2008

NASA Range Safety Annual Report

This 2008 Range Safety Annual Report
is produced by virtue of
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B. DEVELOPMENT, IMPLEMENTATION, SUPPORT OF RANGE SAFETY POLICY

1. Constellation Tailoring

NASA Range Safety continued to support the Constellation Program in its efforts for a 2009 Ares 1-X test flight by tailoring range safety requirements with the 45th Space Wing and the Program. Since the Program is required to meet the combined requirements of NASA Procedural Requirements (NPR) 8715.5, *Range Safety Program*, and Air Force Space Command Manual (AFSPCMAN) 91-710, *Range Safety User Requirements*, we worked jointly to bring these requirements into one document, Cx 70155-01, *Air Force Space Command Manual 91-710 / NPR 8715.5 Range Safety User Requirements Manual Tailored for the Ares I-X Flight Test Vehicle Mission.* A version of the tailored Ares 1-X Range Safety Flight Test Vehicle Mission document is complete with final signatures from the KSC Center Director, Constellation Program Manager, and 45th Space Wing Commander. The new document codifies the philosophy of shared responsibility for all aspects of range safety between the 45th Space Wing and NASA and will serve as the foundation for future tailoring efforts between the two organizations.

Departures from current baseline requirements were documented via four range safety waivers. Although not the normal process, the team agreed after considerable discussion that this method was the most appropriate for documenting the noncompliances associated with the decision to incorporate heritage Shuttle Flight Termination System (FTS) components.

Development of a tailored document to support the Ares 1 launch vehicle has also begun. All of the FTS noncompliances with the AFSPCMAN 91-710 baseline are expected to be eliminated for Ares I. This document will also incorporate the philosophy of shared range safety responsibility between the 45th Space Wing and NASA.

Integral to both of these joint tailored documents is the Launch Constellation Range Safety Panel (LCRSP), which is the group responsible for range safety activities for elements of Constellation launch vehicle flights and preoperational test flights (e.g., Crew Launch Vehicle (CLV), Cargo Launch Vehicle (CaLV), and the Crew Exploration Vehicle (CEV), etc.). These documents are briefed through the LCRSP prior to final coordination and approvals by the KSC Center Director, Constellation Program Manager, and 45th Space Wing Commander.

For more background and information on Constellation Tailoring, *click here.*

2. NPR 8715.5 Revision

As NASA Range Safety continues to grow and mature, it became evident that our range safety requirements needed to do the same. In late 2007, we initiated an effort to revise our current NPR requirements document, NRP 8715.5, *Range Safety Program*, dated 8 July, 2005. To aid in this effort, an NPR Technical Interchange Meeting (TIM) was conducted in Colorado Springs, CO involving subject matter experts from NASA, Air Force Space Command, and the Federal Aviation Administration (FAA). The TIM yielded positive results with respect to commonality of requirements and updates to our range safety requirements.

We have spent the majority of 2008 vetting comments and coordinating deletions, updates, and language within our organization and NASA Headquarters. There have been a few challenges

that we continue to work, such as noncompliance terminology, aggregate risk, and Unmanned Aerial Systems, to mention a few.

There is an ongoing discussion within NASA to utilize common terms and definitions associated with noncompliances, be it variance, deviation, waiver, or equivalent level of safety (ELS). We are working to ensure that these terms are consistent with other NASA procedural requirements documents and throughout all NASA programs. Both the Air Force and FAA use the terms waiver and ELS to identify noticeable or marked departures from requirements, standards, or procedures. Although these terms are commonly understood within the range safety community, they may not be consistently interpreted by other NASA programs.

Even before a Werner Von Braun-led V-2 rocket launched from White Sands Missile Range landed outside of its containment area just east of Alamogordo, New Mexico on 15 May, 1947, there have been questions with respect to the acceptable risk criteria for workers and the general public. Early in the space program, risks were largely unknown, and as a precaution, isolated areas were selected as launch sites to accommodate a public safety containment philosophy. As the space program has evolved, containment has become more difficult due to the increasing range populations and explosive potential of launch vehicles, encroachment of populations and municipalities around launch sites, and increased sensitivity to public risk. To help deal with these concerns, a risk management philosophy was adopted to help ensure people are not subjected to a risk of injury that is greater than that associated with normal day-to-day risk.

Today, NASA's risk criteria is expressed in terms of Probability of Impact, Probability of Casualty (Pc) (or individual risk), and Casualty Expectation (Ec) (or collective risk). These criteria can be applied per mission or annually but are always applied on a per hazard basis. These acceptable risk criteria have been in our NPR since its posting in 2005 and have been a community standard for many years. In 2006, the Range Commanders Council decided to transition from the collective risk criteria to an aggregate risk criterion to better encompass a combination of all risks associated with a mission.

Transitioning to aggregate risk will change how the range safety community and risk acceptors apply collective risk via the aggregate risk criteria. Individuals must not be exposed to a probability of casualty greater than 1E-6 for any single mission from all hazards. Collective risk for the general public now must not exceed a casualty expectation of 100E-6 (1E-4) for any single mission from all hazards. According to RCC 321, *Common Risk Criteria Standards for National Test Ranges*:

> Limiting the collective risk for the general public to 100E-6 (1E-4) expected casualties per mission ensures protection that is generally consistent with, or more conservative than, the previous limit of 30E-6 (3E-4) expected *fatalities due to inert debris.* Specifically, the typical ratio of fatality expectation to casualty expectation for the typical hazards indicate that the 100E-6 (1E-4) expected casualties criteria is likely to limit a range activity more than the previous limit, unless the range activity presents inert debris hazards only. For example, a launch with inert and explosive debris hazards and a risk estimate of 100E-6 (1E-4) expected casualties would typically correspond to about 25E-6 expected fatalities. So the 100E-6 expected casualty limit provides more protection than the 30E-6 expected fatality limit, particularly if toxic or DFO risks are significant. Thus, the current standard for expected casualties is rational: consistent with the previous expected fatality criteria from a safety perspective.

> This same ratio between the expected casualties and expected fatalities criteria for General Public is carried over the Mission Essential/Critical Operations Personnel categories and Annual criteria.

Additionally, there has been a move afoot over the past few years to transition from the term "uninhabited aerial vehicle (UAV)" to "unmanned aerial system (UAS)." The rationale behind this move is to focus on the entire system, encompassing the ground control station, remote control operators, computer systems, and the aerial vehicle, not just the aerial vehicle itself. In late 2006/early 2007, the FAA mandated the use of the term UAS when applying for a certificate of authorization (CoA) to fly in national airspace. Based on that mandate, the DoD was the first agency to comply and has fully integrated the term into its programs. Corporate enterprises have since made the transition. With the ever expanding role of UAVs, it is only appropriate that NASA make the transition, too.

In addition to these topics, NASA Range Safety is keeping a close watch on the collision avoidance process with respect to impact probabilities and miss distances, changes in range architecture, and frequency management issues and concerns. NASA Range Safety continues to work these issues to better understand the rationale behind each potential change and incorporate items in the NPR based on sound technical judgment while staying attuned to our dynamic environment.

3. Range Safety Launch Support Policy

In previous annual reports, we have focused on how NASA Range Safety implements NASA Range Safety policy and explained the various Memorandums of Agreement (MOA) and launch support policy letters that were developed with the Eastern and Western Ranges in order for NASA Range Safety to adequately support pre-launch, launch, and post-launch activities.

In 2008, NASA Range Safety continued work on developing a change to the Space Shuttle Program (SSP) Launch Commit Criteria (LCC) in an effort to implement the requirements of NPR 8715.5. Emphasis was placed on establishing a shared responsibility for range safety with the 45th Space Wing, establishing a real-time variance process and identifying appropriate countdown risk acceptors. Acceptable risk criteria consistent with the Range Safety Risk Management Plan (RSRMP) for the SSP, vehicle tracking, and command requirements are also being added. Furthermore, we worked with the 1st Range Operations Squadron to update mandatory criteria for the Range Safety Display System for Flight Operations Version 1 (FOV 1). The resulting proposed LCC Change Notice (LCN) is being worked through the Space Shuttle Range Safety Panel.

Additionally, NASA Range Safety has been working an update to the KSC PLN 2804, *John F. Kennedy Space Center Range Safety Landing Implementation Plan for Space Shuttle and the Landing Implementation Plan*, and to KSC PLN 2805, *John F. Kennedy Space Center Range Safety Risk Management Plan for Launch and Landing of the Space Shuttle*, into a single document which includes the addition of Ares 1-X acceptable risk criteria.

We are coordinating a review of our current MOA with the 45th Space Wing which is scheduled for its triennial review in February 2009. During this review process, we will jointly determine the applicability of each piece of the agreement and make updates and/or deletions where necessary. Our initial Range Safety MOA with the 30th Space Wing is still being coordinated

through Vandenberg Air Force Base leadership. We expect this MOA to be signed in early 2009.

We have also been very active in the development and implementation of tailored requirements for the Constellation Program for both Ares 1-X and Ares 1 as delineated in other included articles. Throughout 2009, we will continue to focus on the preparation of Launch Commit Criteria for Ares 1-X that allows shared responsibility of range safety requirements as described in AFSPCMAN 91-710 and NPR 8715.5.

For more background and information on Range Safety Launch Support Policy, *click here.*

4. Range Safety Group

For more background and information on the Range Safety Group, *click here.*

a. Range Commanders Council Range Safety Group Recap

The Range Commanders Council (RCC) was founded in 1951 to provide a way for DoD test ranges to communicate and discuss problems common to all test ranges. Until this year, NASA was an Associate Member of the RCC with representatives on 6 of the 14 RCC working groups. In the 24 July, 2008 RCC meeting, NASA provided a detailed presentation of their research, development, and test capabilities and applied for full membership. The RCC unanimously approved the request, and NASA became an official voting member.

The RCC Range Safety Group (RSG) continues to provide a forum in which ranges can standardize, develop, and improve on a variety of subjects and processes related to range safety. Range Safety representatives from NASA HQ, KSC, DFRC, and WFF actively support the RSG and its subcommittees on a regular basis. The RSG chair for 2008 was from DFRC, and the new vice chair for 2009 is from WFF. There were two RSG meetings in 2008, summarized below.

b. 102nd Range Safety Group Conference

The 102nd RSG conference was hosted by the 30th Space Wing, Vandenberg Air Force Base, in Santa Maria, CA. The RSG main committee and Flight Termination Systems Committee (FTSC) met. The Directed Energy Range Safety Committee (DERSC) and the Risk Committee (RC) did not meet.

In the main committee, special presentations were made by NAVAIR Pax River (UAV Incidents and Range Safety Criteria for UAVs); NASA DRFC (State Diagram for Standard FTS Tone Receivers), and Mantech SRS (Reusable Launch Vehicle Launch and Reentry and Non-reusable Reentry Safety Requirements). The latter presented issues and concerns for the re-write of AFSPCMAN 91-710 and 91-711. These presentations were followed by Range Reports from each range.

Some of the topics discussed in the FTSC were the Enhanced Flight Termination System (EFTS) program update and status, various Autonomous Flight Termination System briefings, advanced high voltage ordnance initiation systems, a Subminiature Flight Safety System (SFSS) update, and commercial off-the-shelf software in ground transmitter systems. Special

presentations were also made by several vendors in attendance, including Ensign-Bickford, ATK Launch Systems, Honeywell, and ABSL Space Products.

c. 103rd Range Safety Group Conference

The 103rd RSG conference was hosted by Navy SCORE (Southern California Offshore Range) in October. It was held in San Diego at the Naval Air Station North Island Naval Base, Coronado. The RSG main committee and FTSC met; the RC and DERSC did not.

In the RSG main committee, Navy SCORE gave an excellent briefing on their facilities and operations, which includes the nations largest underwater test range. Wallops Flight Facility also gave an in-depth presentation and discussion on the recent ALV-X1 failure at WFF, which included a successful activation of the Flight Termination System (see the WFF status report for more information on this event). These presentations were followed by the standard activity reports from each range.

The main topic at the FTSC was EFTS. Several Ranges presented their implementation plans for EFTS and the timeline associated with this endeavor, including Eglin Air Force Base, Edwards Air Force Base/Dryden Flight Research Center, White Sands Missile Range, China Lake, and Point Mugu NAVAIR Pacific. The FTSC also discussed the various RCC documents that would need to be developed or updated to include EFTS. RCC 319, *Flight Termination Systems Commonality Standard,* would have to be revised and updated to include EFTS. Three documents would most likely have to be created to cover specific EFTS topics: an RCC, integrated requirements document that the EFTS program has developed; a second RCC document, the EFTS receiver specification that the EFTS program developed with L-3 Cincinnati Electronics; and finally, the test standard for EFTS receivers, similar to RCC 313, *Test Standards for Flight Termination Receivers/Decoders*.

The FTSC and EFTS program also assigned range identifiers to each test range. These range identifiers are part of the EFTS command message that is sent to the vehicle. Each range has a range ID that is used during operations and each receiver has this range ID loaded into it for verification. This prevents a range from inadvertently terminating a nominal vehicle operating on another range.

The Risk Committee did not meet at either of these conferences because they were awaiting approval and funding for task proposals from the executive committee. Prior to the October RSG in San Diego, the Risk Committee received approval and funding for three tasks:

1. An update to RCC 321-07 to include detailed guidelines on treatment of uncertainty in risk assessments and recommendations for evaluating catastrophic risk

2. An update to RCC 321-07 to include conditional risk guidelines and criteria

3. An update to RCC 321-07 to include specific actions for asset protection

5. Air Force and Federal Aviation Administration Common Standards Working Group (AF/FAA CSWG)

Link from areas identified below for AFSPCMAN 91-710, 91-711, and Code of Federal Regulations Title 14, in folder (to date 91-712 not out)

For more background and information on the Air Force and Federal Aviation Administration Common Standards Working Group, *click here.*

a. Reusable Launch Vehicles (RLV) Requirements

The AF/FAA CSWG RLV Sub-Group was formed in April 2006 to initiate the development of public safety requirements for the launch, reentry, and recovery of reusable launch vehicles. The group completed initial development of public safety requirements and sent the updates out to industry for comment. We spent approximately three months dispositioning comments and providing responses to industry. The estimated completion of manned RLV requirements (via incorporation into AFSPCMAN 91-710) is CY 09. Additionally, the group worked RLV requirement inputs for AFSPCMAN 91-711, which will be the focus once AFSPCMAN 91-710 RLV requirements are complete.

As new and emerging space launch technologies surface, the CSWG will continue to provide a forum through which the Air Force, FAA, NASA, and other government agencies can communicate. The goal of this group has been, and will always be, to maintain public safety in all phases of launch activities while developing and implementing common range safety standards.

b. AFSPCMAN 91-710 Update

Air Force Space Command Manual 91-710 (AFSPCMAN 91-710), *Range Safety User Requirements* specifies range user launch safety requirements. It was distributed to industry, NASA, and AFSPC organizations for review and comment in an effort to update the current July 2004 version. Consolidated comments to the plan have been received, with the review and update process scheduled to being in early 2009.

c. AFSPCMAN 91-712

HQ AFSPC/SE will revise and combine the computer and software requirements for range users (currently in AFSPCMAN 91-710) and the computer and software requirements for range operators/acquirers into a single document, Air Force Space Command Manual 91-712 (AFSPCMAN 91-712), *Launch Safety Software and Computing System Requirements*. AFSPC convened an AF/FAA CSWG Software Sub-Group to develop and coordinate these requirements. The draft computer and software requirements were sent to industry, range users (including NASA), and range operators/acquirers for their review and comment. HQ AFSPC/SEC continues the process of reviewing and dispositioning these comments. Both the AF and FAA want to ensure that the software requirements remain common between the two agencies. Currently there is no projected release date for this document.

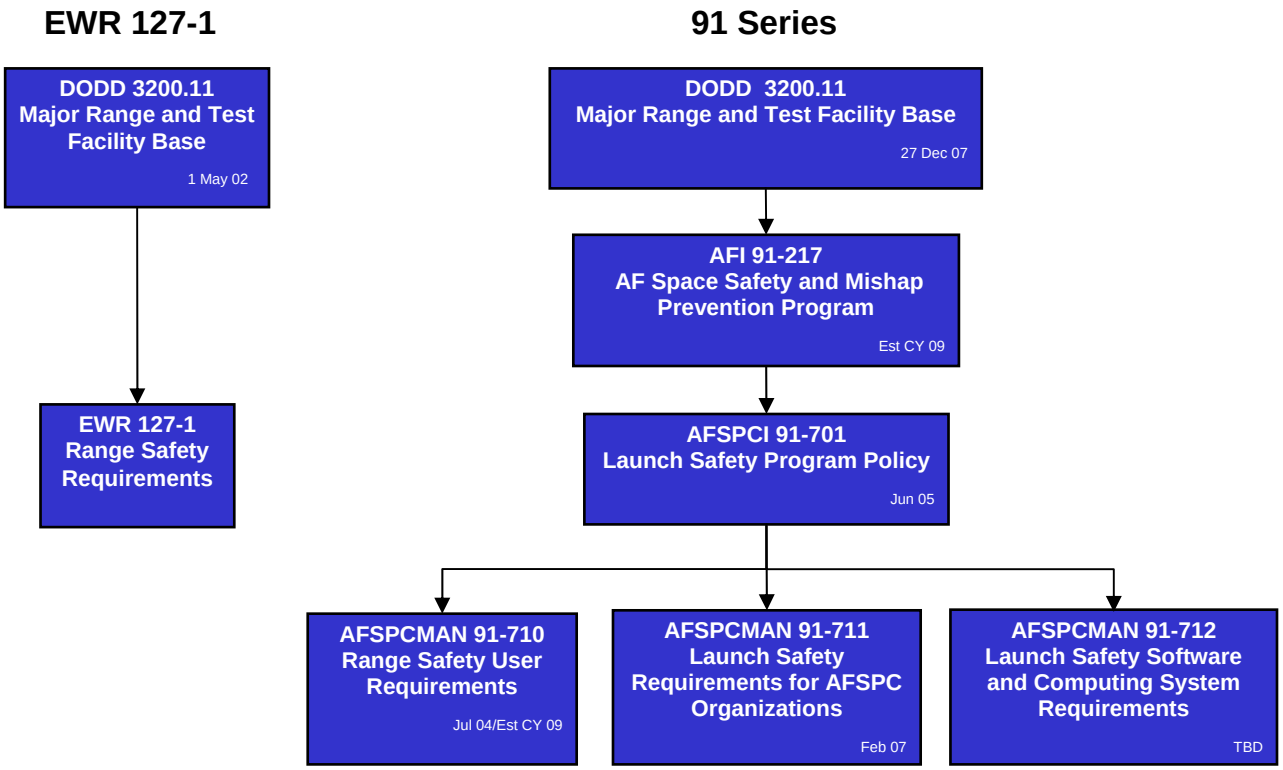

FIGURE 6: TRANSITION FROM EWR 127-1 TO THE 91 SERIES

6. Unmanned Aerial Systems Working Group (UASWG) Policy Development Update

For more background and information on the UASWG Policy Development Update, *click here.*

a. An Evolution Trending Towards Revolution

Unmanned Aerial Systems (UAS) is a technology evolving at an increasing pace. During the last two decades, there was a gradual evolution in the field from drones and Remotely Piloted Vehicles to Unmanned Air Vehicles (UAV). In the 1990s, the technology accelerated to include consideration of the entire flight system – the unmanned aircraft, the command and control links, the ground control system, the navigational inputs, and the controller. By 2000, such flight systems had evolved into network-centric and mature systems vital to fulfilling our national needs. These flight systems encompass a wide range of UASs, including hypersonic vehicles, rotary wing hover systems, lighter than air systems, and various hybrid vehicles. Included in this group are vehicles ranging in size from full scale aircraft down to vehicles the size of houseflies. All are considered UASs since they are controlled by computer programs or the pilot is not on board.

As the technology advances, UASs will soon be operating at all altitudes of the atmosphere and beyond, and it is now difficult to distinguish any difference between an unmanned re-entering Reusable Launch Vehicle and an Unmanned Aerial System.

In 2005, the NASA Range Safety office, the NASA Applied Technology Directorate, and the USAF 45th Space Wing Range Safety office formed an Unmanned Aerial Systems Working Group (UASWG) to address the range support and range safety issues for such diverse systems operating near the launch head of the Eastern Range.

b. Development of Range Safety Requirements

Since 2005, a major technical thrust has been the development of range safety requirements specifically designed to the unique risks at the Eastern Range for unmanned aerial system operations near the launch head. Such challenges include rocket plume effects upon unmanned aerial system flight hardware, additional risks from unmanned aerial system accidents impacting highly volatile rocket propellant facilities, and the application of risk management principles for the safety of personnel and public in relatively close proximity.

During past efforts to address these challenges, the UASWG conducted an extensive document review (2005-2006) to identify subtopics to be addressed in a requirements document and a flight operations manual. Upon the completion of the document review, an outline was developed and sections were assigned to personnel to construct requirements. The rapidly evolving operational concepts and current considerations for operating unmanned aerial systems in the National Airspace create challenges in the development of range safety requirements. In 2007, the safety risk management process was significantly refined in order to address mature operational unmanned aerial systems.

During 2008, the Common Standards Working Group (CSWG) composed of members from Air Force Space Command, NASA, Federal Aviation Administration, and the commercial spacelift industry, worked diligently to rewrite Air Force Range Safety Manuals and AFSPCM 91-710 and 711 to mitigate risks to public safety from the reentry of reusable launch vehicles. Efforts from the NASA-USAF UASWG were useful for these reusable launch vehicle operations. Terminology and paradigm differences between the aviation and rocketry communities were recognized and resolved by the creation of a “Flight Safety System Rosetta Stone.” Paradigms for unmanned aerial system flight safety systems are now being applied to reusable launch vehicle re-entry flight safety systems and risk-based safety requirements for manned and unmanned ballistic, aerodynamic, and buoyant flight operations are approaching consistency.

c. Operational Priorities

Prior to 2008, large unmanned aerial system operations at Cape Canaveral AFS and Kennedy Space Center were not considered appropriate since they generated unwarranted risks to high priority national launch head assets and were an unnecessary hindrance to the primary mission of launch operations. This viewpoint changed with the DoD “Big Safari” Program in 2008, which involved several days of Predator B (aka Reaper) landing and takeoff operations from the Cape Canaveral Air Force Station Skid Strip.

To accommodate the goals of Big Safari, Air Force Range Safety developed range safety practices for the program using concepts developed in the draft Unmanned Aerial Systems Range Safety Requirements Document. Air Force Range Safety arranged flight patterns to avoid overflight of “risk multipliers” or launch head assets that would generate significant secondary risks if impacted by a flight accident. Air Force Range Safety established “Ditch Sites” at the end of every flight pattern leg and prior to the Skid Strip approach to safely terminate the flight if critical vehicle control performance parameters could not be confirmed.

Big Safari was conducted during and in close proximity to ongoing preparations for a Delta II launch without hindrance or unacceptable risk to either operation.

Currently, support for other large, mature DoD and Department of Homeland Security unmanned aerial systems is being considered, and the possibility of home-basing is being assessed. As requests are received for UAS operations of varying maturities and risks, further attention must be given to addressing safety critical technical challenges and configuring an approach for team responsiveness.

d. Technical Challenges

Two major technical challenges came to the forefront this year. First, determine how to manage relatively mature Unmanned Aerial Systems within one or two orders of magnitude as reliable as traditional manned aviation systems. Second, determine how to recognize and certify critical Flight Safety Systems that are not standard from a traditional ballistic launch vehicle perspective but utilized in manned aircraft flight test.

e. Managing Mature UASs

The Big Safari operational support brought the first operationally mature unmanned aerial system to CCAFS, initiating the technical challenges introduced in this section. To evaluate the actual maturity of the UAS, a maturity assessment was made, noting an Air Force-issued Airworthiness Certificate (AFMC Form 273) and taking into careful consideration accident rate data. This posed a challenge, however, as much of the accident rate data is recorded in terms of accidents per cumulative flight hours, whereas primary Launch Head safety concerns need to be addressed in terms of accident rates and cause during take-off, landing, and airfield flight pattern flight modes. Flight time risks during off-shore cruising flight modes confined within special use airspace are managed by procedural control mitigations.

Risks during critical take-off, landing, and airfield flight pattern modes can be identified by first seeking data via a checklist derived from RCC Standard 323. Risks to the public and the launch head can be identified from this data. These risks were significantly mitigated by establishing flight rules establishing flight pattern and flight system health confirmations, coordination of radio and radar interferences, and minimum safe altitudes over critical areas. Emergency procedures were predefined for lost links, ditching, and crash landing. Compliance with Range Safety procedures was confirmed by the presence of a Range Safety Observer in the Ground Control Station (GCS) during critical phases of flight within 30 minutes of takeoff and landing. During all other phases, the Range Safety Observer was readily available.

f. Reorganizing and Certifying UAS Flight Safety Systems

Regarding the second technical challenge, an approach was needed to define broader requirements accommodating alternative, and as yet unforeseen, Flight Safety System options while ensuring public safety.

Many Flight Safety System alternatives are in use throughout the aerospace industry including manned air flight, unmanned aerial systems, precision guided munitions, manned spaceflight, small sounding rockets, re-entry payloads, etc. Flight Safety Systems provide a means of control during flight to prevent hazards from flight vehicles or payloads from reaching populated or protected area in the event of a flight vehicle failure. Flight Safety Systems include all airborne and ground hardware, software, and any human-in-the-loop controls used to protect

the public. Human-in-the-loop controls include associated human-systems interfaces and may involve ground-based Mission Flight Control Officers or Range Safety Officers, flight vehicle-based pilots or Flight Safety Officers, or any combination of these elements.

As a Range Safety tool, a Flight Safety System may be used to minimize public safety risk, liability, or emergency management functions. Risk management involves reducing risk to an acceptable level by methods such as destructively terminating flight, terminating thrust, or altering unacceptable vectors or momentum (occasional nudge or flight mode change). Liability management to record and document event outcomes may utilize a Flight Safety System's tracking capability. Likewise, emergency management functions need to know when, where, and how to execute emergency response protocols.

A Flight Safety System may include any or all of the following subsystems depending on the nature of the risks to be mitigated:

(1) Range Tracking Subsystem (RTS) - a method to track the flight vehicle.

(2) A method to receive safety critical status data from the vehicle.

(3) Command Subsystem - A method to either manually, autonomously, or by a combination of both to compare tracking and critical status data to the following established criteria:

- Decide when and if corrective action is required to ensure the criteria is not violated.
- Timely execute the appropriate actions based on the data received or the absence of such data.
- Individuals performing such manual functions may be referred to as Mission Flight Control Officers (MFCOs), Range Safety Officers (RSOs), or Pilots.

(4) A method to affect change to ensure safety criteria is fulfilled, by either:

- Flight Termination Subsystem (FTS) – all components that provide the ability to terminate a launch vehicle's flight in a controlled manner; the flight termination system consists of all command terminate subsystems, inadvertent separation destruct subsystems, or other subsystems and their components that are used to terminate flight.
- Contingency Management Subsystem (CMS) – a method to execute commands to either place the vehicle in a safe or recovery mode or affect real-time corrective actions to resume safer flight.

The reliability of a Flight Safety System is dependent upon the reliability of all components of the subsystems required in the solution to execute a safety control function. This includes components that are ground-based assets; aboard the risk-generating flight vehicle; aboard any other mobile or fixed relay or sensing platforms; inertial, GPS, or any other positional or state-vector determining inputs; software; and the decision making process. Quantifying and confirming attainment of a Flight Safety System's reliability may be a critical and challenging

requirement. Therefore these reliability requirements need to be scalable dependent upon the specific risks and the specific risk mitigating solution.

The aviation community continues to express concern over allowing unmanned aerial system flight operations in shared airspace. Some unmanned aerialsystems are quite mature, but before they become as safe and reliable as piloted aircraft, technologies must continue to evolve. In pursuit of this goal, attention must be paid to the following:

- A reliable means to "sense and avoid" other planes and obstructions.
- New air-traffic control systems based on electronic rather than voice communications.
- Ability to address and resolve in-flight unmanned aerial system anomalies.

g. Teaming for Responsiveness

In 2005, the NASA Applied Technology directorate initiated the partnership with the Air Force to establish a joint UAS program for UAS operations at KSC, CCAFS, and PAFB with the common goal of meeting identified range mission goals. The need for the establishment of a UAS program was identified by NASA and the Air Force through work encompassed in a NASA-Air Force Memorandum of Agreement (MOA) for setting advanced range technology development goals, and proceeding with next generation technology development and demonstration. This was a NASA Range Safety funded activity.

UAS range functions, as identified by the NASA programs and the Air Force, include UAS:

- To be a relay site between launch vehicles and ground-based operations control centers, providing tracking, telemetry, and launch vehicle commanding.
- To provide rapid responses; tracking and surveillance (i.e., SIGINT, ISR) utilizing thermal, optical, chemical, weather, radar systems.
- To permit real-time, simultaneous monitoring of near-field and far-field zones.
- To provide broadband communication (i.e., IRIS, iNET) extending to large areas.

The NASA-AF UAS range goals will be met by:

- Establishing a NASA-AF UAS Customer Process, UAS Requirements, UAS Concept-of-Operations (CONOPS) for mission support.
- Building a UAS customer base for development and on-site flight demonstrations of instrumentation and systems to meet NASA-AF range CONOPS goals.
- Partnering with Services, Agencies, and Coalition elements to provide the best capabilities for future launches, with the benefit of simultaneous mission needs and cost sharing.
- Seeking the best technical and operational concept solutions from Defense, industry and academic sources.

The NASA Applied Technology Directorate represented KSC in a new Integrated NASA UAS Working Group (INUWG), the first meeting being held at Ames Research Center in 2008. INUWG, a NASA-wide forum, was established to improve Agency-wide communication and coordination of UAS information, promote integration between NASA and other agencies, mitigate risk to mission, and optimize safety. INUWG members intend to standardize high-level NASA policies and procedures for UAS activity that will effect changes to each centers requirements process. The results of the INUWG will be reported annually to the NASA Inter-Center Aviation Operations Panel (IAOP) Chair and NASA HQ Aviation Management Division (AMD). The NASA-AF UAS initiative will benefit from the INUWG membership through opportunities to share recent changes to FAA-NASA-DoD policies, procedures, and hazard identification summaries.

The NASA-AF Unmanned Aerial Systems Working Group continues to strive for operational robustness to protect personnel, property, other aircraft, and national assets, while enabling new flight systems to operate with appropriately managed risk. As UAS operations and range support become routine, the range safety requirements need to meld, possibly via a Common Standards Working Group subcommittee, to standardize USAF, FAA, and NASA Unmanned Aerial System requirements. Range-unique concerns, avoiding risk to specific high value or hazardous national launch head assets, or conducting critical flight operations within hostile launch exhaust or accident environments could be addressed by such a subcommittee to seek requirements commonality and ability to link to range-specific supplemental requirements documents. Furthermore, such a subcommittee could enable the pursuit of developments for optimized collision avoidance systems and innovative flight safety systems.

7. Flight Safety System Update

For more background and information on the Flight Safety System Update, *click here.*

a. Flight Safety System Challenges

To protect of the public, the local workforce, and property, NASA Range Safety ensures that the Flight Safety System (FSS) associated with the launch vehicle is robust and reliable. NASA Range Safety is often faced with issues that could affect how the FSS functions and operates, and these issues must be vigorously investigated to ensure that the FSS will function properly when activated. Some of the major FSS challenges NASA Range Safety dealt with in 2008 are discussed below.

b. Pyrotechnic Shock Testing Concerns

One of the main test services providing pyrotechnic shock testing was found to be inadequate.

Shock testing is performed on launch vehicle system components to ensure that components and systems will perform nominally during flight. The test levels should envelope the maximum predicted environment (MPE) for that component plus some margin to account for nonnominal flight. There are a variety of different types of shock testing such as beam shock, drop shock, and pyrotechnic shock, as well as several different environmental testing services used to perform this testing.

The pyrotechnic shock test service was found to be inadequate because a digital data acquisition system was being used without the use of an anti-aliasing filter. This caused the

reported shock test levels to be significantly higher than the actual shock levels, resulting in an under-test condition.

The magnitude of the shock under-test varied with the specific test setup. For some components, the variation was as much as 20 dB or more at certain frequencies. Since several programs and vendors have their hardware tested at this location, it was determined that this poses a significant problem. Of particular interest to NASA Range Safety were the components located in the vehicle flight termination system. Numerous components were involved and were cleared for flight based on rationale such as design features, subsequent confidence testing, flight history, post-flight testing, and previous qualification and acceptance testing.

Based on these test histories and associated analysis, NASA Range Safety had to make recommendations regarding these components and their ability to function nominally during flight.

c. Constellation

NASA Range Safety continues to work with the Constellation program to ensure that all range safety requirements are met.

NASA Range Safety met with representatives from the Constellation Program, 45th Space Wing Safety Office and contractor personnel to continue the tailoring process of NPR 8715.5, *Range Safety Program*, and AFSPCMAN 91-710, *Range Safety User Requirements*. When finished, this document will be the official joint “Range Safety” document for the Constellation Program.

d. Frequency Concerns

Flight termination systems can be designed to use various frequencies for operation. The frequency used is dependant on the range. Each range has a set of frequencies or a frequency band in which they operate. The Eastern and Western Ranges have operated various programs and vehicles on 416.5 megahertz (MHz) for decades. However, the National Telecommunications and Information Administration (NTIA) recently directed that 416.5 MHz no longer be used for flight termination purposes. In addition to their objection to overcrowding, the NTIA feels that wideband ultra high frequency systems, such as FTS, should be operating in the 420-450 MHz spectrum.

Range users have agreed to migrate to the 420-450 MHz band but have expressed concern that existing hardware has been purchased and implemented for 416.5 MHz use. Therefore, remaining launches already scheduled to use 416.5 MHz have been granted approval, while ultra high frequency systems for all subsequent flights will operate in the 420-450 MHz region. The one exception for the Eastern Range is the Space Shuttle Program. This program has a waiver to operate on 416.5 MHz through 2010. If Shuttle does not fly out by this date, another waiver will be requested.

Another concern with transitioning to the 420-450 MHz region is that some high powered radars located at various installations operate in this frequency band. Some of these radars, such as the PAVE PAWS radar, have proven they can indeed interfere with the flight termination receivers located on the launch vehicle.

The Eastern and Western Ranges have mitigation actions in place to coordinate range operations with the various installations using PAVE PAWS to ensure that no interference

occurs. One long term solution to this problem is migration to another frequency band where these radars do not exist. The Range Commanders Council Frequency Management Group has put in an official request for use of the 370-380 MHz band for FTS operations. As of this writing, no decision has been made.

FIGURE 7: PAVE PAWS RADAR

For more information *click here* for last year's article.

e. Emerging Technology Development

NASA Range Safety continues their involvement with emerging technology such as the Enhanced Flight Termination System (EFTS), the Autonomous Flight Safety System (AFSS), Reusable Launch Vehicles (RLVs), Unmanned Aerial Systems (UAS), and Space-Based Range Demonstration and Certification (SBRDC). Through various groups and technical interchanges including the Range Commanders Council Range Safety Group and the Common Standards Working Group, NASA Range Safety has been able to stay fully aware of the various programs and technologies that are being developed and continues to monitor these programs for future use and implementation