

Managing a Safe and Successful Multi-User Spaceport

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ABSTRACT

Encouraged by the creation of the Office of Commercial Space Transportation within the U.S. Federal Aviation Administration (FAA) in 1984 and the Commercial Space Act of 1998, the National Aeronautics and Space Administration (NASA) now relies on an extensive network of support from commercial companies and organizations. At NASA's Kennedy Space Center (KSC), this collaboration opens competitive opportunities for launch providers, including repurposing underutilized Shuttle Program resources, constructing new facilities, and utilizing center services and laboratories. The resulting multi-user spaceport fosters diverse activity, though it engenders risk from hazards associated with various spaceflight processing activities. The KSC Safety & Mission Assurance (S&MA) Directorate, in coordination with the center's Spaceport Integration and Center Planning & Development organizations, has developed a novel approach to protect NASA's workforce, critical assets, and the public from hazardous, space-related activity associated with KSC's multi-user spaceport.

For NASA KSC S&MA, the transformation to a multi-user spaceport required implementing methods to foster safe and successful commercial activity while resolving challenges involving:

- Retirement of the Space Shuttle program
- Co-location of multiple NASA programs
- Relationships between the NASA programs
- Complex relationships between NASA programs and commercial partner operations in exclusive-use facilities
- Complex relationships between NASA programs and commercial partner operations in shared-use facilities

NASA KSC S&MA challenges were met with long-term planning and solutions involving cooperation with the Spaceport Integration and Services Directorate. This directorate is responsible for managing active commercial partnerships with customer advocacy and services management, providing a dedicated and consistent level of support to a wide array of commercial operations. This paper explores these solutions, their relevance to the current commercial space industry, and the challenges that continue to drive improvement with a focus on areas of safety management and risk assessment that have been crucial in KSC's evolution into a multi-user spaceport. These solutions may be useful to government entities and private companies looking to partner with the commercial space industry.

1. BACKGROUND

The realm of outer space, from low-earth-orbit to extraterrestrial bodies and beyond, is always viewed with great potential, and national pursuit of these endeavors spurs both technical and economic growth. In the United States (US), the road to promote a commercial space industry was shaped by national policy as well as the high risk of the activity. The National Aeronautics and Space Act of 1958, and subsequent creation of the National Aeronautics and Space Administration (NASA), declared that this civilian agency will exercise control of aeronautical and space activities, but could enter into cooperative agreements with other entities to conduct its work [1]. The US Space Program historically was a joint undertaking of the federal government and private industry, but this relationship principally existed through the use of commercial contractors for federally managed programs. An increased presence of commercially produced vehicles and satellites through NASA's first few decades led to renewed interest in enabling commercial space enterprise. The

Commercial Space Launch Act of 1984 recognized the contributions of private industry, and declared that the United States should encourage private sector launches [2]. The Act directed NASA and the United States to promote entrepreneurial activity in space, and facilitate the use of government-developed technology to encourage the private sector. This act created the Office of Commercial Space Transportation within the Federal Aviation Administration (FAA), and subsequent NASA Authorization Acts saw similar language incorporated to promote private sector launches.

1.1 Kennedy Space Center

The Kennedy Space Center (KSC), located on Merritt Island, FL, serves as NASA's primary launch center for its spaceflight programs. Containing over 140,000 acres of land, KSC has the capabilities to support transportation via land, air, rail, sea, and space. The location of KSC on the Eastern Seaboard allows for multiple launch capabilities, including horizontal and vertical, human-rated and unmanned launch vehicles. The KSC organizational structure is composed of multiple directorates, which provide planning and implementation services for ground operations and spaceflight programs. These programs manage and share a unique infrastructure of processing facilities, launch pads, testing facilities, and laboratories. KSC assets are utilized by multiple NASA programs and contractors, and mostly recently, commercial partners. The KSC Institution supports these programs by providing and managing the essential functions of the center. Among these organizations, the Spaceport Integration and Services directorate integrates and manages center services and customer support to spaceport users. KSC's Safety & Mission Assurance (S&MA) Directorate sustains and strengthens the success of KSC's organizational structure, serving as an independent and value-added partner ensuring the mission success of programs while protecting the safety and health of the public, program team members, and those assets that the US entrusts to NASA [3].

From concept development, to production, to operation and retirement, the lifecycle of many programs existed at KSC. The last major program lifecycle to reach retirement, the Space Shuttle program, left KSC with not only excess real and

personal property capacity, but a large amount of legacy procedures and processes to maintain. The center, and S&MA sought to consolidate the legacy documentation from the Space Shuttle program. S&MA as an organization originated within the program and engineering directorates, reporting directly to program management and providing safety engineering services to the center. NASA reassessed this model after the tragedies of Space Shuttle Challenger, and Space Shuttle Columbia. The Rogers Commission Report, investigating the Challenger accident, and the Columbia Accident Investigation Board noted that independent authority did not exist to manage technical requirements that addressed hazards [4, 5]. NASA's Office of Safety and Mission Assurance realigned to provide independent Technical Authority to each center's safety organization. This Technical Authority allows the KSC S&MA organization to perform independent assessment of NASA activity, and manage programmatic and institutional risks for the hazards of a government-managed spaceport.

The Space Shuttle program remained the largest NASA program on KSC for several decades, up until the final launch of STS-135 in July 2011. The presence of purely commercial work at KSC had been historically small, in comparison to the sizeable NASA contractor workforce and amount of center resources and infrastructure. External partnerships, both domestic and international, have increased in the last three decades. In 1998, NASA introduced the Launch Services Program to procure launch vehicle services from commercial providers. Although these providers launched federal payloads with NASA oversight, the launch provider managed a larger portion of risk, with NASA safety and quality participating in the reviews. The International Space Station program brought international partners and payloads to KSC's Space Station Processing Facility, where S&MA provided safety oversight for both civil servant, contractor, and international partner workforces. Throughout all of these efforts, NASA retained the primary responsibility for operations and processing activities. KSC also increased partnerships with academic research, prominently in the center's Space Life Sciences Laboratory. NASA had dedicated the bulk of the center's facilities, services, and workforce to the successful completion of the Space

Shuttle program's mission.

1.2 Multi-User Spaceport

The transition and retirement of the Space Shuttle program freed up a number of assets at KSC previously utilized by the Shuttle processing and launch flows. NASA's current manned exploration vehicle, the Space Launch System, will be processed and launched from KSC. KSC determined that the facilities and services required for current and future NASA programs left many existing assets underutilized or mothballed. Maintaining these facilities and services at their previous capacity would result in excess cost to the government. A strategic goal in NASA's 2007 Strategic Plan was to, "encourage the pursuit of appropriate partnerships with the emerging commercial space sector." [6] A solution, therefore, was to partner with non-NASA entities, including federal, state, commercial and academic organizations, to make use of these assets. The NASA Authorization Act of 2010 identified KSC as a multi-user launch complex, for both government and commercial programs [7]. NASA sought commercial partners through both open solicitation for NASA partnerships, and by public announcements of available facilities. NASA made certain facilities available for exclusive-use including the Launch Complex 39A, the Orbiter Processing Facilities, Shuttle Landing Facility, Hypergolic Maintenance Facility, and others, and also proposed sharing space within active NASA facilities, including the Vehicle Assembly Building, Launch Control Center and laboratories.

2. REQUIREMENTS DEVELOPMENT

This concept for a space center with multiple users required a thorough review of existing requirements to determine how commercial launch activity would be incorporated. Within S&MA, this started with general institutional safety requirements. The basis for the NASA Safety programs, at an agency level, is defined in the NASA Procedural Requirements (NPR) document NPR 8715.3 NASA General Safety Program Requirements. This document implements a comprehensive safety program that defines institutional, program, system, operational, training, and discipline-specific safety programs [8]. Referenced NASA standards and technical

requirements included explosives safety, pressure vessels, lifting devices and equipment, lightning safety, personal protective equipment, and other occupational safety policies (industrial health and fire protection, while referenced in the NPR, are maintained under separate documents at the center level). This document provides a framework for NASA centers to detail specific requirements for their center. At KSC, these further requirements are addressed via the KSC Procedural Requirements (KNPR) 8715.3 document. This KNPR addresses the governing requirements and demonstrates how KSC implements the NASA Safety program and NASA Safety standards at KSC [9]. The document applies to all entities, including civil servants, contractors, and visitors, that operate at KSC.

S&MA developed the KNPR as a catch-all to safety programs and practices on the center. KSC S&MA was concerned that these NASA requirements could be burdensome to companies looking to conduct business at KSC. KSC previously developed S&MA requirements to accommodate large-scale federal programs. Industrial safety requirements in several areas exceeded those specified by the US Occupational Safety & Health Administration (OSHA), and other standards such as the Safety Standard for Explosives are supplemental to existing federal requirements. Many commercial companies interested in partnerships maintain existing safety & health programs. KSC did not intend to supplant these existing safety programs and introduce strain in complying with a new set of requirements. S&MA needed to understand how to bring these safety & health programs under the umbrella of KSC's existing safety culture. Multiple safety and health programs would need to operate in harmony, with NASA's safety program acting as the final authority if required. NASA sought to fully understand and define an acceptable level of risk from commercial activity to NASA personnel and programs. The S&MA organization formulated two questions to guide development of a solution to this problem. First, what are the minimum necessary requirements to develop an acceptable risk profile for commercial activity? Secondly, what facets of the safety program must be universally standard on center?

2.1 Evolving Rationale

To develop a framework for a minimum set of NASA requirements, the KSC S&MA organization looked externally to find rationale. If general industry operated within the boundaries of the center, then KSC would have to understand general industry. A key facet of how OSHA interprets fault among multiple parties in the same location is by its Multiple Employer Citation Policy [10]. In the event of an accident that involves multiple organizations, OSHA distinguishes these employers into four categories: creating, controlling, correcting, and exposing employers. The creating employer introduces the source of the hazard, the controlling employer manages the hazard, the correcting employer mitigates the hazard, and the exposing employer has employees that could be harmed by the hazard. This is useful in determining responsibility in an incident, however the citation policy only engages once the accident has occurred. It is prudent for a worksite manager to ensure hazards are appropriately controlled in order to prevent such a mishap from occurring. This categorization of employers still provided a useful framework to understand how NASA wanted to position itself as a spaceport manager. Considerations included how NASA or partners introduced hazards to the center, how hazards are controlled and mitigated, and how respective employees might be exposed to those hazards. To address the question of minimum necessary requirements, S&MA considered NASA to be an exposing employer. According to the OSHA policy, in the event of a mishap an employer can be cited if it, “knew of the hazardous condition or failed to exercise reasonable diligence to discover the condition.” [10] KSC requirements on agreements with commercial partners would reflect due diligence by S&MA to understand local hazards, and through coordination with a partner, work to control them.

Hazard communication between NASA, partners, the public, and other participants of the multi-user spaceport is a strong component of KSC’s S&MA policy. Communication and coordination alone does not satisfy the principles of NPR 8715.3 with regards to risk evaluation and acceptance. Safety policy must withstand the rigors of hazards specific to aerospace, including launch and reentry activities. The NPR states that NASA will, “ensure the conduct of

assessments of quantitative and qualitative safety risks to people, property, or equipment, and include recommendations to either reduce the risks or accept them.” [8] This is flowed down to the KNPR 8715.3 in the assessment section, under Chapter 4: Operational Requirements. Chapter 4 requires that organizations on KSC establish a process to review and accept risks, perform an assessment to evaluate hazards associated with operations, and establish controls for the hazards [9]. This applies to NASA as the sole employer identifying, assessing, and controlling its own risks. In assessing a third party, and without the full complement of NASA requirements, the government would have to be judicious in how it collected information through an agreement. The solution was to pare down the requirements of KNPR 8715.3 to the minimum safety standards necessary to regulate activity on center, while bolstering the capabilities of the operational assessment that identifies hazard controls.

2.2 Operational Assessment

The core of this new multi-use safety policy is NASA’s operational assessment, derived from the original Chapter 4 in KNPR 8715.3. NASA’s ability to control and manage hazards is only as strong as its ability to have information available for assessment of the existing hazards. As a baseline, NASA maintains the final authority to mitigate a hazard, should partner-managed controls not be sufficient to reduce the risk to KSC personnel or property. At the same time, NASA wants partners to keep their safety programs and requirements intact, and acknowledges different approaches in safety. A commercial partner already must comply with all federal, state and local requirements, including OSHA and other incorporated standards, by operating in the United States. NASA is not responsible for enforcing a commercial company’s compliance to OSHA and other laws as they pertain to the company’s own employees. Rather than levy the full slate of KSC requirements on a partner, a partner could demonstrate that their safety programs represent an equivalent level of safety to NASA requirements that either exceed federal laws or target specific aerospace hazards. This equivalence would be assessed against the risk to KSC personnel and activity governed by NASA. The more partner documentation and data NASA could review, the better NASA could

understand gaps between partner and NASA safety requirements. A complete review of a partner's business and company documentation would require significant time and resources on behalf of both parties, and might impose an undue burden on companies wishing to conduct operations. NASA would have to be judicious in its selection of material to review, while ensuring appropriate breadth to adequately assess risk.

The modification of the operational assessment began with specifying particular documents that NASA required prior to a partner initiating operations. The first of these is a partner's concept of operations, which defines the full extent, at a high-level, of all proposed activity. The partner has discretion on what form this concept of operations takes, and could originate from an existing document or as a new product. Acknowledging partner recommendations, NASA retains the authority to ask for further information or depth for a full assessment. Along with a concept of operations, partners would include a description of all hazards associated with those operations, and the corresponding controls or mitigations for those hazards. This is meant to be encapsulating language that included activity covering launch processing and ground operations. General hazards include occupational hazards to personnel, pressurized systems, hazardous chemicals, ordnance, critical lifting, and others to be identified by the partner. The partner would also report all hazardous chemicals so that KSC could catalogue existing chemicals on center and ensure compliance with NASA's Safety Standard for Explosives [11]. To prevent cataloguing insignificant quantities, chemicals identified as hazardous by the OSHA General Industry Hazard Communication standard served to encapsulate the information NASA sought [12]. With this information as a basis, NASA could begin to craft a complete story of the proposed activity and the hazards brought on KSC property. Further requirements would address specific highly hazardous activity, including high-pressure operations, ordnance, and range operations, but these would be tailored from the existing NASA standards. Any coordination on this information would need to begin well in advance of operations, to ensure no delays in NASA receiving the relevant information.

3.1 The Safety Requirement Volumes

Once NASA S&MA understood the hazards posed by a partner's operations, it was necessary to ensure those operations were compatible amongst existing center programs. The concept of operations document includes information on all locations utilized by the partner at KSC. The locations made available for commercial use fell into two categories: facilities whose operation, maintenance, and usage are fully transferred to a partner; and shared areas within existing NASA-controlled facilities. At facilities operated and maintained by a partner, designated exclusive-use, NASA would have flexibility to allow partner safety programs to manage the facility, provided NASA had full awareness of these policies and deemed them compatible with existing facility policies. Facilities designated for exclusive-use also contained NASA systems that fed through or originated within those facilities, traces of the former Shuttle program facility architecture. These facilities would require routine access from KSC personnel for maintenance or inspection, and KSC S&MA needed oversight of safety controls at these sites. Within a NASA-controlled facility or shared-use, NASA maintains existing security, safety, and scheduling procedures to be complied with by all occupants, including partners. Assessing each agreement and each facility to tailor the KNPR 8715.3 would be a laborious process, as each facility had unique attributes and infrastructure designed to support flight hardware processing. S&MA decided to take the original KNPR and split it into three volumes: the existing document relabeled Volume 1 for civil servants and contractors, a new Volume 2 for partners within shared-use or NASA managed facilities, and Volume 3 for partners within exclusive-use facilities. These individual volumes could be placed within an agreement, and accommodate a majority of safety provisions and concerns, with additional tailoring as needed to accommodate the specific needs of a partnership.

3. SURVEILLANCE AND VERIFICATION

The information gathered from the operational assessment of Volumes 2 and 3 provides the foundation of KSC's risk assessment of partners, but NASA must perform its own due diligence to ensure the information is accurate and complete. NASA

develops a surveillance plan for each agreement to assess the partner's compliance to S&MA requirements in the agreement. These agreement requirements largely come from Volumes 2 or 3, since these documents are intended to exist on a majority of agreements. The plans document which requirements are targeted, and how often KSC S&MA performs surveillance. S&MA decided that to reduce the burden on partners and manage the resources of KSC S&MA, the surveillance frequency would only be performed on a monthly, quarterly, or annual basis. The frequency is based on current KSC construction surveillance practices, and S&MA constantly reassesses the frequency of evaluation. Whether a contractor or partner has a satisfactory record of compliance or not, the evaluator may increase or decrease the surveillance frequency.

Surveillance of KSC S&MA partnership requirements falls into two general types: documentation reviews, and site visits. Documentation reviews occur early in the partnership process, and initially reference the documents requested in the operational assessment. At a minimum this includes a review of the concept of operations, hazard and chemical lists, and a copy of the partner's safety & health plan (or program), but may also include operational or design documentation and risk analysis. These reviews provide both NASA and the partner with a baseline of activities associated with ground and flight operational schedules, safety policies and surveillance activity over the life of the agreement. It also provides sufficient lead time should a particular activity require additional controls or coordination with NASA. Generally, these reviews are conducted once, at the inception of the partnership, but will be subsequently reviewed as updates are available. These are particularly critical for flight safety analyses developed for commercial launches, since NASA may perform a review in addition to those required by range regulators. The second type, site visits, are the best opportunities to verify that the information in the documentation is current and adequate. Site visits are precoordinated with the partner on a non-interference basis, and surveillance is only performed on requirements identified in the agreement or associated KNPR 8715.3 Volume. Stop-work authority, a critical item in KSC's safety culture that allows personnel to call a halt to immediate unsafe activity, is always explicitly clear for any activity.

4. SPACEPORT INTEGRATION

The usefulness of surveillance relies on close coordination with NASA partnership management, which lies within two key center organizations. S&MA maintains relationships with KSC managers and stakeholders of partnerships for awareness of any concerns with regards to safety requirements and policies. To understand how these relationships are maintained, it is important to describe how KSC realigned its structure to better support the multi-user spaceport concept. The Center Planning and Development directorate leads the development of partnership agreements at KSC, and thus is responsible for early partner coordination, negotiations, and ensuring the development of an executable and enforceable agreement which includes all relevant safety requirements. The management of the multi-user spaceport, and the liaisons to partner operations fall under the responsibility of the Spaceport Integration and Services Directorate.

The Spaceport Integration and Services directorate is responsible for the overall planning and assimilation of Kennedy Space Center processing activities and the execution of center services across NASA projects and programs, other government agencies, and commercial partners. These functions are integrated to create consistently safe, innovative, responsive, and cost-effective solutions, driving the success of all spaceport customers. The primary goal of the directorate is to ensure that the institutional needs of all spaceport customers, including NASA programs and commercial partners, are met. This is done by providing a consolidated operations and scheduling function for the center which includes developing and maintaining a top-level operations master schedule that integrates commercial and government entities operating at KSC to ensure awareness and deconfliction of hazardous and other operations that have potential impact across the customer base.

The directorate also provides customer liaisons to customers of the KSC spaceport for the purposes of identifying, coordinating, deconflicting, scheduling, and managing KSC spaceport services. These customer liaisons interface directly with partners on a daily basis to develop and communicate requirements, identify creative solutions to issues, and integrate between the various users and stakeholders of the spaceport (including S&MA). These liaisons also manage and implement the process for partners to

procure services from KSC, facilitate approval for any customer-proposed modifications, and coordinate customers' requests with KSC implementing organizations to provide a viable support plan to the customer.

Through close partnership with Spaceport Integration and Services, S&MA is able to maintain a good understanding of the nature of operations occurring at KSC, the level of interaction between spaceport users and their operations, and the types of issues being faced by the customers. This partnership is critical to helping both organizations be successful and in ensuring that the spaceport enables the safe and successful operations of all government and commercial activity.

4.1 KSC Technical Integration

In addition to working with stakeholders from other directorates at KSC for agreement development and implementation, S&MA also retains institutional and programmatic safety, quality, and reliability experts within its organization. During the early stages of agreement development, the subject matter experts (SMEs) are consulted for specific requirements on activities that are expected to be highly sensitive or highly hazardous, including: program schedules, explosive siting, lifting device, pressure vessel and range safety priorities. During agreement implementation, NASA KSC SMEs are available for interpretations of technical safety standards and program safety priorities. They also assist in the development of targeted surveillance activity for their disciplines.

5.0 COMMERCIAL LAUNCH PROVIDERS

The authority of KSC safety requirements also required reevaluation for commercial launches licensed by the FAA. For NASA-managed or procured launches, safety analysis is performed under existing cooperative agreements with its neighbor, the Air Force's 45th Space Wing. The Webb-McNamara Agreement, established in 1963 to minimize the duplication of responsibilities from both NASA and Air Force launch operations, drove this cooperation [13]. However, Webb-McNamara did not account for purely commercial launches, and the review and licensing of launch providers by the FAA therefore creates another regulatory entity. A review in 2013 by the NASA Executive Council determined that for

FAA-licensed launches, safety reviews could be conducted by the 45th Space-Wing or an FAA-approved entity. This creates more options for commercial providers, but moves away from the traditional NASA model for safety review and concurrence.

The flight safety analysis required in the application for an FAA launch license is reviewed by the FAA. With the FAA maintaining the licensing authority, NASA does not have mandated approval of a launch, as the FAA ensures protection of the public. As the manager of the spaceport where this launch activity would occur, though, NASA still holds a fundamental responsibility for protecting personnel and property. Using the previous risk-based approach from the Operational Assessment in the KNPR Volumes, NASA will request and review a minimum set of data from the flight safety analysis for assurance that risk is minimized. If the risk to NASA facilities exceeds criteria established in the NPR 8715.5A Range Flight Safety Program, NASA will work with the launch provider to better quantify or control the risk [14]. Likewise, processing and ground safety operations will be conducted according to the shared or exclusive-use facility requirements in KNPR 8715.3 Volumes 2 and 3, respectively. The ability to review data, request information, and implement controls through these document Volumes allows any risk-based safety concerns, regardless of origin, to be covered by the KNPR requirements. Even in situations where NASA does not have immediate approval authority, NASA must manage the risk to its spaceport. Through coordination and levying prudent requirements, NASA will fully understand launch hazards and ensure the risk is acceptable to the center. KSC stakeholders and S&MA will work with commercial launch providers to identify controls and modifications that will allow them to successfully execute an FAA-licensed launch.

6.0 CONCLUSION

The multi-user spaceport concept invites new perspectives, novel engineering, and cutting-edge technologies to the KSC. The success of commercial partnerships, and NASA missions, hinges on cooperation and shared awareness. This awareness is the core of both KSC's Spaceport Integration and Services policies and S&MA safety policies that

govern the risks and challenges inherent to the multi-user concept. Strong and suitable policies allow KSC to support a wide variety of partnerships without any compromise to NASA KSC's safety culture

The center accepts the new risks associated with commercial launch activity, and has adapted its structure, and requirements, to better promote these partnerships. In enabling the multi-user spaceport, KSC also addresses its mission as levied in the NASA's Space Act to foster an environment for commercial space access. As this access to space will always offer great rewards at great risk, it is the S&MA organization's continued mission to provide a framework that allows these goals to be safely attained.

7.0 REFERENCES

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