported classroom and hands on training. STEC had limited time to interact with the new system and its changes making training development more challenging. While a training simulator would have eased the training campaign, it was not an ORS-5 requirement and not funded. AFSPC had no additional funds to support operations and training activities.

Because early training was unsuccessful, compressed scheduling for the operations readiness campaign was four months from May-August 2017. The spacecraft had shipped to the launch base by this time so the flight software was stable reducing the impact to ground system software baselines. This allowed the trainers to develop procedures and understand the user interface. Executing quickly to certify team members prior to launch, MITLL subject matter experts, 1SOPS, and SMC personnel combined events. During this time, it was imperative to work on relationship building between the ground system developers, contractor operators/trainers, government program team, and 1SOPS community. This took time. A lot of trust was lost with the system delays and lack of readiness for training events. All sides made compromises, and everyone rallied towards a single goal--launch. The team was ready, the operators contacted the spacecraft during its first orbit, and the team was able to troubleshoot and resolve issues with the AFSCN.

During the L&EO campaign at Kirtland AFB, development focus shifted to the MMSOC 2.1 system at SAFB's SOC-11. Due to parts obsolescence, SMC/AD purchased and installed "soft" front-end processors (FEPs) which employed virtual machines to ingest and process data. SMC/AD re-designed this system as MMSOC2.1v. While the new FEPs initially appeared to be a minor change, they were not. The new equipment required more changes to the MMSOC 2.1v, Neptune, and OPAL software. There were new integration challenges for the developers to overcome requiring the same level of face-to-face communication experienced during MMSOC 2.1 development at Kirtland AFB. It became clear there was a need to have a technical expert who understood each piece of mission software. One example was troubleshooting two-line element set (TLE) and timing issues on the ground system. A Neptune expert was only available with limited phone support. After struggling for several weeks, the team discovered the issues were procedural caused by a lack of understanding of how Neptune software worked. As the L&EO campaign ended, the

planned transfer of the system to SAFB slipped from October 2017 to March 2018. Because there was no secure data connectivity from the RSC to the 18th Space Control Squadron, the warfighter did not get the data as early as planned.

Due to delays in the ground system transfer to Schriever AFB, operations had to continue at Kirtland AFB with contractor operators for four months after the original date in November 2017. To support, the program office had to re-allocate funds, and SMC/AD reprioritized those contractor operators from other missions. During this time, the contractor operators were able to make advances in automation. Automation was not a program requirement but a request from 1SOPS to assist with manning concerns. With this automation, the contractor operators at the RSC were able to test the mission as a lights-out operation and work day shifts with minimal personnel. This allowed program costs to stay low and reallocation of contractors to upcoming missions.

ORS-5 satellite control transferred from the SpRCO to 1SOPS on March 17, 2018 after operator training on the changes to the system, mission data verification, and a successful shadow operations period. The system entered Operational Test (OT) conducted by the 17 Test Squadron (17TS). Operator buy-in and trust at this point was critical to the program success. 1SOPS quickly advocated for the program to the 17TS on the acceptability of workarounds and operator impacts, which kept OT on track. After OT, the system entered a 30-day trial period on April 22, 2018. The team installed automation scripts and additional OPAL tuning and data exploitation tools during this time.

On 31 May 2018, AFPSC operationally accepted the ORS-5 system and declared Initial Operational Capability.

Successes:

- RSC contractor operators adapted and supported increased requirements for training and procedure development
- Operators made successful first contact with the spacecraft
- Automation development mitigated operator manning challenges
- Operator buy in and trust enabled successful L&EO and OT

Regrets:

- Impacts to the change in operational squadron not fully assessed
- Lack of secure data line at Kirtland AFB delayed early use of data to customer
- Processes and procedures were not delivered in time to support early training sessions as it was still unknown how the system would operate
- Expectation management and risk acceptance at senior operator level
- Different configurations between the RSC and SAFB

COMMUNITY STAKEHOLDERS

ORS-5 was a new type of mission for many stakeholders who were used to large ACAT-I type programs with five to ten years of development prior to launch. The ORS-5 program frequently pushed stakeholders from AFSPC headquarters, operators, and other SMC functional organizations outside their comfort zones. Even though this was a relatively low cost Class “C” space system, many did not understand or agree with the level of risk taken throughout program execution and transition to operations. Program documentation tailoring required a lot of coordination and discussions on what was appropriate. Additional reviews and higher-level coordination inappropriate for a \$100 million prototype mission took months of program time. Complicating matters, as community stakeholder personnel swapped out, discussions and coordination started over. For a small program office, this was costly exercise. Plans are currently underway at AFSPC to develop streamlined processes and documentation for prototype systems.

Success:

- Set the template for developing and transitioning future operational prototype systems

Regrets:

- HQ guidance to expedite demonstration/prototype mission onboarding was insufficient
- Stakeholders not of the same risk mindset for small programs
- Tailoring needs to be approved at appropriate levels and continued through personnel changes

CONCLUSION

On August 26, 2017, the SpRCO launched the ORS-5 SensorSat on a Minotaur IV from Cape Canaveral in

response to an urgent need for space-based situational awareness. The first space vehicle to operate on MMSOC 2.1 at Kirtland AFB and then Schriever AFB, ORS-5 currently provides data to warfighters in the Joint Space Operations Center at Vandenberg AFB. The three-year timeline from approval to proceed and launch drove a higher risk posture for system design and operations transition. While the team mitigated some design risks by maintaining a stable requirements base and using a series of increasing fidelity system demonstrations, the SpRCO actively managed other risks throughout program execution and into launch integration. Due to parts obsolescence-driven hardware changes, the ground system team lost time because lessons learned from the Kirtland AFB development did not fully apply to Schriever AFB. A seemingly minor change in operating squadron compounded this further. Both factors had second order effects increasing program costs and schedule after launch. As space prototype missions become more frequent, it is important to understand how to apply the following successes and regrets to future small, rapid programs.

Importance of the data. In retrospect, the primary goal was to get data to the user. There were many delays getting that data to the user--time spent exploring trade space on launch vehicles, changing operational squadrons, and not installing the appropriate secure data lines to the RSC. If the focus had remained on the data, then those decisions may have had a different outcome.

Consider the number of variables. The ground system had many pieces in concurrent development adding risks carried up to launch integration. When developing prototypes, choose a focus--the spacecraft, the ground system, launch vehicle, etc. Choose what to invest time and resources in developing and keep the rest of the system as stable and simple as possible.

Tailoring needs to stick. If small satellite programs and prototypes require tailoring of processes from ACAT I systems, then the tailoring needs to stick and endure through personnel changes. While tailoring streamlines the process later, it takes time up front to work through stakeholder equities. Ideally, formal guidance on how to handle these types of programs would accomplish the tailoring once for all following programs.

Cultural mindset for small satellites need to change. In other domains, the Air Force fields small acquisition programs quickly. The same needs to be true for space systems. Stakeholders continue to advocate for processes for which they are familiar, usually ACAT I size programs. The paradigm needs to change if the Air Force plans to launch small satellites more rapidly in the future at lower cost. Taking more risk on these

programs makes sense. The consequence of loss is not as severe as with an ACAT I system. The lessons gleaned are valuable.

Balance the high risk with the exquisite. Small satellites and prototypes can provide a huge boost to mission areas, but they do not eliminate the need for exquisite capabilities. Both types complement each other and can work together to ensure resiliency across mission areas.