2008

NASA Range Safety Annual Report

This 2008 Range Safety Annual Report
is produced by virtue of
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VI. STATUS REPORTS

A. Kennedy Space Center (KSC)

The Kennedy Space Center Range Safety Representative is tasked with implementing NASA policy and keeping the Agency Range Safety Manager informed of all activities related to range safety. Over the course of the past year, the KSC Range Safety Representative supported a multitude of range safety activities, ranging from prelaunch policy interpretation and guidance to providing on-console support during launch campaigns.

For more background and information on the KSC Status Report, *click here.*

1. Constellation Program

The Kennedy Space Center Range Safety Representative participated in meetings and technical exchange sessions supporting the development of a set of tailored range safety requirements for the Ares 1-X Test Flight Mission. The tailored Range Safety Document, identified as CxP 70155-01, was approved by the Constellation Program Manager, the KSC Center Director, and the 45th Space Wing Commander in late October. The mission will be required to meet both the Air Force Space Command Manual (AFSPCMAN) 91-710, *Range Safety User Requirements* and NPR 8715.5, *Range Safety Program Requirements*. Working through the Launch Constellation Range Safety Panel (LCRSP), the 45th Space Wing Safety Office, Constellation Program Office, and NASA Range Safety successfully developed a single joint tailored document that includes all range safety requirements. This unique teaming process set the groundwork for future tailoring of Constellation Program range safety requirements. The effort also exemplified NASA's philosophy of accepting (or sharing) responsibility for all aspects of range safety. A draft set of tailored requirements for the Ares 1 Launch Vehicle is also underway.

The KSC Range Safety Representative led an effort to prepare a requirements document that will be used to develop a Constellation Program Range Safety Risk Analysis Tool Kit. In 2008, a team consisting of NASA Range Safety, JSC, the 45th Space Wing, and risk model development support contractors completed a requirements draft document that will pave the way for future risk model development. The document includes preferred modeling capabilities but also focuses on verification and validation (V&V) and configuration management requirements. Although the ascent debris hazard assessment capability will be developed first, other hazards such as decent debris, distant focusing overpressure (DFO), and toxics risk are also being considered. The draft requirements document was presented to a LCRSP splinter group in October and received positive feedback.

The Range Safety Representative also provided continued support to the LCRSP and associated Constellation Program working groups.

2. Space Shuttle Program

The KSC Range Safety Representative was involved in the development of an update to the Launch Commit Criteria (LCC) for the Space Shuttle Program Document which will implement NPR 8715.5, *Range Safety Program* requirements. Working through the Shuttle Range Safety Panel, a proposed Launch Change Notice (LCN) incorporating KSC Center Director and Space Shuttle Program Manger responsibilities has been completed, as well as updated acceptable

risk criteria. The change is expected to be presented to the LCC Working Group in late 2008 or early 2009.

Launch and entry risk estimates were evaluated for STS-122, STS-123, STS-124, and STS-126, with mitigation efforts initiated through the KSC Emergency Operations Center when appropriate.

The KSC Range Safety Representative also provided continued support to the Shuttle Range Safety Panel and supported STS-122, STS-123, STS-124, and STS-126 launches on console in the Morrell Operations Center (MOC).

3. Launch Services Program

The KSC Range Safety Representative supported a number of NASA expendable launch vehicle campaigns for the Launch Services Program (LSP), including GLAST, OSTM, and IBEX. This effort involved attending all the NASA and Air Force Safety readiness reviews and ensuring NPR requirements were being met during the respective prelaunch and launch countdowns. In 2008, KSC Range Safety became an active participant in the LSP risk boards, presenting items that may increase the public safety risk to the public and workforce.

4. Agency Activities

The KSC Range Safety Representative served as a NASA point of contact to the Range Safety Group and supported committees charged with developing or rewriting nationwide standards on a number of important range safety issues. These topics included developing reusable launch vehicles, uninhabited aerial systems and system requirements. The KSC Range Safety Representative was also active in the development of a proposed policy for the future use of autonomous flight safety systems within NASA. KSC is closely monitoring the status of the AFSPC-proposed decommissioning of Eastern and Western Range ground tracking and command assets through their Future Range Architecture Team.

2008 was a challenging year, supporting a number of launch and entry campaigns, providing critical support to the Constellation Program, continuing to ensure Kennedy Space Center safely implements NASA Range Safety requirements, and tracking emerging technologies. The coming year promises to be equally busy, and the Kennedy Space Center Range Safety Representative will continue to provide critical support where necessary when called upon by NASA programs or to address issues as they arise.

B. WALLOPS FLIGHT FACILITY

Wallops Flight Facility (WFF) had a particularly active and successful year in 2008. The Wallops Safety Office (Code 803) supports all missions at Wallops and also provides support at various other locations around the world as needed. This support includes ground safety and flight safety analysis, documentation of operational rules, and active support of ground processing and flight operations. Listed below are various project/programs that the Wallops Safety Office supports.

For more background and information on the WFF Status Report, *click here.*

1. Sounding Rocket Program

The Sounding Rocket Program (SRP) conducted 9 missions, highlighted by a record breaking launch of a Black Brant XII from Andoya, Norway, which reached an apogee of 1,470 km. Four missions were launched from Wallops including two developmental test flights of a new vehicle based on the surplus M-26 Multi-Launch Rocket System motor and a very successful flight of Suborbital Technology Experiment Carrier (Sub-TEC II) payload, which was recovered approximately 70 miles offshore of Wallops. An additional four missions were successfully launched and recovered from the White Sands Missile Range. The Sounding Rockets program achieved an overall mission success rate of 100% for the missions launched in 2008.

FIGURE 27: SUB-TEC II

FIGURE 28: BLACK BRANT IX

2. Balloon Program Office

The Balloon Program Office at WFF conducted 14 missions during fiscal year 2008. Flight operations were conducted from Fort Sumner, New Mexico, and McMurdo, Antarctica, in support of Space and Earth Science payloads, as well as developmental test flights for new balloon design and balloon film qualification. Flight durations ranged from 4 hours to 30.5 days with the longest flight occurring over Antarctica. The Balloon Program Office continued the Ultra Long Duration Balloon (ULDB) vehicle development. Flight testing of larger scale designs of the

ULDB is planned for 2009. This balloon is being developed to provide extended duration flights (upwards of 60-100 days) at constant float altitudes.

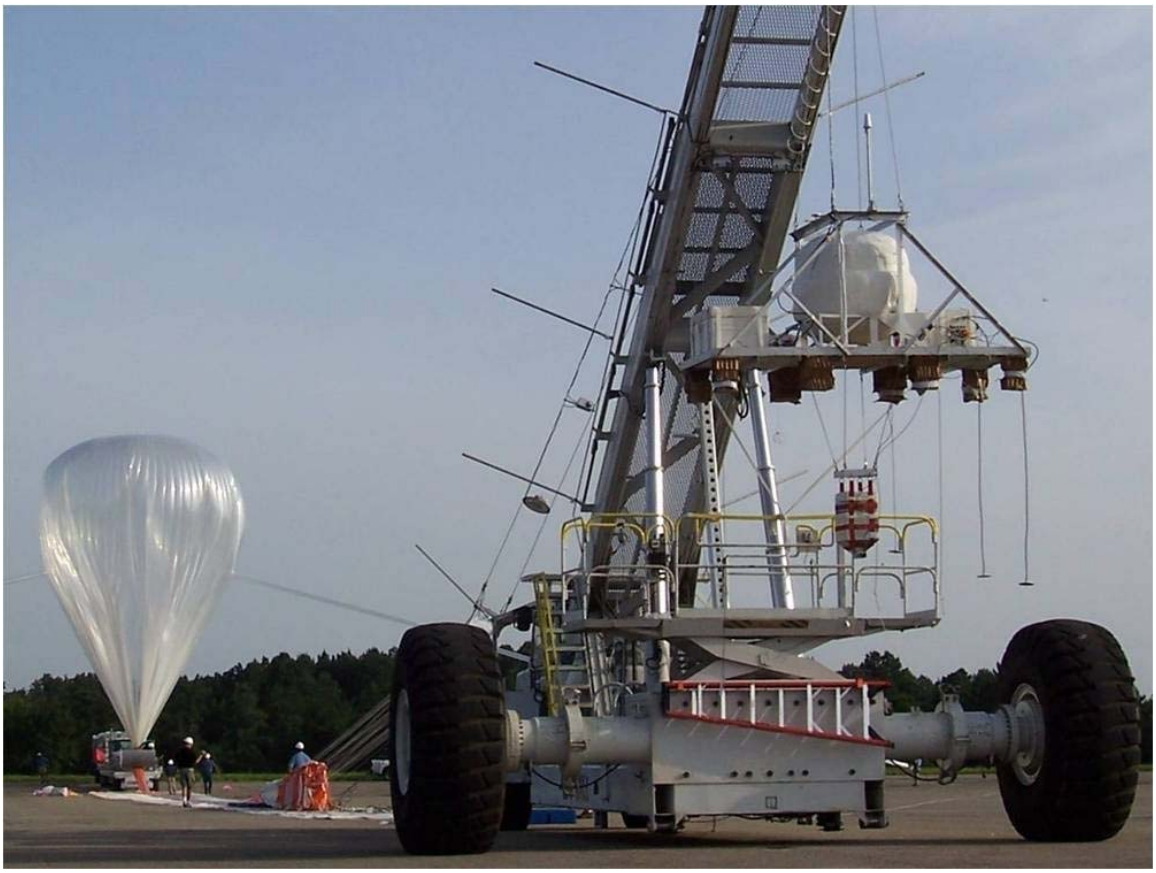

FIGURE 29: TYPICAL BALLOON LAUNCH

3. Airborne Science Program

The Airborne Science Program conducted a series of missions in 2008 using the Wallops P-3B research aircraft including Arctic Climate Change Flights (ARCTAS) over Canada, Alaska, and Greenland from April-July 2008. The ARCTAS mission was the largest of the year, involving flights with multiple agencies and aircraft. The P-3 also flew the Soil Moisture Mapping Validation Experiment (SMAP), which consisted of eight flights flown from Wallops with 100% success in September/October 2008.

In February 2008, the Geostationary Imaging Fabry–Perot Spectrometer (GIFS) mission was flown from Wallops. It is a next-generation geostationary satellite concept for continuous hemispheric imaging of cloud properties, including cloud top pressure, optical depth, fraction, and surface reflectance.

There were four successful P-3 flights in early February off the Atlantic Coast from Virginia to Georgia, with coordinated flights which included CALIPSO underpass flights along with the Langley Research Center (LaRC) B-200 Kingair aircraft. Wallops also continued its hurricane research collaboration with National Oceanic and Atmospheric Administration (NOAA) using the AAI/Aerosonde Unmanned Aerial System (UAS). The Aerosonde UAS (Figure 30) was staged

from Barbados with a small group of NOAA personnel on site; however, the storms dissipated so the mission flights will be flown in the future. Many lessons learned were gathered for future hurricane missions with UAS.

FIGURE 30: AEROSONDE

4. Research Range

In addition to internal NASA sounding rocket and UAV missions, the Research Range conducted numerous missions for NASA and non-NASA organizations. The Range launched the HyBoLT/SOAREX payloads for the LaRC on an ATK launch vehicle. Due to still unknown flight issues, the vehicle was safely terminated at 20 seconds into flight. The Range continues to support multiple test and operational UAS flights for NASA, DoD, and commercial entities. The Range supported two missions for the U. S. Navy; the Advanced Modular Gun Demonstrator (AMGD) test firing, which included one ballistic round exceeding 70 nautical miles in range, and a UAS (Navy BQM-74, see Figure 32) low altitude flight.

FIGURE 31: BQM LAUNCH

FIGURE 32: HYBOLT/SOAREX FLIGHT

Wallops continued development of a number of key technologies intended to improve mission capabilities and lower costs. The third test of the Autonomous Flight Safety System (AFSS), incorporating full functional redundancy and integration of GPS and IMU sensors, is scheduled to be performed on a sounding rocket launched from Wallops. The WFF-developed Low-Cost Tracking and Data Relay Satellite System (TDRSS) Transceiver (LCT2) had several successful transmitter flights. Transceiver capabilities have been added and will be included on the AFSS flight.

A new phased array antenna design that offers opportunity for significantly higher data rates on suborbital and orbital launch vehicles was successfully demonstrated on a sounding rocket in 2008, as was a high data rate (~200MB) Ku Band telemetry system, in an effort sponsored by the Missile Defense Agency.

Wallops continues to upgrade many of its safety critical systems. Funding has been received to upgrade the Flight Termination System (FTS) Command Transmitters to allow for the use of High Alpha and/or the Enhanced Flight Termination System (EFTS) secure commanding capability. Testing continues on the latest version of the real-time computer system that provides flight critical data from various radar and telemetry systems. Requirements documentation has begun on a new mission graphics system. Testing continues of a new aircraft and ship surveillance system. Each of these systems requires safety certification prior to use at WFF.

C. DRYDEN FLIGHT RESEARCH CENTER

The Dryden Flight Research Center (DFRC) located at Edwards Air Force Base, California, is NASA's primary installation for flight research and flight testing. Projects at Dryden over the past 62 years have lead to major advancements in the design and capabilities of many civilian and military aircraft.

The Center supports operations of the Space Shuttle and development of future access-to-space vehicles, conducts airborne science missions and flight operations, and develops piloted and uninhabited aircraft test beds for research and science missions.

Range safety operations at Dryden are managed by the Range Safety Office (RS Office). The Office was established by the Dryden Center Director under an alliance agreement with the Air Force Flight Test Center (AFFTC) to provide independent review and oversight of range safety issues. The Office supports the Center by providing trained Flight Terminations System (FTS) engineers, Range Safety risk analysts, and Range Safety Officers to provide mission and project support for Unmanned Aerial System (UAS) Projects. The DFRC/AFFTC Range Safety Alliance allows both RS Offices to work together, each providing expertise on projects the other office may not be as familiar with.

The DFRC/AFFTC Range Safety Alliance plans to install and test a fixed EFTS transmitter site which should be operational by the end of next calendar year.

Dryden continues to support the testing of a wide range of UASs. The UASs that were flown with Dryden assistance include:

For more background and information on the DFRC Status Report, *click here.*

1. Small UASs

Small UASs (sUAS) are in the model-type classification of flight vehicles. Dryden has established an area that offers sUAS Projects a unique opportunity to conduct flights within the restricted airspace. Dryden has also established a streamlined flight approval process for sUASs that makes the airworthiness and safety review quicker and easier than those performed for larger UASs. Dryden has supported over 300 hours of operations on 9 different platforms from 5 different manufacturers.

2. Blended Wing Body Low Speed Vehicle

The Blended Wing Body (BWB) Low Speed Vehicle (LSV) UAS, also known as X-48B LSV, is a dynamically scaled version of the original concept vehicle. The X-48B LSV Project is a partnership between NASA, Boeing, USAF Research Laboratory, and Cranfield Aerospace. The primary goals of the test and research project are to study the flight and handling characteristics of the BWB design, match the vehicle's performance with engineering predictions based on computer and wind tunnel studies, develop and evaluate digital flight control algorithms, and assess the integration of the propulsion system to the airframe. The BWB testing will address several key areas that future aeronautical designs will face, namely noise reduction, emissions reduction, and improvement in fuel economy. Industry studies suggest that because of its efficient configuration, the BWB would consume 20% less fuel than the

jetliners of today while cruising at high subsonic speeds on flights of up to 7,000 nautical miles. To date, the project has conducted 39 successful flights.

3. NASA Global Hawk

Dryden has acquired two former United States Air Force (USAF) Advanced Concept Technology Demonstration (ACTD) Global Hawk UASs. These preproduction Global Hawks were built by Northrop Grumman for the purpose of carrying reconnaissance payloads. The vehicles will primarily be used to supplement NASA's Science Mission Directorate by providing a high altitude, long endurance airborne science platform. The vehicle has an 11,000 nautical mile range and 30+ hour endurance at altitudes above 60,000 feet mean sea level (MSL). The first airborne science mission flight is scheduled for Spring 2009.

4. Ikhana

NASA's Ikhana UAV is a General Atomics Predator-B modified to support and conduct Earth Science missions for the Science Mission Directorate. The aircraft is designed to be disassembled and transported in a large shipping container aboard standard military transports. Last year, the vehicle successfully flew multiple missions over the western United States in support of the National Interagency Fire Center. The flights reached as far north as Washington, Idaho, and Montana. Recently, the vehicle has flown multiple successful missions over California wildfires, sending near real-time imagery to the firefighters. The vehicle has also flown multiple flights in support of NASA research, specifically the Fiber Optic Wing Shape Sensing tests and Acoustics tests.

Ikhana has been registered with the FAA and given the tail number N870NA.

The Range Safety Office has supported flight planning and risk analysis tasks in support of FAA Certificate of Authorization (COA) applications as well as real-time operations support. The vehicle has flown 20 flights this year with durations lasting as long as 10 hours.

5. Orion

The Orion Project is an element of the Agency's Constellation Program. The Orion Project consists of the Crew Module (CM) and the Launch Abort System (LAS). Dryden is responsible for conducting a series of flight tests to demonstrate proper operation of the LAS and CM recovery systems in response to abort events initiated on the launch pad and during the initial ascent phase of flight. The abort flight tests will be conducted at U.S. Army's White Sands Missile Range (WSMR) in New Mexico.

Dryden is currently in the process of integrating the Crew Module test article for the Pad Abort 1 test flight. Dryden will also be responsible for integration of the second Crew Module test article for the Ascent Abort 1 test flight. Integration of the crew modules for the remaining flights will occur in the Orion Assembly Integration and Test Facility at NASA's Kennedy Space Center.

The development testing that has occurred in Calendar Year 2008 include two successful full-scale static test firings of the LAS jettison motor and one successful full-scale static test firing of the LAS abort motor. The jettison motor is a solid rocket motor designed to separate the LAS from the Crew Module. The abort motor is a solid rocket motor designed to separate the LAS

and Crew Module away from the Ares I launch vehicle in the event of a problem on the launch pad or anytime during first stage burn.

The RS Office tailored NPR 8715.5, *Range Safety Program*, for Pad Abort #1 and provided input to RCC 319, *Flight Termination Systems Commonality Standard* tailoring for Ascent Abort #1.

D. NASA HEADQUARTERS

The Safety and Assurance Requirements Division (SARD) at HQ OSMA provides corporate leadership in the definition and implementation of NASA's Agency-wide Safety and Mission Assurance Policies, Procedures, Standards, Tools, Techniques, and Training. The HQ Range Safety Representative is located within SARD and has oversight responsibilities for the Agency Range Safety and ELV Payload Safety Programs.

The HQ Range Safety Representative and other members of OSMA participated in several primary activities in 2008 in support of the Range Safety and ELV Payload Safety Programs: independent audits of the Agency and local Range Safety functions at Wallops Flight Facility and Ames Research Center; a continuing effort to update NPR 8715.5, *Range Safety Program*; and development and approval of NPR 8715.7, *Expendable Launch Vehicle Payload Safety Program*. The audits were conducted as part of the NASA HQ Safety and Mission Assurance Audits, Reviews, and Assessments Program defined by NPR 8705.6. Numerous proposed revisions to NPR 8715.5 were generated in 2008 by the Agency Range Safety Team. A revised draft document has been developed and will undergo full Agency review in 2009. The HQ Range Safety Representative participated extensively in the development of NPR 8715.7 and was instrumental in its approval on 30 May, 2008.

The HQ Range Safety Representative was directly involved in activities leading up to, during, and after the HyBoLT/SOAREX launch failure at Wallops Flight Facility: served on an Independent Review Team with focus on the Flight Termination System and other flight safety related systems; served on the Range Readiness Review Board; and served on a Special Action Team chartered to conduct a comprehensive review of NASA systems, processes, and performance associated with the launch. The Team verified that NASA followed proper procedures and that the safety systems functioned properly.

Other activities included support to the Range Commanders Council Range Safety Group (RSG), Space Shuttle and Constellation Range Safety Panels, Common Standards Working Group (CSWG), and support to R&D projects such as Joint Advanced Range Safety System, Autonomous Flight Safety System, and Enhanced Flight Termination System (see separate articles on all these projects in this report).

For more background and information on the NASA Headquarters Status Report, *click here.*

E. JOHNSON SPACE CENTER

For more background and information on the JSC Status Report, *click here.*

1. Launch Constellation Range Safety Panel

The Launch Constellation Range Safety Panel (LCRSP) manages launch range safety matters for Constellation program vehicles, including specifying key interfaces with the Department of Defense (DoD) for launch range safety.

This report summarizes the work conducted through the LCRSP and its two chartered working groups.

a. Launch Constellation Range Safety Panel Trajectory Working Group

The Trajectory Working Group (TWG) was the first sub-group chartered by the LCRSP. The primary responsibility of the group is to ensure that each Range Safety trajectory analysis requirement, as specified by the 45th Space Wing, is coordinated among the proper NASA centers.

During 2008, the TWG activities were primarily focused on satisfying range safety requirements for a planned launch of the Ares I-X flight test vehicle in 2009. This effort involved Ares I-X simulation development and comparing the trajectory simulations being utilized at the various NASA centers involved in completing the Ares I-X analysis tasks Also included were activities supporting POST2 (LaRC), MAVERIC (MSFC), and ANTARES (JSC) as an ongoing process of an IV&V effort.

The following official products were completed and delivered for the Preliminary Flight Data Package (PFDP):

(1) Ares I-X 3-Sigma Trajectory Envelopes

These data were created by executing a 6-DOF simulation configured for Monte Carlo analysis using 64 system dispersions. The dispersions sets include aerodynamics, mass properties, sensor errors, propulsion, RSRM thrust vector control, and roll control system thrusters. The vehicle models consist of flight control system, aerodynamic, thrust, and mass properties as of June 2007.

2000 Monte Carlo simulations for each of six wind profiles were executed to compute the six flight envelopes necessary to meet Air Force requirements. East and west wind runs are used to establish the launch area steep (LAS) flight envelope, the maximum instantaneous impact range (MaxIIP) flight envelope, and the minimum instantaneous impact range (MinIIP) flight envelope. The 50 & 230 degree azimuth wind runs are used to establish the launch area lateral (LAL) flight envelope. The north and south winds are used to establish the right and left instantaneous impact point (RIIP/LIIP) flight envelope.

For each flight envelope, determination a single trajectory was identified that closely followed the flight envelope to be used for vehicle debris footprint analysis.

(2) Ares I-X Sonic Boom and Acoustic Analysis

The analysis methods used in generating this data followed the "best practices" as described in NASA SP 8072 and utilized the atmospheric propagation effects as implemented in the Aircraft Noise Prediction Program (ANOPP). These methods were applied to the Ares I-X vehicle flying the nominal ADAC2 trajectory.

The Ares I-X primary propulsion system is comprised of Shuttle legacy hardware consisting of a four-segment solid rocket booster. The propulsion system generates a maximum of 3.1 million pounds of thrust and subsequently 203 dB of acoustic energy. These numbers place the Ares rocket in a category below the Space Shuttle or Saturn V vehicles in terms of an acoustic environment.

The sonic boom and acoustics information delivered was intended for use in both the Preliminary and Final Flight Data Packages unless further analysis by the Range Safety Officer was required or the vehicle or its trajectory undergo substantial modification.

A significant amount of work was also conducted for delivery of the Final Flight Data Package (FFDP) required by the 45th Space Wing early next year:

- Ares I-X Nominal and Malfunction Turn Trajectories including improved malfunction failure mode models. As in the preliminary data delivered in 2007, this dataset will include thousands of trajectories for various credible failure scenarios using updated vehicle models.

- Ares I-X Three Sigma Flight Envelopes developed using the Monte Carlo technique and Space Shuttle trajectory component methodology and updated vehicle models.

NASA centers providing support for these Ares I-X range safety products include Langley Research Center, Johnson Space Center, Marshall Space Flight Center, and Jet Propulsion Laboratory. Representatives from Kennedy Space Center and the 45th Space Wing were also regular participants in the working group and provided technical assistance on many occasions.

b. Launch Constellation Range Safety Panel Probabilistic Risk Assessment Working Group

The Probabilistic Risk Assessment Working Group was first chartered in early 2007 as the forum through which all launch vehicle range safety-related reliability analyses and products would be coordinated for the Constellation Program. This technical forum supports the Launch Constellation Range Safety Panel in all matters related to vehicle failure probability estimation for range safety risk assessments in compliance with the requirements of the Constellation Program, NASA's NPR 8715.5, *Range Safety Program*, and applicable Air Force Range Safety policy and requirements. The members of the working group include representatives from the Launch Vehicle Project Office (Ares, Ares I-X), Mission Operations, Safety and Mission Assurance, and the 45th Space Wing.

The working group completed a number of tasks in 2008 in support of the Ares I-X fight test vehicle. In particular, the group coordinated all tasks pertaining to the final Ares I-X range safety probabilistic risk assessment to be provided to the United States Air Force as part of the Ares I-X final flight data package. The risk assessment was developed by Safety and Mission Assurance personnel at Johnson Space Center, Marshall Space Flight Center, and Langley Research Center.

The Ares I-X range safety risk assessment is a new challenge in that it is a first of its kind vehicle. First flights of vehicles have historically been shown to be significantly riskier than mature vehicles due the unknowns associated with first flight. A new process is being

developed by the working group to estimate first flight failure probability based on probabilistic risk assessment (PRA) models which are developed normally to estimate mature system risk. The methodology being developed links the mature vehicle risk estimate from the PRA model to the empirically-derived first flight risk of 0.3 for experienced rocket developers and adjusts the PRA result based on the difference in complexity of the new vehicle to the “generic” vehicle risk of 0.3. The work and collaboration between NASA and the 45th Space Wing on this issue will continue to evolve.

c. Other Topics Considered by the Launch Constellation Range Safety Panel

Many other topics were again addressed this year, including Ares I Debris Catalog, Ares I-X Requirements Tailoring, Range Safety Tools and Modeling, Launch Enterprise Transformation Study, and Errant Launch Abort System

(1) Ares 1 Debris Characterization

Significant progress was made on the Ares I Debris Catalog using a debris risk assessment process. This process is made up of three phases: generating debris risk input data, developing the debris catalog for Range Safety and Orion aborts, and performing the Range Safety and Orion abort risk assessments.

Several factors were identified that define the debris risk assessment inputs needed to conduct a breakup analysis, including malfunction turn failure modes, malfunction turn breakup estimations, aerodynamic breakup characterization, failure mode identification (explosive, non-explosive), and upper stage and service module reentry rupture data.

24 debris catalogs have been initially estimated when vehicle configuration and breakup modes are considered for each flight event.

(2) Ares I-X Requirements Tailoring

Tailoring of CxP 70155-01, *Ares I-X Range Safety Requirements* document, developed through the Launch Constellation Range Safety Panel, has been completed and approved by the Steering Panel (45th Space Wing Commander, the Constellation Program Manager, and the KSC Center Director).

This single tailored document combines the baseline requirements of AFSPCMAN 91-710 and NPR 8715.5 for Ares I-X.

Volume 1, *Range Safety Policies and Procedures*, along with Volume 2, *Flight Safety Requirements*, and Volume 4, *Airborne Flight Safety System Design, Test, and Documentation Requirements*, were the focus of the tailoring effort.

A request by the 45th Space Wing Commander to identify major departures from the current AFSPCMAN 91-710 requirements was addressed along with the public safety waiver approval process.

Four Range Safety waivers to AFSPCMAN 91-710 requirements were proposed to eliminate major cost and schedule impacts where the public safety risk is considered very low.

(3) Range Safety Tools and Modeling

A special Range Safety Tools and Modeling meeting was held in October to define simulation and processing models that are required to support Range Safety tasks, poll the agencies (NASA, 45th Space Wing, and industry) for possible model sources, and to create a roadmap for acquiring and developing the resources to support Ares I-Y and subsequent projects. The goal of this exchange of information was to leverage off of work done and use available resources where requirements permit.

Stake holders in this effort are the 45th Space Wing who ensure public safety, NASA Range Safety community who provide required data to the 45th Space Wing, and the Constellation Elements who conduct abort and crew risk studies.

This face to face meeting also provided the opportunity for the range safety community to share information on the tools, processes, and analyses that could be used in the *Cx Debris Risk Assessment Process.* This process will be used to create the Ares 1 debris catalogs and perform Range Safety and Orion abort risk assessments.

(4) Launch Enterprise Transformation Study (LETS)

Air Force Space Command (AFSPC) is proposing radical changes to the launch range infrastructure and operations to reduce operating costs. The Launch Enterprise Transformation Study (LETS) seeks to determine the cost and mission impacts if GPS Metric Tracking (MT) followed by an Autonomous Flight Safety System (AFSS) is required by all range users.

The AFSS is an independent subsystem mounted onboard a vehicle that uses onboard tracking and telemetry to make Flight Termination System (FTS) decisions. These decisions are based on redundant independent sensors used to determine vehicle state (position, health, and status) and apply software-based flight rules.

Radars will be reduced to a single modernized Radar Open-System Architecture (ROSA) radar at each launch head and manned ground-based flight termination systems (FTS) will be eliminated. These changes are expected to be phased in from 2010 through 2018.

The Constellation Program is preparing a response to these changes through the Launch Constellation Range Safety Panel (LCRSP). The GPS MT capability is expected beginning with Ares I-Y. There is no program impact expected, although a certification effort will need to be addressed. Constellation may have requirements beyond one launch head radar to track the first and upper stages, so the ability of single ROSA radar to interrogate two different beacons must be understood.

NASA has taken the preliminary position that AFSS may be used only after a significant period of operational use on larger expendable launch vehicles and only in conjunction with man-in-the-loop decision making on the ground. The human decision and the AFSS must agree for a destruct command to be sent. This operational concept meets NASA human error tolerance requirements by requiring two independent decisions for flight termination.

(5) Errant Launch Abort System

Early in the Abort Flight Test (AFT) program, the Flight Test Office determined that the size of the Orion abort motor was such that an evaluation would be required to see if a flight

termination system (FTS) would be required. Addition of an FTS is undesirable from a project standpoint due to additional development and certification activity with significant cost.

The worst case scenario regarding safety from a range standpoint would be an inadvertent separation of the Launch Abort System (LAS) at or near abort motor ignition. It was decided that establishing the maximum range for an “errant LAS” would be a conservative boundary for establishing the launch pad location. The following Orion LAS scenarios were assessed:

- Tail Feather scenario, where the LAS inadvertently separates at T=0. Analysis exhibited stable flight and resulted in a down range distance less than 4 nm.

- Broken Tail Feather scenario, where a complete failure of all the LAS/CM connections results in fly-away LAS without the CM. Analysis exhibited stable flight, and all cases have a downrange distance less than 4 nm.

- Broken Pencil scenario, assuming a complete failure of LAS abort motor/adapter cone field joint. This failure results in fly-away LAS without the CM or adapter cone.

Analysis resulted in marginally stable to unstable flight. A couple of cases out of thousands exceeded 4 nm, indicating this failure scenario has a very low probability of occurring.

After an independent assessment by Mantech, under contract to the KSC Safety Office, the WSMR Flight Safety Office accepted the Errant LAS analysis and concurred that FTS was not required. A 4 nm radius exclusion zone was established for the Pad Abort missions and LC-32E was approved as the launch site.

This report addresses many of the highlights from a very active year for the LCRSP. We are very fortunate to have such a high level of cooperation, focused productivity, and commitment demonstrated by this diverse community, including the 45th Space Wing and multiple NASA centers with their contractor teams.

2. Space Shuttle Range Safety Panel

During 2008, the Space Shuttle Range Safety Panel addressed several topics including the new launch conjunction process, low inclination public entry risk, solid rocket booster (SRB) beacon availability requirements, the Space Shuttle external tank (ET) entry assessment, SRB recovery ship positioning procedure changes, and launch and landing program requirements document updates. The following provides a summary of each of these topics. Also included is a list of Shuttle Range Safety Panel accomplishments for 2008.

a. Space Shuttle Launch Conjunction Process

In 2008, the Shuttle Range Safety Panel began an effort to define the Shuttle Program response to the United States Air Force (USAF) Special Instructions (SPINS) which direct that all launches out of the Eastern and Western ranges will be screened against the entire USSTRATCOM debris catalog. SPINS provides latitude for this screening allowing the use of either miss distance or statistical Probability of Collision (Pc) computations to determine times during the launching vehicle's launch window when unacceptable conjunctions are present. These times would be used to enact cutouts in the launch window.

The Range Safety Panel and the Joint Space Operations Center (JSpOC) are responsible for performing the conjunction analysis and have begun to define the process for Shuttle launches and identify issues that may result from the screening. NASA's primary concern was that the specified 25 km spherical miss distance would produce a large number of cutouts for objects that were not a threat to the Orbiter, since the uncertainty in the Shuttle insertion vector is much better understood than other launch vehicles. To minimize this concern, the Range Safety Panel and JSpOC recommended to USSTRATCOM that the Pc and miss distance criteria that will be used for Shuttle launches be the same as the criteria that are currently contained in the Shuttle flight rules for pre-launch conjunction evaluation.

Additionally, to facilitate this process, Shuttle data will be reformatted into the input format for the JSpOC program that will run the conjunction computations, an analysis will be completed to estimate the expected number of cutouts, and the logistics of handling cutouts that are produced in the firing room will be defined. The USAF is also planning two launches of DoD payloads that will serve as test cases for the new pre-launch Collision Assessment (C/A) process. This process will not be implemented at the ranges until these test cases are complete.

b. Space Shuttle Low Inclination Public Entry Risk: Flight Rule A2-207 and NSTS-60561 Updates as a Result of Hubble Space Telescope (HST) Servicing Mission

Public entry risk analysts assessed the collective risk for the due east launch of STS-125 Hubble Space Telescope servicing mission. The analysis revealed that approximately 23% of the entry opportunities to the Kennedy Space Center (KSC) landing site would be excluded because of the following wording in NPR 8715.5:

> "The assessed collective public risk for Space Shuttle entries shall not exceed the highest risk associated with the ascending entry trajectories into Kennedy Space Center (KSC) from the International Space Station orbit inclination of 51.6 degrees."

The maximum collective risk for the HST mission to KSC is 2370x10-6 casualties per entry while the highest risk from a 51.6 degree orbit inclination, and therefore the maximum allowable casualties per entry, is 1800x10-6. Approximately 23% of HST trajectories exceeded the 1800x10-6 limit.

A collaborative effort between the Space Shuttle Program (SSP), NASA Headquarters (HQ), and the Office of Safety and Mission Assurance (OSMA) to revise and expand the collective public risk policy resulted in NASA Interim Directive (NID), NM8715-66. This revision used the same approach that was taken in developing the original policy for the 51.6 degree trajectories. The addition to the policy allows the SSP to use KSC as its primary landing site for the HST servicing mission, and, as with the ISS mission policy, it establishes a public safety risk threshold to be used when considering alternate landing sites. Concurrently, the NSTS-60561 Range Safety Risk Management Plan for Entry of the Space Shuttle Orbiter document was updated to reflect the 2370x10-6 expected nominal end-of-mission for STS-125. An STS-125 flight rule annex, FR 125_A2-99, was also submitted to outline changes to placards (for 51.6 degree missions) listed in generic FR A2-207, Landing Site Selection. All of the proposed document modifications submitted were approved. Finally, the onsite risk to each continental US landing site workforce and its visitors was evaluated, and range safety personnel at each

site were informed of any changes. Impacts to the sites as a result of this analysis were minimal.

c. Solid Rocket Booster Beacon Availability Requirements

The Shuttle Range Safety Panel addressed the conflict of a Range Operations Supplement requirement for a single functioning solid rocket booster (SRB) beacon with the NASA-accepted Shuttle Launch Commit Criteria (LCC). The SRB beacons provide two advantages:

1. Reliable and robust radar tracking off the pad and during possible catastrophic events.

2. Allows for a delay of flight termination action after a vehicle breakup in first stage to protect the Orbiter when both beacons are operational (per the Range A4-258.C.3 flight rule).

Radar skin track alone is not committed for the first 12 to 15 seconds of flight leaving only optics tracking. However, SRB beacons provide good radar tracking off the launch pad. The Panel agreed that the first 12 to 15 seconds of flight is likely the period of highest public risk and that a SRB beacon will help minimize public risk during this critical period. Additionally, requiring a SRB beacon would allow the Mission Flight Control Officer (MFCO) to delay destruct action after a first stage breakup as they could continue to track the individual SRBs.

The Shuttle Program classifies the SRB beacons as a Crit 3 system with no redundancy on a single SRB. Therefore, requiring both beacons be functional could result in a launch scrub if a single beacon fails prior to launch. Since a launch scrub also provides risk and is more likely than a vehicle breakup scenario, the Range Safety Panel concluded that one beacon should be required and a two beacon requirement was not warranted.

d. Space Shuttle External Tank (ET) Entry Assessment

During the ascent of STS-114 in 2005, a piece of foam was observed shedding from the ET. The Space Shuttle Program (SSP) later decided that tanks should be manufactured without Protuberance Air Load (PAL) ramps in order to reduce the risk of ET debris during ascent. Until tanks could be manufactured without PAL Ramps, all the existing tanks required the PAL Ramps to be removed. The associated ET design changes involved ET TPS thickness which affected ET rupture altitude, a driver in the ET debris footprint size. Mean ET rupture conditions for each of these tanks were assessed against the Shuttle Program requirement documented in Volume X (3.3.3.2.8.5) Mean ET rupture requirement of 249 kft.

New Mean ET Entry trajectories (based on a DI-122 nm mission) were generated in 2006 which provided relief in the nominal mean rupture altitude and yielded acceptable mean rupture conditions. When all of the PAL-Ramp-removed tanks were flown, Shuttle missions utilized tanks manufactured without the PAL Ramps. The DI-122 ET Entry trajectories were re-screened in 2008 to determine if they were applicable for future baseline tanks (manufactured without PAL ramps). The analysis indicated that the original DI-122 ET Entry trajectories were applicable for future tanks and also showed that new entry trajectories would provide thermal relief for the tanks if needed in the future. Based on these results, new DI-122 ET Entry trajectories were delivered for use on International Space Station missions (51.6 degree inclination, DI-122 nmi) that use an ET designed without PAL ramps. The analysis also confirmed that the generic ET entry trajectories already in Volume X (DI-170 nm set) are still applicable for all missions.

e. SRB Recovery Ship Positioning Procedure Changes

Shuttle Solid Rocket Booster (SRB) recovery ships for STS-118 were positioned further south cross-range than is optimal due to insufficient information needed to correctly interpret the Day of Launch (DOL) dual pane launch window. Prior to launch, SRB recovery ships are generally positioned at coordinates, specified by the Surveillance Control Officers (SCOs), for the launch window open (LWO) or in-plane launch time. The in-plane time is often the middle of a 10 minute planar window. However, for STS-118 the dual pane resulted in a launch window of approximately 11 minutes and the recovery ships were incorrectly placed for the in-plane position of a 10 minute window. Additionally, changes from the in-plane time were not appropriately provided to the SCOs to calculate the final ship position. To correct these issues the Launch Countdown (LCD) procedure S0007 was updated so that the Flight Director will pass the in-plane time for the first pane to the NASA Test Director at L-1H30M, and any launch deltas measured from the in-plane time will be passed from the Landing and Recovery Director (LRD) to the SCO for use beginning with STS-120.

f. Launch and Landing Program Requirements Document Update for Jimsphere and AMPS

The Launch and Landing Program Requirements Document (L&L PRD) which represents the formal agreement between the Range and the Space Shuttle Program, lists the jimsphere and AMPS (Automated Meteorological Profiling System) balloon based wind and atmosphere measurement systems as "MANDATORY" for launch. As documented, the Range is required to be NO-GO for launch in the event of a balloon system failure. However, these systems are only required for launch support by the MCC launch and landing assessment teams until about two hours prior to launch. A checkpoint was added to the Loads and DOLILU Officer (LDO) timeline to assess the requirement for the balloon systems at approximately launch minus two hours. If sufficient data has been received from the Range to assess the launch and landing environment, the LDO will notify the Ascent Flight Director (AFD) that the AMPS and Jimsphere balloon systems are no longer "MANDATORY" for launch. The AFD will relay the release of these systems to the NASA Test Director (NTD), who in turn will relay the change in status to the Range. Failure of the balloon systems after this point will not result in an automatic "NO-GO" condition for the Range.

g. Summary of other 2008 Shuttle Range Safety Panel Accomplishments:

- Revised the NSTS Directive Number 42B: *Space Shuttle Program (SSP) Range Safety Management Charter*.

- Proposed LCN update to LCC A4-258.C.3 to state NASA's requirement for one of two SRB beacons for launch.

- Updated the NSTS 60561, Rev. A, *Range Safety Risk Management Plan*.

- Created a NASA Interim Directive (NID) NM8715-66 for the NPR 8715.5 entry range safety policy update for STS-125.

- Updated Flight Rule FR A2-207, *Landing Site Selection,* to reflect the entry range safety policy for STS-125.

- Proposed major updates to KSC's Risk Management Plan, KSC PLN 2805.
- Updated the S0007 checklist with a new step to release the L-1 hr weather data from “mandatory” to “required.”