A NEW DOCUMENTATION PROCESS TO STREAMLINE RANGE SAFETY PROCEDURES

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ABSTRACT

In recent years, there has been an exponential increase in the number of Department of Defense (DoD), NASA and commercial auxiliary payloads at the Air Force's Eastern and Western spacelift ranges. The range safety documentation process is extremely thorough, but it was never designed for this significant increase in small satellites and auxiliary payloads launches. Although it has operated successfully for many years, it is a cumbersome, time-consuming process. As such, it is time to adapt this process to better accommodate increased activity. Spaceflight and Millennium Engineering and Integration Company have proposed a document template to tailor, standardize, merge and potentially automate aspects of the range safety documentation for auxiliary payloads so that only one safety document is required for submittal. Given that range safety processes are integral to the operation of spacelift ranges, the process of using this document template is particularly relevant to the resiliency of our space infrastructure as it would shorten the approval timelines ensuring rapid access to space. The current range safety paradigm requires all auxiliary payloads (including 1 kg CubeSats) to tailor Missile System Pre-launch Safety Packages, to include the AFSPCI 91-710 compliance matrix, Ground Operations Plan and other documentation. The proposed document template known as a Standard Auxiliary Payload Package (SAPP) would be a standalone document covering all safety aspects of an auxiliary payload. While this process is primarily concerned with ensuring that the safety review process never becomes a choke point for access to space, it would also complement Air Force efforts to synchronize Eastern and Western range processes. Furthermore, it would reduce both range operations costs and government satellite development costs associated with launch delays.

INTRODUCTION

There has been a significant increase in the number of Department of Defense (DoD), NASA and commercial auxiliary payloads at the Air Force's Eastern and Western spacelift ranges, necessitating a thorough review of the safety documentation process. This process is quite thorough, but it was never designed for launches that include small satellites and auxiliary payloads. It is a cumbersome, time-consuming process. Spaceflight (Launch Services) (Spaceflight) and Millennium Engineering and Integration Company (Millennium) have proposed a process to tailor, standardize, merge and potentially automate aspects of the range safety documentation for auxiliary payloads so that only one safety document is required for submittal. Given that range safety processes are integral to the operation of spacelift ranges, this process is working to increase resiliency of our space infrastructure as it would shorten the approval timelines ensuring rapid access to space. The current range safety paradigm requires all auxiliary payloads

(including 1 kg CubeSats) to tailor a Missile System Pre-launch Safety Package (MSPSP), to include the AFSPCI 91-710 compliance matrix, Ground Operations Plan (GOP) and other documentation. As with the current process, this proposed process is primarily concerned with safety to people and equipment while ensuring fluid safety review for access to space. This process would also complement current Air Force efforts to synchronize Eastern and Western range processes and reduce both range operations costs and government satellite development costs.

Millennium is a full lifecycle space and defense services and solutions company. Their capabilities and experience span the entire system development cycle, from concept development through all phases of system acquisition, integration, test, operations, and maintenance. With 500+ employees and annual revenue over $155M and $2B in contract value, Millennium provides policy and program support, safety and mission assurance, system engineering and integration, design and development, integration and test, and operations services for our nation's most complex and important programs and advanced technologies, including launch vehicles, manned spacecraft, satellites, range safety, missiles, sensor systems, combat and weapon systems, sensor fusion, and command and control operations. Millennium's customers include the Air Force, Missile Defense Agency, NASA, and Office of the Secretary of Defense. Regarding this effort, Millennium provides launch and range safety to the 45th Space Wing at the Eastern Range as well as providing similar services at NASA's Wallops Flight Facility. These efforts afford Millennium with first-hand experience in working through the launch and range safety documentation process.

Founded in 2010, Spaceflight is a small business focused on enabling frequent low-cost access to space for small spacecraft. Spaceflight has established relationships with numerous Launch Service Providers through whom they procure excess launch vehicle capacity. Spaceflight sells that capacity to secondary payload customers as part of a full end-to-end launch service. Because of demand, Spaceflight recently purchased a dedicated SpaceX Falcon 9 to provide Dedicated Rideshare Missions into the future. To date, Spaceflight has launched 81 spacecraft and has 138 spacecraft under contract for launch. These customers include CubeSat constellations, nanosat constellations, and microsatellites with mass of up to 575 kg. Spaceflight has extensive experience with development of range safety documentation and has experienced first-hand how much time and money is currently spent for small, less complicated spacecraft.

Millennium and Spaceflight will use their combined experience in launch, range, and safety to tailor and focus the safety process in anticipation of increased launch coordination and activities.

Approach

The goal of this proposed effort is to define how best to safely streamline the range safety documentation process resulting in significant cost and schedule savings for small satellite missions. The work discussed herein establishes the steps necessary to further define the steps and key features of the SAPP process.

OVERVIEW OF PROCESS SIMPLIFICATION NEED

The objective of this new documentation template is to create one, standardized integrated range safety requirements document for the launch of auxiliary payloads that encompasses the intent of an MSPSP, a GOP, the AFSPC 91-710 compliance matrix and various hazardous procedures. This document template known as a Standard Auxiliary Payload Package (SAPP) would be a standalone document covering all safety aspects of an auxiliary payload. This documentation process would nominally be applicable to all auxiliary payloads launching in the "powered-off" configuration, having a mass of less than 75 kg and a propulsive delta-V capability less than 60 m/s. While these are nominal parameters, Millennium and Spaceflight propose to further refine these parameters and then codify the applicability of the process into a prototype web-based tool for generating required SAPP sections through the use of decision tree logic.

Given that range safety processes are integral to the operation of spacelift ranges, this proposed process is relevant to the requirement of "Increased Resiliency of Space Infrastructure" as it would shorten the range safety review timelines, thereby ensuring rapid access to space. This would be especially relevant to "Launch on Demand"

scenarios where reconstitution of a capability is paramount. Under the current paradigm, safety approval could become a critical path to launch. Furthermore, the web-based software tool actually enables quality assurance (QA) through standardization. With the use of a standardized document, satellite developers will know exactly what information they need to include in their range safety documentation. Standardization ensures that small details are not forgotten, therefore promoting QA. The proposed process enables the following characteristics:

• **Enhanced Military Capability** – The proposed documentation template enhances military capability by adjusting processes rather than by acquiring materiel solutions which is consistent with the Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) framework. A streamlined process that continues to ensure public safety therefore enables the military to react quickly to satellite outages or degradations due to kinetic/non-kinetic attack or environmental factors. For example, in the case of a degraded GPS constellation, multiple GPS gap-filler satellites could be rapidly flowed through this SAPP process leading to the restoration of capability more quickly and without the need to tailor range safety processes on the fly when tensions are high. In short, the SAPP process is an enabler for Operationally Responsive Space actions and for them to be done safely.

• **Accelerated Military Development Capability** – While the SAPP process would not speed up the development of satellites, it would result in a more responsive architecture, capable of efficiently fielding auxiliary solutions as launch ranges are a choke point for access to space. With a process to get from the launch site into space is accomplished more rapidly, capabilities can be realized more quickly.

• **Reduced Costs** – This process will standardize the documentation that the range receives for small satellites. Standardization translates into cost savings by reducing the amount of time to review a document. Integration of documentation into one document makes filing easier and supports configuration management (i.e., only one document to manage) which also translates into increased efficiency. A quicker, more streamlined process would also enable a larger throughput of payloads at the ranges. As rocket missions with no clear, primary payload become common in the coming years, it will be beneficial to standardize the process as much as possible.

While this topic may have not been of significant interest to the government five or more years ago, small satellites are becoming increasingly relevant for the future of space. **Exhibit 1** shows the estimated launch cadence for small satellites by class in 2015, 2016 and 2017. The data in this figure come from Spaceflight's Requirements Mangement System[1].

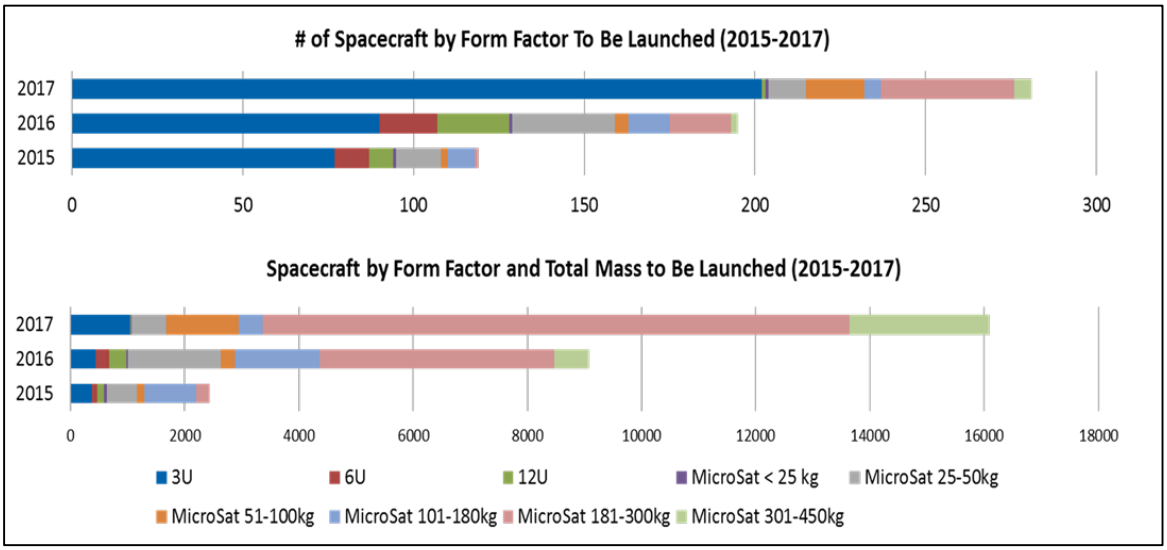

Exhibit 1: Estimated launch cadence for Small Satellites based on current projections. (data taken from Spaceflight and SpaceWorks report[1])

Exhibit 1 shows the significant rise in the number of small spacecraft scheduled for launch in the near term. However, this trend will likely continue with further increases meaning that small satellites could very well become a choke point for the range safety review process. In cases where there are a dozen or more payloads co-manifested on a rocket, as in the case of Spaceflight's SHERPA which will host 89 small satellites on the Formosat-5 mission, the need for a refined process becomes more apparent.

Exhibit 2 shows the recent increase in small satellite launches between 2011 and 2014. According to Spaceflight's Internal Management System and SpaceWorks, there was a 72% increase in small satellites launched between 2013 and 2014. While **Exhibits 1** and **2** reflect large changes in the commercial market, it is worth noting that the government is becoming increasingly interested in the utility of small satellites as well. Recently, there were several requests for proposal released by NASA for commercial launch brokering and small launchers for CubeSats and announcements of the next series of Earth Venture Class missions for CubeSats and microsatellite programs, and the Air Force requests for Rideshare opportunities totaling close to $500M in Fiscal Year 2017. The overarching goal of this proposed process is to streamline the range safety processes for smaller, less complicated spacecraft. A series of activities are planned to achieve this goal.

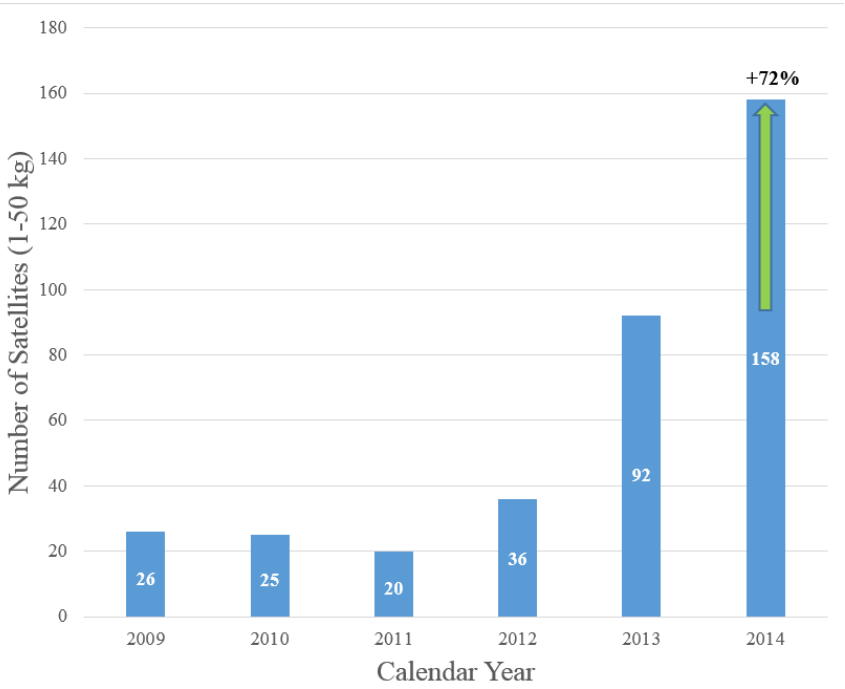

Exhibit 2: Nano/Microsatellite Launch History. (data taken from Bradford[2])

SAPP PROCESS GENERATION STEPS

The proposed effort begins with a survey of the applicable range safety requirements documents such as AFSPC 91-710. The survey continues of documents such as any supplements to 91-710 mandated by the 30th Space Wing (Vandenberg AFB) or the 45th Space Wing (Patrick AFB/Cape Canaveral AFS) as a thorough understanding of all existing policies is necessary in order to define an all-encompassing range safety document template.

Auxiliary payloads are next followed by their associated ground support equipment requirements and other applicable requirements to understand the types of small satellites that are likely to be launched in the coming years. Additionally, the team will assess emerging technological developments with safety implications (e.g., propulsive CubeSats) that might be relevant to this effort. The team will accomplish this survey of auxiliary payloads by leveraging its vast network of auxiliary payload developers, and by leveraging its own collective 60+ years of space enterprise experience. This will inform the layout of the templates as well as the logic of the software tool.

The team will map the range safety requirements to the various design features of existing and emerging auxiliary payloads. The mapping of requirements to design features will inform the layout of the template document. Additionally, requirements for GOPs and procedure submittals would be assessed and analogous information included in the SAPP document. In order to create the SAPP document template, the team will either use a previous program's information or define a template satellite program so that the document can be completed for a notional program.

As a part of the process to define what class of satellite should be able to take advantage of this more streamlined approach, a decision tree analysis tool will be developed to automate large chunks of the documentation process as applicable to the example satellite. The decision tree analysis parses through the database of different linked range safety documentation in an efficient, automated manner. A front-end survey of satellite classification parameters (e.g., mass properties, propulsion, range, orbit, orbit de-confliction plans, sensitivity, and other analysis on the primary mission) will be employed to determine which aspects of the entire range safety spectrum would apply to the particular mission. The SAPP automation tool will be used to determine various courses of action, as necessary, in order to automate and streamline range safety approval processes. Known logical steps (based on the provided range safety documentation standards) and comparisons and outcomes (based on survey of auxiliary and primary mission requirements) will be provided and saved into the system to ensure appropriate resultant actions are well-defined and known, yielding appropriate determinate outcomes.

Throughout the development process, the team proposes to socialize the projected process with relevant parties including Eastern and Western range safety, 14th Air Force safety and Air Force Space Command safety personnel (as available) before being submitted to the government's program office. Additionally, the team believes that collaboration with these organizations as well as NASA Wallops and any other required organizations is critical to success.

The SAPP automation tool will also be a natural fit for operations at State Spaceports, such as the Pacific Spaceport Complex in Alaska, the Mid-Atlantic Regional Spaceport in Virginia, and Spaceport America in New Mexico. These non-Federal launch sites already tailor the existing Federal range safety documentation in order to address each customer's unique capabilities and requirements. However, the State Spaceports are often challenged to perform custom safety analyses for multiple customers simultaneously. The SAPP process is a natural fit to streamline this process for both customers and Spaceport Safety Officers to quickly identify the unique hazards associated with each satellite in order to maximize mitigation planning time and reduce the cost of processing unnecessary documentation. **Exhibit 3** shows the notional flow of the SAPP process efficiencies compared to the exisiting processes.

As previously mentioned, this activity includes the development of a prototype tool for SAPP automation. The web-based SAPP automation tool is essentially an input form of mission parameters backed by decision tree analysis to automate the sorting functions through thousands of pages of range documenation. The decision tree analysis parses through the database of different linked range safety documentation to create efficiencies. Of course, there are potential risks with attempting to automate aspects of the range safety documentation generation process. For example, there could be potential issues with decision tree mapping with the software tool such that the automated tool does not generate a required section. Therefore, significant effort will go into not only understanding all of the requirements, but also the subtleties of how range safety may differ between ranges. As for a test methodology, a static decision tree methodology will be applied to the validation process to determine appropriate action items for a given mission. By rapidly evaluating mission-specific parameters with basic conditional questioning, relevant branches of the tree are followed to derive final manual steps for the end user, automating and removing many extra steps in the process. This method is accurate and consistent, capable of ignoring many unneeded steps that are not part of the correct decision branch.

The proposed effort follows a straightforward research and development methodology. Comprehensive research of Air Force Space Command requirements as well as range-specific requirements leads to an initial set of standards

applicable to small and auxiliary space systems. These initial findings are then proposed to the Air Force ranges for feedback and iteration.

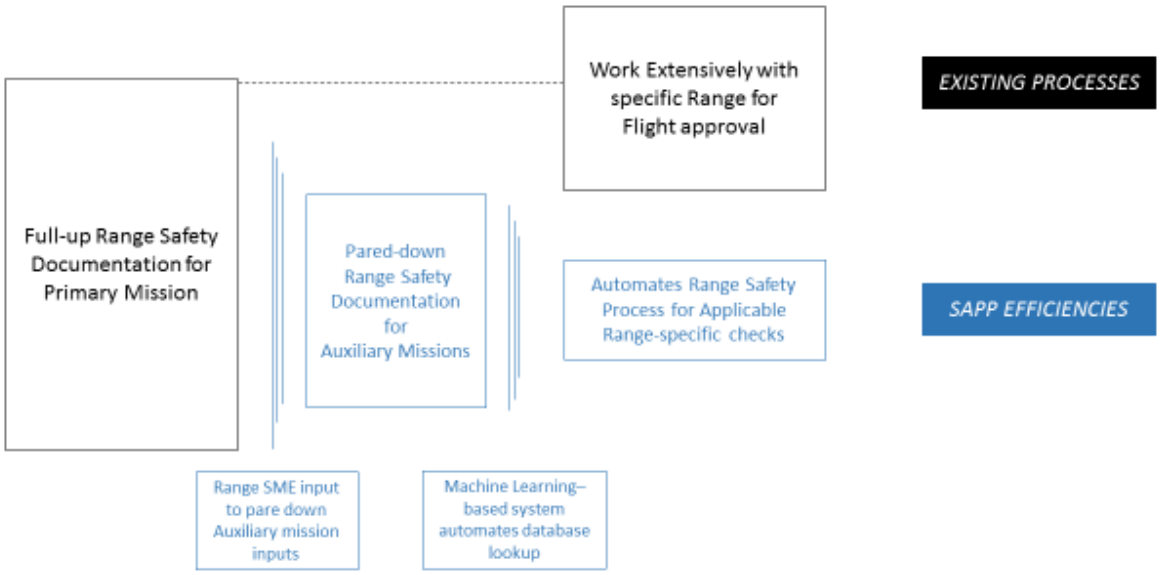

Exhibit 3: SAPP Efficiencies Compared to Current Processes.

From there, the next logical step is to automate as much of the process as possible through a web-based survey tool that sorts through the full suite of range safety requirements. This work will successfully create a system-specific set of range safety requirements for small and auxiliary space systems, as well as reduce cost and schedule requirements that currently exist to research such system launch readiness. In addition, the proposed effort aims to introduce a great deal of flexibility into the range safety architecture, as the auxiliary systems are schedule-dependent on the primary system being launched. Potential issues associated with scheduling with all of the relevant parties is mitigated by proactively engaging with the stakeholders while potential issues with software accuracy and precision can be mitigated through rigorous testing.

RISK ANALYSIS

There are two primary risks with this effort: buy-in risk and the accuracy of the web-based tool. We recognize that it may be difficult to gain buy-in from all of the stakeholders and that any changes to processes could be risky. This concern is mitigated by the fact that the team is not planning on recommending any changes to policies; adaptations to the process will work within the confines of existing range safety constraints. The idea is to make the range safety constraints easier to work with rather than changing the requirements themselves. The team is confident that by clearly communicating to stakeholders that we are not looking at changing policies and collaborating with them on developing the solution, we can gain buy-in from all parties and develop the best products possible.

There is risk that the software and its associated decision tree will introduce room for error that did not previously exist with human review. In order for the software tool to have sufficient utility, it must be accurate in addressing all of the potential range safety concerns that might exist. If it is not sufficiently accurate, users will not have confidence in it as an effective means for saving time. Millennium and Spaceflight will test the software against the sample satellite mission which will run through the complete process, ensuring the automated SAPP process captures the necessary elements of the current process.

SUMMARY

Due to the precipitous rise in auxiliary missions, Millennium and Spaceflight propose an update to traditional methodologies for range safety processes when it comes to smaller, non-primary missions. The proposed procedures would be packaged into a more applicable and targeted approach to range safety, taking into consideration the smaller scope and lower level of risk of typical auxiliary missions. Further, an automated database sorting system is proposed in order to speed up adoption and integration of such updated packages, simply automating the multi-parameter lookup of mission context, mass properties, propulsives, range, mission category, etc. for assurance and efficiency. The efficiencies proposed would benefit military missions and smaller auxiliary space missions. For military missions, a more streamlined process will create more opportunity for fast response, and accelerate timelines for development of new missions, all at a reduced cost. For auxiliary missions, the efficiencies proposed would enable further adoption of smaller space vehicle missions by increasing flexibility for auxiliary missions to get to orbit.

Millennium and Spaceflight believe that moving towards a more standardized and automated system for the production of range safety documentation is the best approach for ensuring that range safety documentation never becomes the primary choke point for access to space. Additionally, getting significant buy-in and input from the ranges will ensure the most accurate information can be programmed into the software in order to mitigate the risk of not producing all required documentation.

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[1] Spaceflight Requirements Management System & SpaceWorks 2015 Report

[2] Bradford, J., *2015 Small Satellite Market Observations*, Retrieved from http://www.spaceworksforecast.com/docs/SpaceWorks_Small_Satellite_Market_oberstations_2015.pdf