

2007

**NASA Range Safety
Annual Report**

**This 2007 Range Safety Annual Report
Is produced by virtue of
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Introduction

NASA Range Safety Program Manager

Welcome to the 2007 edition of the NASA Range Safety Annual Report. This report, funded by NASA Headquarters, provides a NASA Range Safety overview for current and potential range users. Once again this year we present summaries from the various NASA Range Safety Program activities that took place throughout the year, as well as information on several special projects that appear to have a profound impact on the way we will do business in the future.

The sections include a program overview and 2007 highlights of Range Safety Training, Range Safety Policy, Independent Assessments and Common Risk Tools Development; Support to Program Operations at all ranges that NASA conducts launch operations; a continuing overview of emerging range safety related technologies that will take us into the next century; Special Interests Items that include recent changes in the ELV Payload Safety Program; and status reports from all of the NASA Centers that have Range Safety responsibilities.

As is the case each year, contributors to this report are too numerous to mention, but we thank individuals from the NASA Centers, the Department of Defense, and civilian organizations for their contributions. We've made a great effort to include the most current information available. We recommend the report be used only for guidance and the validity and accuracy of all articles be verified for any updates since this writing.

This is the second year we've utilized this web based format for the annual report. We received lots of positive feedback from our first web based edition last year, and we hope you enjoy this year's product as well.

This concludes my first year as the NASA Range Safety Manager. It's been a busy and productive year on many fronts as you'll note as you review this report. Thank you to everyone that's contributed to make this first year a successful one, and I look forward to working with all of you in the years to come.

Alan Dumont
NASA Range Safety Manager

Overview

Agency Range Safety Program Overview and 2007 Highlights

2007 proved to be yet another eventful and exciting year in the Range Safety realm. Before we highlight the areas covered in this year's edition, it's important to restate the goal of the NASA Range Safety Program. The program is defined in NPR 8715.5, *Range Safety Program*, dated 8 July 2005, and is signed by the NASA Administrator. The goal of the program is to protect the public, the workforce, and property during range operations such as launching, flying, landing, and testing launch/flight vehicles.

This goal applies to all NASA centers and test facilities and all NASA vehicle programs including expendable launch vehicles, reusable launch vehicles, unmanned aerial vehicles, and the Space Shuttle as well as any NASA-funded commercial ventures that involve range operations. We meet the goal of the NPR by mitigating and controlling hazards, such as uncontrolled vehicles, debris, explosives, and toxics associated with range operations. Of note this year is that all NASA Centers with a range safety responsibility and the Headquarters Office of Safety and Mission Assurance held a meeting to do a line-by-line review of the NPR to look at areas that need updating and suggest additions to strengthen the policy arm of NASA Range Safety.

This is the second year we've published this report in a web-based format, and our outline remains mostly unchanged from last year. Once again, we cover several areas of range safety that point to how we meet or implement the range safety program. One of our primary focuses relates to range safety training and our continuing efforts regarding the NASA Range Safety Training Program. We brought one additional class on-line in 2006, and completed the Range Safety course curriculum by bringing the Range Safety Operations Course on-line this year.

We remain extremely busy in the development, implementation, and support of range safety policy. The Constellation program is in full swing, and we've been supporting tailoring exercises with representatives from the program, the 45th Space Wing, and the Launch Constellation Range Safety Panel. We take a close look at our variance and risk process and the changes that have taken place in that arena due to fully implementing the NPR requirements. We supported several launches this year and continue to work updated agreements with our partners at the Eastern and Western Ranges.

NASA Range Safety personnel continue to support the Range Commander's Council meetings and have been involved in updating policy related to flight safety systems and flight safety analysis. A recap of these efforts is highlighted. We address our continued support to the Common Standards Working Group in efforts to codify requirements for reusable launch vehicles and updates to AFSPCMAN 91-710, *Range Safety User Requirements*; 91-711, *Launch Safety Requirements for AFSPC Organizations*; and 91-712, *Launch Safety Software and Computing System Requirements*. Unmanned aerial vehicle policy development for operations at the Eastern Range is highlighted as well as continuing efforts regarding several challenges that we faced in the flight safety systems realm this year.

The Kennedy Space Center Range Safety Program was the focus of headquarters-sponsored Institutional, Facilities, and Operations Audit and we provide a synopsis of these efforts in this report. One area that received a lot of attention this year was the plan for development of a common risk analysis tool for all NASA Range Safety efforts. We discuss this effort in depth. We address launch operations at Kennedy Space Center, the Eastern and Western Ranges, Dryden Flight Research Center, and Wallops Flight Facility.

One area that continues to hold the interest of many in the range safety community is emerging range safety technology. Several articles focus on efforts that have taken place over the past year.

We once again provide insight to some special interest items, specifically the effort on the Eastern Range regarding Space Florida, expendable launch vehicle payload safety NPR development progress, and NASA Range Safety support to educational scientific balloon releases.

We wrap up this issue with range safety reports from the NASA Centers that were actively involved with range safety issues throughout the year. The graphic below gives a brief overview of the major topics contained in this report. Feel free to migrate directly to any topic by selecting items that are of interest.

NASA Range Safety Training 2007

The NASA Range Safety Training program grew to full strength this year. Efforts that began in 2002 with a Phase 1 *Range Safety Orientation* course saw the completion of Phase 2 training development with the *Range Flight Safety Operations* course. These courses provide the training needs for range safety personnel and are applicable and available to NASA, the Department of Defense, and the Federal Aviation Administration as well as government support contractors. Courses are conducted at the NASA Safety Training Center and the Wallops Flight Facility. Although development is complete, we are always looking for inputs on updates for the course and potential instructors.

The development strategy originally put in place has served well in reaching critical milestones. An original steering group comprised of NASA, the Air Force, and the Federal Aviation Administration provided the foundation for the basic outlines of the courses.

Depending on the course content, the Range Safety Training Group had representatives from NASA Headquarters, Kennedy Space Center, Dryden Flight Research Center, Wallops Flight Facility, the 45th and 30th Space Wings, the Air Force Flight Test Center, the Federal Aviation Administration, the Missile Defense Agency, and members of the Range Safety Group of the Range Commanders Council.

To date, we've conducted 17 *Range Safety Orientation* courses with 464 students in attendance, four *Range Flight Safety Analysis* courses with 65 students in attendance, three *Range Flight Safety Systems* courses with 52 students, and one *Range Flight Safety Operations Course* with 6 students. The schedule for all courses for 2008 is shown below.

Range Safety Orientation

As you can see in the outline below, the *Range Safety Orientation* course is designed to give NASA senior, program, and project managers an understanding of the Range Safety mission, associated policies and requirements, and NASA roles and responsibilities. It introduces students to the major ranges and their capabilities and services, defines and discusses the major elements of Range Safety, and briefly addresses associated range safety topics such as ground safety, frequency management, and unmanned aerial vehicles.

The course emphasizes the principles of safety risk management to ensure the public and NASA workforces are not subjected to risk of injury greater than their normal day-to-day activities. This course includes a visit to range safety facilities at Cape Canaveral Air Force Station and Kennedy Space Center and is normally only given at this location. If you wish to discuss presenting the class at your location, please contact the NASA Safety Training Center staff.

Target Audience: Senior, program, and project managers; Safety, Reliability, Quality, and Maintainability professionals with an interest in range safety activities

Range Flight Safety Analysis

The *Range Flight Safety Analysis* course provides a detailed understanding of range safety analysis. It includes NASA, Federal Aviation Administration, and Department of Defense requirements for flight safety analysis; a discussion of range operations hazards, risk criteria, and risk management processes; and an in-depth coverage of the containment and risk management analyses performed for expendable launch vehicles at the Eastern Range.

Although the course is based on expendable launch vehicles at the Eastern Range, the overall analysis process and concepts are applicable to other vehicles and other ranges as well. The course concentrates on debris hazards and analyses but includes an overview of toxic, blast, and radiation analyses. The course includes a class exercise that covers the entire analysis process.

Prerequisite: NSTC 074, *Range Safety Orientation* or equivalent experience (engineering degree and a background in range safety)

Target Audience: NASA, Federal Aviation Administration, and Department of Defense Range Safety Analysts; range safety personnel in other disciplines; and program/project managers and engineers who design potentially hazardous systems to operate on a range

The *Range Flight Safety Analysis* course outline is shown in the graphic below.

Range Flight Safety Systems

The *Range Flight Safety Systems* course was taught for the first time at Kennedy Space Center in September of 2007 with 15 students in attendance. The course size is limited by tours we conduct at the Navy Trident trainer facility. The course describes required safety responsibilities and flight termination system procedures and plans. It also includes flight termination system component design, performance, test, and subsystem pre-launch requirements.

The module then transitions to the applicable flight termination system ground support and monitoring equipment, flight termination system analysis, and component test history. The course continues with a review of unmanned aerial vehicle flight termination systems, balloon universal termination packages, and the enhanced flight termination system. The class ends with a description of the autonomous flight safety system.

Prerequisites: NSTC 074, *Range Safety Orientation* or equivalent level of experience or training, is required; NSTC 002, *System Safety Fundamentals* or NSTC 008, *System Safety Workshop*, is recommended

Target Audience: NASA, Federal Aviation Administration, and Department of Defense Range Safety Personnel working Flight Safety Systems issues; range safety personnel in other disciplines; program/project managers and engineers who design potentially hazardous systems to operate on a range; personnel who conduct hazardous operations on a range.

Range Flight Safety Operations

The *Range Flight Safety Operations* course was completed in early 2007 and the pilot course conducted in February with representatives from NASA Headquarters, Kennedy Space Center, Wallops Flight Facility, Dryden Flight Research Center, and Federal Aviation Administration in attendance. The first official course was held in July 2007. Unlike previous courses, this course is only taught at Wallops Flight Facility to take advantage of its range safety and control room facilities, as well as the mobile range safety system assets.

To ensure mission success and the safety of operations for the range, a formal process has evolved among the different ranges to provide range safety operations. As you can see from the outline below, this course focuses on the roles and responsibilities of the Range Safety Officer for range safety operations, as well as real-time support, including pre-launch, launch, flight, landing, and required mitigation actions. Launch commit criteria, mission rules, countdown activities, and display techniques are presented.

Tracking and telemetry, post operations, lessons learned, and the use and importance of contingency plans are discussed. Those participating in the course receive hands-on simulator training and exercises to reinforce techniques and procedures to successfully conduct launch operations. Due to the unique interaction with real-world equipment, a maximum of six students may attend each class. The course centers on the topics shown in the graphic below.

If you wish to attend any of the courses offered, please contact your Center training manager, or refer to the NSTC web site course catalogue located at:
http://www6.jsc.nasa.gov/safety/calendar/NSTC/Docs/2008_Catalog.doc

Development, Implementation, Support of Range Safety Policy

Constellation Tailoring

With the Constellation Program ramping up efforts to support a 2009 ARES 1-X test flight, the tailoring of range safety requirements has begun. The program is required to meet the combined requirements of NPR 8715.5; *Range Safety Program*, and Air Force Space Command Manual (AFSPCMAN) 91-710; *Range Safety User Requirements*. To better support the program, the Air Force and NASA, through the Launch Constellation Range Safety Panel, have combined efforts and developed one document that includes the complete set of range safety requirements.

A draft version of the tailored ARES 1-X Range Safety Flight Test Vehicle Mission document is complete with final signatures expected in mid 2008. The new document codifies the philosophy of shared responsibility for all aspects of range safety between the Air Force and NASA and will serve as the foundation for future tailoring efforts between the two organizations. With few exceptions, the requirements contained in the tailored range safety document mirror the requirements of both the Air Force and NASA documents.

The Launch Constellation Range Safety Panel agreed to use some design characteristics of heritage flight termination systems that may not be in compliance with all AFSPCMAN 91-710 requirements, but meet the current flight termination system requirements of the Space Shuttle Program. In particular, the launch vehicle fails to incorporate redundancy in a few components, mainly the linear-shaped charge and safe and arm device.

The limited physical separation of other redundant components also deviates from the AFSPCMAN 91-710 requirements. The panel agreed to these deviations based on the many successful flights of similar flight termination configurations flown on Shuttle solid rocket boosters. Other minor flight termination system deviations that meet the Space Shuttle Program flight termination system requirements have been approved through the panel. A vast improvement over the Shuttle flight termination system design incorporates the addition of an aft segment linear-shaped charge, which should significantly lower public safety risk.

Development of a tailored document to support the ARES 1 launch vehicle (shown below) is also underway. Many of the FTS non-compliances with the AFSPCMAN 91-710/NPR 8715.5 baselines will be eliminated for ARES 1. It is anticipated this document will also incorporate the philosophy of shared range safety responsibility between the Air Force and NASA.

Range Safety Variance Process

According to NPR 8715.5, *Range Safety Program*, a *variance* is documented and approved permission to perform some act or operation contrary to established requirements; and *tailoring*, *deviations*, and *waivers* are types of variances. The variance process for operations at Kennedy Space Center and Vandenberg Air Force Base is outlined in KDP-KSC-P-3829, signed in June of 2006.

The objective of the process is to effectively apply the NASA procedural review process with consideration given to the unique relationships between NASA/Kennedy Space Center and the 30th and 45th Space Wings. Each of the Space Wings has their own processes, and the KDP outlines how the NASA/Kennedy Space Center Range Safety Representative meets the intent of NPR 8715.5 with regard to variances.

Listed below are the definitions of terms as they currently exist in the NPR:

- **Tailoring.** The process where the authority responsible for a set of range safety requirements (e.g., the Independent Technical Authority for technical requirements) and the range user review each requirement and jointly document whether or not the requirement is applicable and, if it is applicable, whether or not the range user will meet the requirement as written or achieve an equivalent level of safety through an acceptable alternative. Tailoring includes the approval of deviations. Tailoring does not include the approval of waivers, which are addressed by a separate process.
- **Deviation.** A variance that authorizes departure from a particular safety requirement that does not strictly apply or where the intent of the requirement is being met through alternate means that provide an equivalent level of safety.
- **Waiver.** A variance that authorizes departure from a specific safety requirement where an increase in risk, due to the fact that the requirement is not satisfied, has been documented and accepted by the appropriate authority.

Although these definitions and process are used for new range safety related variances for both the Shuttle and the Launch Service Program, changes to both terminology and process are being vetted for the Constellation and other future programs. Additionally, NPR 8715.5 is currently being reviewed to determine if changes are needed to effectively operate the variance process NASA wide.

The most notable change being discussed is the use of the term *variance*. This term may no longer be used as an inclusive term for tailoring, waivers, and deviations. In the future, the terms *waiver* and *exception* (equivalent level of safety) may be used. This is a NASA-wide initiative to ensure commonality throughout the agency and to have NASA terminology that is more consistent with the Department of Defense and the Federal Aviation Administration.

A *waiver* will be required when there is rationale for not meeting a requirement as written. This includes meeting the intent, exceeding the requirement, or not meeting the requirement and may or may not be a change in risk. The rationale will be documented and agreed to on the waiver form.

When a waiver is brought forward due to increased risk to the public, workforce, and/or property, the “burden of proof” or rationale for acceptance and approval of the increased risk is on the entity bringing forward the request. The waiver will not be approved without acceptable rationale. With that in mind, the entity bringing the waiver forward should use available expertise to help determine the following:

- The rationale is reasonable.
- Hazard mitigation is in place.
- A get well plan is available to correct the noncompliance.

Today, the NASA Range Safety Manager is the waiver approval authority for all range safety related variances for NASA launches where there is not a range safety office. For launches at the Western Range, the Program accepts the increased risk, and for launches at Kennedy Space Center, this responsibility falls on the Kennedy Space Center Center Director and the program manager. But with the proposed changes, all NPR requirements are being reviewed to determine the appropriate level for approval, so the current approval and acceptance authorities may change for future programs. The current NASA Range Safety Variance process is shown in the flowpath below.

Range Safety Risk Process

The objectives of the range safety risk process, KDP-KSC-P-3628, for managing range safety risks for launch and entry at Kennedy Space Center are to ensure the safety of the Kennedy Space Center workforce and visitors during launches, to comply with KCA 1305, the Memorandum of Understanding for Range Safety between Kennedy Space Center, the Space Shuttle Program Office, and the 45th Space Wing, and to comply with NPR 8715.5, *Range Safety Program*, requirements. The process also outlines the requirements for the Kennedy Space Center risk assessment board should additional mitigation action be required to reduce risk to an acceptable level for launch and landing operations.

Definitions

The baseline definition for *risk* is the combination of the two criteria listed below:

1. The probability (qualitative or quantitative) that a program will experience an undesired event such as cost overrun, schedule slippage, safety mishap, or failure to achieve a needed technological breakthrough; and
2. The consequences, impact, or severity of the undesired event were it to occur.

For Range Safety, *risk* is expressed as casualty expectation, a measure that takes into consideration both the probability of occurrence and the consequence of a hazard to a population or installation. *Risk* is measured in the same units as the consequence, such as number of injuries, fatalities, or dollar loss.

For the purposes of range safety risk management, the *public* includes visitors and personnel inside and outside NASA-controlled property who may be on land, on waterborne vessels, or in aircraft. This category does not include *center essential personnel*.

Center essential personnel are government or contractor personnel who perform functions necessary for continued operations at a NASA Center or other site where NASA has control and responsibility. For a specific range operation, the *center essential personnel* include a workforce subset referred to as *mission essential personnel*.

Mission essential personnel are government or contractor personnel who are directly involved in ensuring the safety and success of range operations associated with a mission. This category does not include any crew on board a spacecraft.

Range Safety Analysis

With these definitions in mind, each range operation undergoes a range safety analysis to establish any design or operational constraints needed to control risk to people and property. Once the analysis is complete, Range Safety assesses the analysis and provides additional mitigation or suggests acceptance of increased risk, if required.

Launch Risk Notification

Approximately two weeks before a launch, Kennedy Space Center Program Office and Kennedy Space Center Range Safety Manager receive a Launch Risk Notification letter from the 45th Space Wing. This letter serves as documentation of results from risk analysis performed for the mission. The launch risk evaluation includes hazards resulting from launch vehicle debris impact, distant focusing overpressure, and toxic effluent dispersions, with respect to population and facility input data. If the risk meets acceptable criteria in NPR 8715.5, the results are documented and the launch will proceed.

Convening of the Space Flight Risk Assessment Board

If the risk exceeds acceptable criteria in NPR 8715.5, the Center Director has the discretion to convene a Space Flight Risk Assessment Board. The board consists of the following members:

- Safety and Mission Assurance Director, Chair
- Safety and Mission Assurance Deputy Director, Vice-Chair
- NASA Range Safety Manager
- Kennedy Space Center Range Safety Manager
- Kennedy Space Center Chief Counsel
- Launch Services Program (VA) Director
- Launch Vehicle Processing (PH) Director
- Cape Canaveral Spaceport Management Office (CCSMO) (JP) Director
- Constellation Project (LX) Director
- Launch Integration (MK) Director
- Center Operations (TA) Director
- International Space Station (ISS) and Spacecraft Processing (UB) Director
- External Relations (XA) Director
- Applied Technologies (KT) Director

The Kennedy Space Center Center Director may choose not to convene a board if the risk has been minimized to the maximum extent possible and the risk is documented and accepted using the standard range safety variance process. However, if an Assessment Board is convened, a minimum of four topics must be presented to the board at least one week before the mission.

- 45th Space Wing Safety Office or Johnson Space Center, Flight Design and Dynamics Office provides:
 - Assumptions in the analysis and calculation methodology
 - Risk assessment results
- Space Shuttle Program or Launch Services Program – provides program inputs
- External Relations – presents visitor population numbers
- Safety and Mission Assurance – provides mitigation options and the effect, if any, on the Risk Measure of Collective Casualty Expectation, E_c

Risk Assessment Board Recommendations

After receiving and reviewing all the information presented, the Assessment Board will make one of two recommendations to the NASA Range Safety Manager.

1. Mitigate residual risk to an acceptable level, or
2. Request the NASA Range Safety Manager to waive residual risk, with Center Director acceptance of the increased risk.

If the risk can be mitigated, the Kennedy Space Center Range Safety Manager will be notified and mitigation efforts will be documented and a copy forwarded to the Space Wing Chief of Safety and the NASA Range Safety Manager. However, if a waiver is required, the Kennedy Space Center Range Safety Manager will write the waiver and coordinate it for acceptance with the Program Manager and the Center Director.

If neither the Program Manager nor the Center Director accepts the waiver, the issue will be sent back for further mitigation efforts. But once the waiver has been accepted, the Chief of the Office of Safety and Mission Assurance and Office of the Chief Engineer will be notified. Additionally, a copy of the approved waiver will be forwarded to the Space Wing Chief of Safety and the NASA Range Safety Manager and the mission will proceed with a clear understanding of the risks associated launch.

Shuttle Landing Activities Process

The process is similar for Shuttle landing activities with the exception that the risk analysis is performed by the Johnson Space Center, Flight Design and Dynamics Office, not the 45th Space Wing. Risk analysis data is forwarded to the Kennedy Space Center Range Safety Manager approximately two weeks before the scheduled landing of the Shuttle.

This analysis is updated three days before landing and may be updated again one day before landing based on events such as a change in weather or extension of the mission. If the risks are deemed to be unacceptable, risk mitigation efforts will be implemented to help ensure the safety of the public and workforce before the Shuttle lands.

A flowpath of the Kennedy Space Center space flight risk assessment process is shown in the graphic below.

Range Safety Launch Support Policy

NASA's policy for protecting public safety has become more definitive in recent years. In June of 1997, NASA issued NPD 8700.1, *NASA Policy for Safety and Mission Success*, which stated:

It is NASA policy to avoid loss of life, personal injury or illness, property loss or damage, or environmental harm from any of its activities and assure safe and healthful conditions for persons working at or visiting NASA facilities.

In October of 2002, NASA issued a revision to NPD 8700.1 (Revision C) providing an updated NASA policy stating:

Protect the public, Astronauts and pilots, NASA workforce, and high-value equipment and property from potential harm as a result of NASA activities and operations by providing safe programs, technologies, operations, and facilities; and protect the environment.

Until 2005, although policy to protect the public had been established, no guidelines on how to protect the public or to what levels were documented. In June 2005, NPR 8715.5, *Range Safety Program*, was signed by the Administrator and established policy with respect to public and workforce protection from range (launch) operations. The document focused on:

- Compliance with minimum launch architecture and associated safety processes and procedures
- Compliance with flight termination system requirements
- Assessment of residual risks for safe and reliable operations
- Acceptable risk criteria for general public and workforce
- Establishing a variance process that identifies risk acceptors

In previous annual reports, we've focused on how NASA Range Safety implements NASA range safety policy and explained the various Memorandums of Agreement and launch support policy letters that were developed with the Eastern and Western ranges in order for Range Safety to adequately support pre-launch, launch countdown, and post-launch activities.

In 2007, NASA Range Safety began work on developing a change to the Space Shuttle Program launch commit criteria 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 for the Space Shuttle Program, vehicle tracking, and command requirements are also being added. The resulting proposed Launch Commit Criteria Change Notice will be worked through the Launch Commit Criteria Working Group in early 2008.

We've also been very active in development of tailored requirements for the Constellation Program, as delineated in other included articles. Throughout 2008, we will continue to focus on preparation of launch commit criteria for the Constellation program that allows shared responsibility of range safety requirements as described in AFSPCMAN 91-710, *Range Safety User Requirements*, and NPR 8715.5.

Range Safety Group (RSG)

Risk Committee

In early 2004, the Range Safety Group of the Range Commanders Council initiated Phase II of a Risk and Lethality Commonality Team effort to revise RCC 321, *Common Risk Criteria for National Test Ranges*. The acceptable risk criteria defined in NASA Procedural Requirements NPR 8715.5; *Range Safety Program*, is based on the guidance provided by this document. Because injury criteria were not defined during Phase I of the Risk and Lethality Commonality Team effort, the Department of Defense major range and test facility bases have diverged from use of the standard since it addresses acceptable risk criteria pertaining only to fatalities.

Establishing Risk Criteria Based on Casualties

The second phase of the Risk and Lethality Commonality Team effort has focused on establishing acceptable risk criteria based on casualties. The Range Safety Group also recommended that RCC 321 be updated and expanded to include flight safety hazards in addition to inert debris. The second phase of the Risk and Lethality Commonality Team was initially established as an ad hoc committee under the Range Safety Group. However, after a few meetings, the identification of additional risk-related topics and the more detailed development of tasks, the need for a standing committee was realized.

In February 2005, the Risk and Lethality Commonality Team was renamed the Risk Committee with a specific objective to rewrite RCC 321. In 2007, the Risk Committee was formally recognized as a standing committee by the Range Safety Group. Over the last four years, the committee has focused on establishing updated acceptable risk criterion and developing detailed supporting rationale for inert debris and other range hazards, including distant focusing overpressure and toxics. The group has also decided to establish an aggregated risk criterion, evaluating the combination of all launch hazard risk against one acceptable level. Current practice consists of evaluating each hazard against hazard unique criterion.

Update of RCC 321, Common Risk Criteria for National Test Ranges

In June of 2007, RCC 321-07 was officially issued through the Range Commanders Council. Updates to the document included the following:

- Risk acceptability criteria and supporting rationale for additional flight safety hazards and consequences potentially generated by range operations
- The major activities required to conduct the entire risk management process and considerations to address hazards beyond just inert debris
- Top-level requirements for computational models used to analyze the risks posed by inert and explosive debris

- Updated hazard thresholds for inert and explosive debris, as well as screening criteria for other hazards including toxics, distant focusing overpressure, and ionizing and non-ionizing radiation
- Factors and considerations for acceptable debris risk assessment models. Additional Topics Requiring Discussion

Additional Topics Requiring Discussion

During the revised document development effort and through discussions at Risk Committee meetings, the group has identified a number of additional topics that require discussion. Following review by the Range Commanders Council Executive Committee, approved topics will be addressed by the committee and guidance provided in upcoming revisions to RCC-321. The topics include:

- *State of the art review of risk uncertainty and catastrophe aversion and development of approaches to launch risk uncertainty for application to risk acceptability.* A state-of-the-art review of how industries and governments which have technological endeavors that could produce high risk to the public deal with the uncertainties from their risk assessments and also with the quantification of catastrophe potential.
- *Treatment of conditional risk criteria for foreseeable conditions.* Development of guidelines and rationale for modeling the risk from controlled activities such as flight termination action, engine shutdown, and use of alternative flight paths for reusable launch vehicle aborts.
- *Asset protection.* Establishment of roles, responsibilities, guidelines, and criteria for the protection of critical assets.
- *Responsibility for satellite protection beyond orbital insertion.* Establishment of roles and responsibilities for satellite tracking beyond orbital insertion and for unmanned space systems.
- *Space craft protection for exo-atmospheric and orbital debris hazards.* Development of consensus criteria and characteristics for analyses used to address exo-atmospheric and orbital debris hazard risk to space craft.
- *Business jet vulnerability criteria.* Development of vulnerability thresholds and modeling characteristics for assessment of transoceanic business class jets.
- *Mitigation of large numbers of minor injuries.* Investigate the need to develop acceptable risk criteria and/or mitigation guidelines for minor injuries such as those resulting primarily from toxics and explosive debris.
- *Reusable launch vehicle and other controlled reentry related issues.* Development of policy and guidelines for range operations involving reusable launch vehicles and reentry issues associated with any vehicle.
- *Hazard threshold for land vehicles.* Development of hazard thresholds to protect land vehicles such as automobiles, buses, trucks, and trains from shock waves from explosions and impacting debris.

Submittal of the above tasks has been completed with Executive Committee review anticipated in January 2008.

Flight Termination Systems Committee

The Flight Termination Systems Committee provides a forum for all issues and technologies related to flight termination systems. Members from several different ranges support this effort and come together to discuss various flight termination issues and concerns that need to be addressed. Some of the major efforts and issues that the committee discussed in 2007 included the following:

- RCC 319, *Flight Termination Systems Commonality Standard* rewrite
- The enhanced flight termination system
- The autonomous flight safety system/autonomous flight termination system
- Frequency interference
- National Security Agency High Alphabet decertification

RCC 319, *Flight Termination Systems Commonality Standard*

RCC 319 was revised to include new technologies and lessons learned that were used to update and clarify various flight termination system requirements. This task began in 2003. The standard was completed and released in 2007.

Enhanced Flight Termination System

A major topic of discussion in 2007 was the enhanced flight termination system. Members of the Flight Termination Systems Committee supported various testing and operations associated with this program in 2007 and continue to play an important role in developing this system. Some of the issues the committee is working on are listed below:

- The process for communicating with possible new vendors wishing to design enhanced flight termination system receivers and/or ground equipment
- How the enhanced flight termination system will be incorporated into RCC 319
- How the enhanced flight termination system will affect RCC 313, *Test Standards for Flight Termination Receivers/Decoders*

Many milestones were accomplished this year as the enhanced flight termination system continues to progress toward becoming a certified system while the committee continues to support this program and its endeavors.

Autonomous Flight Safety System/Autonomous Flight Termination System

The committee also discussed various uses and implementations of the autonomous flight safety system/autonomous flight termination system. Right now, there is no plan to use this system on any of the major ranges. More testing and qualification will have to be done on this technology before the ranges will consider using it.

Frequency Interference

Frequency interference is still a major concern at several ranges. There is still some concern with PAVE PAWS radars located at Beale Air Force Base in California and at Cape Cod in Massachusetts. However, through coordination with these operators, a mitigation effort has been used for all launches from the Eastern and Western ranges.

At other missile ranges, the enhanced position location reporting system is also a major concern. Along with other organizations, the Flight Termination Systems Committee is working hard to come up with a viable, long-term solution to the frequency interference issue.

National Security Agency High Alphabet Decertification

Another issue that has been discussed recently is the decision to decertify High Alphabet as a secure system. Today High Alphabet is the most secure flight termination system available. However, the National Security Agency has stated a desire to move toward a more secure and encrypted system.

High Alphabet is used on numerous launch vehicles around the country and those programs will be forced to move to a new system if High Alphabet is decertified. As of now, the National Security Agency has stated that they will no longer support High Alphabet after 1 January 2015. The Flight Termination Systems Committee will be working with ranges and programs to help provide a smooth transition and ensure that range operations are not adversely affected during this timeframe.

Flight Termination Systems Committee Meetings

During 2007, the Flight Termination Systems Committee participated in two meetings held by the Range Commanders Council, Range Safety Group. The meetings took place in June in Florida and in November in New Mexico. Topics discussed are presented below.

June Recap

In June, the Flight Termination Systems Committee met at the Range Safety Group meeting at Patrick Air Force Base to discuss ongoing issues relevant to flight termination systems. The main topic of discussion was the enhanced flight termination system. Major milestones accomplished by the program as well as future applications and implementation of the system were discussed. Members of the enhanced flight termination system program presented the status and future of the program to the committee.

Other topics discussed were the release of RCC 319, *Flight Termination Systems Commonality Standard*, the autonomous flight termination system/autonomous flight safety system, frequency interference at various ranges, and National System Agency decertification of the High Alphabet system.

November Recap

At the November meeting in Albuquerque, the Flight Termination Systems Committee discussed ongoing issues relevant to flight termination systems. Once again, the main topic of discussion was the enhanced flight termination system. The current status of the program as well as future milestones and applications were presented. Other topics discussed included emerging unmanned aerial vehicle programs and the impacts to RCC 319, Herley flight termination system receiver issues, and directed energy applications and their impact on flight termination system components and requirements.

Range Commanders Council Range Safety Group Meeting Recap

Founded in 1951, the Range Commanders Council is dedicated to serving the technical and operational needs of the United States test, training, and operational ranges. The council was organized to preserve and enhance the efficiency and effectiveness of member ranges, thereby increasing their research and development, operational test and evaluation, and training and readiness capabilities.

The Range Commanders Council provides a framework wherein common needs are identified and common solutions are sought, technical standards are established and disseminated, joint procurement opportunities are explored, technical and equipment exchanges are facilitated and advanced concepts and technical innovations are assessed and their potential applications identified.

As an associate member, NASA maintains active participation in the Range Commanders Council and many of its working groups, including the Range Safety Group.

Member Ranges

Members include Army, Navy, Air Force, and DOE ranges. Their locations are shown in the graphic below and identified in the following table.

Locations of Member Ranges

Army	Air Force	Navy	Department of Energy
Aberdeen Test Center, Aberdeen Proving Ground, Aberdeen, MD	30 th Space Wing, Vandenberg Air Force Base, CA	NAVAIR Atlantic Ranges, Patuxent River, MD	Department of Energy Nevada Test Site
Dugway Proving Ground, Dugway, UT	45 th Space Wing, Patrick Air Force Base, FL	NAVAIR Pacific Ranges, China Lake and Point Mugu, CA	
Electronic Proving Ground, Ft Huachuca, AZ	Air Armament Center, Eglin Air Force Base, FL	Naval Undersea Warfare Center Division Keyport, Keyport, WA	
National Training Center, Fort Irwin, CA	Air Force Flight Test Center, Edwards Air Force Base, CA	Naval Undersea Warfare Center Division Newport, Newport, RI	
Reagan Test Site, APO AP	Arnold Engineering Development Center, Tullahoma, TN	Pacific Missile Range Facility, Kekaha, HI	
White Sands Missile Range, White Sands, NM	Goldwater Range, Luke Air Force Base, AZ		
Yuma Proving Ground, Yuma, AZ			

Range Safety Group

Through standardization, development, and continuous improvement, the Range Safety Group of the Range Commanders Council supports the safe conduct of hazardous operations on the test, training, and operational ranges and related facilities. Hazardous operations include, but are not limited to, ordnance and expendable releases, directed energy and laser operations, missile flight, space launch and reentry, unmanned vehicle operation, gunfire, explosive use, and hazardous emissions.

100th Meeting of the Range Commanders Council Range Safety Group

The 100th meeting of the Range Safety Group was hosted by the 45th Space Wing Safety Office at Patrick Air Force Base. The meeting was held in Indialantic, Florida from June 5 through June 7. This conference included a number of special topics briefings, including:

- Demo-2 test flight of the autonomous flight safety system
- Unmanned aerospace vehicle and systems range safety requirements document development
- Directed energy test and evaluation capability
- Range reports from all participating Major Range Test Facility Bases

NASA provided range safety related training status reports and range reports for Kennedy Space Center, Wallops Flight Facility, and Dryden Flight Research Center. The Flight Termination Systems Committee and Risk Committee also met. NASA participated in the meetings of both these committees.

Flight Termination Systems Committee Meeting

The Flight Termination Systems Committee met at Patrick Air Force Base to discuss ongoing issues relevant to flight termination systems. The main topic of discussion was the enhanced flight termination system. Major milestones accomplished by the program as well as future applications and implementation of the enhanced flight termination system were discussed. Members of the enhanced flight termination system program presented the status and future of the program to the committee. Other topics discussed were the release of RCC 319, *Flight Termination Systems Commonality Standard*, autonomous flight termination system/autonomous flight safety system, frequency interference at various ranges, and National Security Agency decertification of the High Alphabet system.

Risk Committee Meeting

During the Range Safety Group meeting, the Risk Committee selected a new chairperson, Mr. Paul Rosati from the 45th Space Wing. The primary focus of the Risk Committee was the determination of task proposals to the Range Commanders Council for 2008. All task proposals were briefed, and it was decided to submit the following task proposals to create or expand on risk criteria in RCC 321-07, *Common Risk Criteria Standards for National Test Ranges*:

- Risk Committee Secretariat Position
- State of the art review of risk uncertainty and catastrophe aversion and development of approaches to launch risk uncertainty for application to risk acceptability
- Treatment of conditional risk criteria for foreseeable conditions
- Asset protection
- Responsibility for satellite protection beyond orbital insertion and space craft protection for exo-atmospheric and orbital debris hazards
- Business jet vulnerability criteria
- Mitigation of large numbers of minor injuries
- Reusable launch vehicle and other controlled reentry related issues
- Hazard threshold for land vehicles
- Toxic concentration levels for toxic hazard corridors
- Voluntary public risk

101st Meeting of the Range Commanders Council Range Safety Group

Sandia National Laboratories in Albuquerque, New Mexico hosted the 101st meeting of the Range Commanders Council Range Safety Group, held November 27 through 29. This conference included a special topic briefing on Sandia National Laboratories and range reports from all participating Major Range Test Facility Bases, as well as a session for the Flight Termination Systems Committee. The Risk Committee did not meet during this session.

NASA provided range safety related training status reports and range reports to the group for Kennedy Space Center, Wallops Flight Facility, and Dryden Flight Research Center and participated on the Flight Termination Systems Committee during this session.

The Flight Termination Systems Committee discussed ongoing issues relevant to flight termination systems. The main topic of discussion was the enhanced flight termination system. An overview of the system, as well as improvements and enhancements by the program were discussed. Additionally, future applications and implementation of the system were briefed.

Other briefings included the following:

- Directed energy and flight termination system requirements
- Herley Industries flight termination receiver 60-1 issues and requalification processes
- Emerging unmanned aerial vehicle programs and RCC-319

- Enhanced flight termination system documentation and concept of operations
- Enhanced flight termination system database discussion focusing on range identifications and other command fields

The discussion about range identifications brought to light the possibility of using the Flight Termination Systems Committee as the clearinghouse for issuing enhanced flight termination system range identifications and perhaps vehicle identifications. It was determined that more discussion was necessary before the committee would undertake this task.

Air Force and Federal Administration Common Standards Working Group (CSWG)

The Air Force and Federal Aviation Administration Common Standards Working Group is an interagency partnership established to develop, publish, and maintain Air Force and the Federal Aviation Administration, Associate Administrator for Commercial Space Transportation common launch safety requirements and practices to protect the public during launch and re-entry operations.

The charter for the Common Standards Working Group implemented the *Memorandum of Agreement Between the Department of the Air Force and Federal Administration on Safety for Space Transportation and Range Activities* and related matters at the direction of the Senior Steering Group. The memorandum, dated 16 January 2001, stated that the Air Force and the Federal Aviation Administration would work together to achieve common safety requirements for launches.

The tangible benefits from the creation of common safety standards include a stable framework of safety requirements for the U.S. space launch industry and minimal administrative burdens for the government and commercial sectors. Another welcome by-product is the creation of a system of checks and balances between the two agencies.

Senior Steering Group

The Senior Steering Group provides senior executive leadership and guidance to the Common Standards Working Group to accomplish its objectives. The Senior Steering Group meets semi-annually, or more frequently as needed, and is composed of the following:

- ◆ The Federal Aviation Administration Associate Administrator for Commercial Space Transportation
- ◆ The Director of National Security Space Integration, Headquarters United States Air Force
- ◆ The Director of Space Operations and Integration, Headquarters United States Air Force
- ◆ The Director of Air and Space Operations, Headquarters Air Force Space Command
- ◆ The 14th Air Force Commander

The co-chairs of the Senior Steering Group determine the meetings of the Common Standards Working Group.

Working Group

The Common Standards Working Group is a government-only forum. Commercial launch industry representatives are not permitted to participate due to the Department of Transportation policy regarding rulemaking. Membership in the group consists of representatives of the Air Force and Federal Administration Association organizations that are responsible for the development and implementation of launch and re-entry safety requirements, practices, activities, and policies as well as representatives from other agencies as identified by the Senior Steering Group co-chairs. Representatives from the agencies listed below are current members of the working group.

- ◆ 14th Air Force, Safety, A3
- ◆ 30th Space Wing, Safety
- ◆ 45th Space Wing, Safety
- ◆ Air Force Space Command, Safety (A3, A5)
- ◆ Air Force Safety Center
- ◆ Federal Aviation Administration, Associate Administrator for Commercial Space Transportation
- ◆ Headquarters United States Air Force (A30-S)
- ◆ Secretary of the Air Force
- ◆ Space and Missile Center (Safety and Launch and Range Systems Wing)

NASA, the National Reconnaissance Office, and the Missile Defense Agency are also current members of the group. Although not a formal member, NASA Range Safety has been an integral part of the Common Standards Working Group since 2004, providing range safety insight and professional technical expertise on numerous issues for subgroups that formulate, recommend, and evaluate range safety policies and procedures.

Evolution of Range Safety Policy and Procedures

The figure below shows the evolution of the major safety documents from EWR 127-1 to the 91 document series generated by the Common Standards Working Group. The status of the documents is discussed in the topics following the figure.

Past Accomplishments

The Common Standards Working Group has made significant progress since its inception, drafting and publishing the following Air Force documents:

- ◆ *Launch Safety Program Policy* (AFSPCI-91-701), May 2004
- ◆ *Range Safety User Requirements* (AFSPCMAN 91-710), July 2004
- ◆ *Launch Safety Requirements for AFSPC Organizations* (AFSPCMAN 91-711), February 2007

Additionally, the Federal Aviation Administration, in conjunction with the Common Standards Working Group, issued its first *Notice of Proposed Rulemaking* in October 2000. The agency then issued a supplemental notice in July 2002 and published and posted its second supplemental notice in 2003. Along with the new rule, the Common Standards Working Group also developed a Launch Safety Site Assessment and a Memorandum of Understanding between the Federal Aviation Administration and the Air Force for resolving requests for relief from common launch safety requirements.

Also, in 2003, the working group agreed on a framework for determining probabilities of failure for new expendable launch vehicles. The group established a list of factors that are requirements and practices used by the Federal Aviation Administration and the Air Force to protect public safety during launch and re-entry. The Federal Aviation Administration requirements have been codified in 14 Code of Federal Regulations, Chapter III.

Since the vehicles in question were new with little existing empirical data, it was determined that initial evaluations would be conducted based in part on data from vehicles developed and launched under similar circumstances. An independent assessment of the proposed requirements and methods was conducted, and the Common Standards Working Group published the final guidelines in 2004.

Current Projects

The Common Standards Working Group and its subgroups are currently working on the following projects.

AFSPCMAN 91-710

AFSPCMAN 91-710, Range Safety User Requirements, is being updated. The document was distributed to industry, NASA, and Air Force Space Command organizations for review and comment in order to update the July 2004 version. Consolidated comments have been received with the review and update process scheduled for a 2008/2009 timeframe.

AFSPCMAN 91-712

Headquarters Air Force Space Command Safety 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 and Acquirers into a single document.

These requirements will be published as AFSPCMAN 91-712, *Range Software and Computing System Requirements*. Space Command convened the Software Subgroup to develop and coordinate these requirements.

The draft computer and software requirements have been sent to industry, Range Users (including NASA), and Range Operators and Acquirers for review and comment. After Headquarters Air Force Space Command Safety review, the comments will be provided to the Federal Aviation Administration for review. Both the Air Force and the Federal Aviation Administration want to ensure that the software requirements remain common between the two agencies. This document is scheduled for publication in 2008.

Reusable Launch Vehicles

The Reusable Launch Vehicle Subgroup was formed in April 2006 to develop public safety requirements for the launch, reentry, and recovery of reusable launch vehicles. Membership in this group includes the Air Force and Federal Aviation Administration, with participation from NASA. The subgroup was formed for the following reasons:

- ◆ When AFSPCMAN 91-710, *Range Safety User Requirements*, was released in July 2004, reusable launch vehicle requirements had not been adequately addressed.
- ◆ The potential for near-term reusable launch vehicle users (SpaceX and the Air Force's Orbital Test Vehicle) on Space Command ranges has resulted in requests for guidance from the Safety Offices of the 30th and 45th Space Wings in their efforts to aid potential users in their vehicle designs.
- ◆ The flight of Spaceship One showed that entrepreneurs developing reusable launch vehicles are becoming a reality.
- ◆ The Space Shuttle Columbia accident revealed that safety concerns for the public during launch vehicle reentry needed to be addressed in more detail.

The Reusable Launch Vehicle Subgroup meets weekly via teleconferences and is nearing the completion of development of public safety requirements for unmanned reusable launch vehicles. Estimated completion is November 2007.

The development of manned reusable launch vehicle requirements will be initiated after the completion of the unmanned requirements. The estimated completion of the manned reusable launch vehicle requirements is November 2008. The reusable launch vehicles requirements will be incorporated into AFSPCMAN 91-710.

As new and emerging space launch technologies surface, the Common Standards Working Group will continue to provide a forum through which the Air Force, the Federal Aviation Administration, NASA, and other government agencies can communicate on further development and implementation of common range safety standards. The goal of this group has been, and will always be, to maintain public safety in all phases of launch activities.

Unmanned Aerospace Systems Working Group Policy Development Update

The development of unmanned aerospace systems is a rapidly evolving technology area. An evolution from drones and remotely piloted vehicles, these flight systems now encompass everything from hypersonic vehicles (shown right), to rotary wing hover systems (shown below), to lighter than air systems, and to any sort of hybrid imaginable – so long as the pilot is either not on board or the flight system is computer programmed.

These flight systems, with sizes ranging from housefly to full scale aircraft, are now being visualized for operations at all altitudes of the atmosphere and beyond and are much more than just flight hardware.

Formerly referred to as *unmanned aerial vehicles* and inclusive of unmanned aircraft systems, the rapid evolution of unmanned aerospace systems continues to blur, alter, or make obsolete definitions of flight systems as their capabilities evolve into and between the domains of air, space, and near-space.

Orbital, suborbital, and aircraft-like flight may possibly be integrated using combinations of ballistic, buoyant, or aerodynamic processes. As systems, these unmanned aerospace systems may include control stations, computers, human operators, remote sensing technology, communication and control links and relays, and Range Safety systems spanning the globe.

In 2005, the NASA Applied Technology Directorate, the NASA Range Safety office, and the United States Air Force 45th Space Wing Safety Office formed a working group to address the range support and Range Safety issues for such diverse systems operating near the launch head of the Eastern Range.

Development of Range Safety Requirements

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

To address these challenges, the working group conducted an extensive document review in 2005-2006 to aid in determining the compulsory subtopics to be addressed in a requirements document and a flight operations manual. Once completed, an exhaustive outline was formulated and sections were assigned to personnel to develop requirements based on subject matter expertise.

The working group was further challenged to incorporate rapidly evolving operational concepts and current considerations for operating unmanned aerospace systems in the National Airspace. In 2007, this safety risk management process was significantly refined to also address mature operational unmanned aerospace systems.

In 2007, technical interchanges expanded to include the Air Force Space Command Future Range Architecture Team, the NASA advanced range technology community, and the Range Commanders Council Range Safety Group. Development of a customer oriented Kennedy Space Center-45th Space Wing concept of operations support process was initiated. In the midst of these developmental efforts, requests for unmanned aerospace system operations of varying maturities and risks were submitted to the Range causing accelerated attention to developing these unmanned aerospace system support processes.

Technical Challenges

Meanwhile, technical challenges remain. Of urgent significance is the need to consider alternative classifications of range safety systems or contingency management systems that can accommodate the diverse unmanned aerospace system operational situations that are quite different from rocket launch or piloted aircraft operations.

Depending on risks involved, such systems might be of several reliability classes. Such systems may be challenged to operate over short to very long duration missions, be relatively inexpensive for expendable operations or stamina for repetitive operations, possibly micro-miniaturized, or operate in environments spanning from Federal Aviation Administration controlled national airspace to remote operations in hostile combat arenas.

Presently the aviation community is addressing the concerns of allowing unmanned aerospace system flight operations alongside airliners. Some unmanned aerospace systems are rapidly maturing, but before they become as safe and reliable as piloted aircraft, technologies must further evolve; for example, attention must be paid to the following:

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

As unmanned aerospace systems continue to evolve, current definitions or paradigms for reusable launch vehicles, “fly-back” stages, and re-entering payloads from the ballistic launch community may need to be revised or melded. Paradigms of dedicated links and cyber systems for flight safety systems or flight control may soon be challenged by evolving network centric efficiencies supporting not only launch range, but also sustained unmanned aerospace system flight, and other operations yet to be considered.

Along with the robust evolution of unmanned aerospace system technology, robust requirements must also address the synergistic overlap and melding of space, cyber, and unmanned aerial vehicle communities. The unmanned aerospace systems working group is striving for operational robustness to protect personnel, property, other aircraft, and national assets, while enabling new flight systems to operate with appropriately managed risk.

Flight Safety System Challenges

Range Safety is often faced with many challenges when trying to ensure the protection of the public, the local workforce, and property. These challenges must be met with steadfast determination and urgency to ensure that public safety and mission success are preserved. Some of the biggest issues NASA Range Safety dealt with in 2007 are discussed below.

Constellation

NASA Range Safety has been heavily involved in supporting the Constellation program. A major topic of concern in 2007 was ensuring that the Constellation program would meet all applicable range safety requirements. NASA Range Safety met with Constellation program personnel, 45th Space Wing Safety personnel, and pertinent contractors to discuss flight termination system options for the Ares I vehicle shown right and all range safety requirements that the Constellation program must meet.

This group met numerous times to review NPR 8715.5, *Range Safety Program*, and AFSPCMAN 91-710, *Range Safety User Requirements*. NPR 8715.5 is the NASA Range Safety program document while AFSPCMAN 91-710 is the range safety document used by the Eastern Range (45th Space Wing) for new programs. These documents contain range safety user requirements such as airborne flight safety system design, test, and documentation. This group is tailoring these documents to include only the requirements applicable to the Ares I program. This activity is close to completion and it is perceived that this same process will be used for the Ares V vehicle as well. NASA Range Safety will continue to work with this group and others to make sure all applicable range safety requirements are met to help ensure a safe and successful return to the moon and beyond.

Frequency Migration

Many different frequencies are used for flight termination. Each range uses a set of frequencies for flight termination operations. One of the frequencies that has been used for many years at various ranges, including the Eastern and Western ranges, is 416.5 megahertz. However, the National Telecommunications and Information Administration directed the Department of Defense to stop use of 416.5 megahertz for flight termination systems no later than the last day of calendar year 2006. The reason for the change was due to overcrowding in that frequency range and the fact that ultra high frequency wideband systems, such as flight termination systems, are required to operate in the 420-450 megahertz spectrum while 400-420 megahertz is reserved for narrow band systems.

However, range users at the Eastern and Western ranges were not able to meet this mandate so both ranges requested "Exception to Policy" waivers for continued use of 416.5 megahertz. The Eastern Range received approval through 2010 for the fly-out of Shuttle only, while the Western Range received approval through 2008 for Missile Defense Agency launches only. All range users have agreed to migrate to 421 megahertz and have begun to transition. Therefore, the remaining launches scheduled to use 416.5 megahertz have been granted approval.

The Eastern and Western ranges have also used 425 megahertz for quite some time, but due to the interference concern with high-powered radars, it was decided to phase out this frequency to minimize the impact of the radars. Users will be allowed to fly out remaining 425 megahertz receivers through 2008. After this date, they must use 421 megahertz as their flight termination frequency.

Frequency Interference

Some concern still remains over frequency interference between high-powered radars and flight termination system operations at the Eastern and Western ranges. High-powered radars such as the PAVE PAWS radar have shown that they can interfere with flight termination receivers onboard a launch vehicle. These high-powered radars, like the one shown right at Clear Air Force Base in Alaska, operate in the 420-450 megahertz region, the same region that some flight termination receivers operate in. Much research has been done in the last year on these radars and their effect on flight termination receivers. The Eastern and Western ranges have enacted mitigation efforts during range operations to ensure that there is no interference.

Long term solutions, such as moving to a new frequency band or using an autonomous flight safety system, are still being investigated. As long as the radar operators and range personnel agree to the mitigation efforts currently in place, an immediate long term decision is not likely.

Autonomous Flight Safety System

As in previous years, the autonomous flight safety system was a topic of concern for NASA Range Safety in 2007. As the range climate continues to change and evolve, so does the prospect for future technology. Research is being done on autonomous flight safety system now more than ever before to answer key questions about the system. Key concerns that range safety representatives are working include:

- Can this type of system and all relevant components meet applicable range safety requirements?
- What kind of certification program and how much testing will this system need before it is deemed “certified” to fly alone or with command capability?
- Can this type of system be man-rated and used for manned flight?

Whether or not an autonomous flight safety system could be used for a NASA or NASA-sponsored mission remains to be seen, but NASA Range Safety continues to work with other entities to come up with a viable go-forward plan for this technology and to ensure that this type of system will meet all range safety requirements and not add increased risk during range operations.

Enhanced Flight Termination System

NASA Range Safety has been involved in the enhanced flight termination system program for many years now. NASA Range Safety supported numerous meetings and teleconferences pertaining to the design, testing, and implementation of this system. Although there were several technical issues and problems that arose, 2007 was a year of milestones and accomplishment.

In 2007, the enhanced flight termination system program completed qualification testing on the first set of receivers and also completed the first end-to-end demonstration of the system. The system performed successfully and all goals of the mission were satisfied. NASA Range Safety representation was present during this mission in order to gain a better understanding of enhanced flight termination system operations. With this successful mission, the enhanced flight termination system is on its way to becoming a legitimate, certified system. NASA Range Safety continues to be a part of the enhanced flight termination system program and provides technical support when needed.

Secure Flight Termination System

Presently, two different types of flight termination systems are in use: non-secure and secure. The secure system is known as High Alphabet and is used on most launch vehicles operating at the Eastern and Western ranges. However, after 2014 High Alphabet will no longer be available for use.

The National Security Agency will de-certify High Alphabet as a secure system effective 1 January 2015. The agency no longer views High Alphabet as a robust system viable for space launch applications and range operations. If a secure system is to be used for a mission, NASA and the Department of Defense are both bound by requirements that state a secure system must use National Security Agency-approved cryptography. Being that High Alphabet will no longer be National Security Agency approved, ranges and range users must transition to an alternative.

Right now the only viable option is the enhanced flight termination system, a National Security Agency-approved, encrypted system. However, this system is very new and has little experience. To migrate to this new system, both ranges and range users must upgrade their equipment to support the enhanced flight termination system.

The colored boxes shown below in the diagram of the enhanced flight termination system vehicle and ground systems are components that the ranges and range users must upgrade to support the enhanced flight termination system. NASA Range Safety will continue to work with range users and range personnel to make this transition as easy as possible.

Independent Assessment

KSC

In accordance with NPR 8715.5, *Range Safety Program*, the NASA Range Safety Manager is required to conduct an independent assessment of applicable NASA Centers, component and range facilities, and programs at least once every two years to verify conformance with range safety policies, procedures, and requirements. NASA Range Safety has conducted audits at a number of facilities over the past few years, including Dryden Flight Research Center, Wallops Flight Facility, and the Goddard Center.

Conduct of Audit

In April of 2007, NASA Headquarters performed an Institutional/Facility/Operational Safety Audit at the Kennedy Space Center.

Although this discussion focuses on the Range Safety aspects of the audit, other disciplines reviewed included the following:

- Pressure Vessel Systems
- Electrical Safety
- Lifting and Handling Equipment
- Fire Protection
- Kennedy Space Center Government-Industry Data Exchange Program.

This safety audit satisfies the Range Safety Manager requirement for assessing Kennedy Space Center.

Range Safety Audit Results

The Range Safety portion of the audit focused on ensuring Kennedy Space Center compliance with the requirements of NPR 8715.5. Although the audit found Kennedy Space Center Range Safety to be in compliance with the document with no major deficiencies, a few items that require action are identified below.

- **Item:** There is no Range Safety risk management plan for expendable launch vehicle launches as required by NPR 8715.5, paragraph 3.2.4.4. **Corrective Action:** Range Safety is working with the Launch Service Program to develop Range Safety risk management plans for expendable launch vehicles.
- **Item:** KDP-KSC-P-3619, *NASA Range Safety Variance (Waiver)* process needs to be expanded to address the unique aspects of dealing with variance/waiver situations that can occur in real time during a launch countdown. **Corrective Action:** Range Safety has worked with headquarters to develop a real time process and to capture the process within a new revision of NPR 8715.5 which is expected in 2008. Range Safety is working locally with the Space Shuttle Program Launch Commit Criteria Working Group to develop a similar process. A similar process will be worked with the Launch Services Program.

- **Item:** KSC-PLN-2805, *KSC Range Safety Risk Management Plan for Launch and Landing of the Space Shuttle*, needs to be updated to fully describe how Kennedy Space Center manages toxics and distant focusing overpressure. A revision to NPR distant focus overpressure risks during Shuttle launches and to demonstrate how that approach satisfies the risk criteria of NPR 8715.5 is needed. **Corrective Action:** Range Safety is working with Kennedy Space Center, Center Operations to fully describe the risk mitigation efforts performed during a Space Shuttle launch countdown and document how these processes lower overall risk estimates and aid in satisfying the acceptable risk criterion of NPR 8715.5.

All corrective actions are expected to be completed in early to mid 2008.

Common Risk Analysis Tools Development

As required by NPR 8715.5; *Range Safety Program*, each range operation (launch or flight) shall undergo a range safety analysis to establish any design or operational constraints needed to control risk to persons and property. To accomplish this task, each NASA center has developed analysis tools to estimate risk associated with different hazards. Risk models currently used by the centers were mostly developed by Range Safety support contractors according to their particular technical expertise and based on specific center requirements and/or concerns. Some of the existing models have had peer review but have not been subjected to an extensive validation and verification program. Most of the models also lack well defined configuration management requirements and user training programs.

Purpose and Goal of Common Tool Kit Development

The purpose of the common tool kit development is an attempt to better manage public safety risk models used by NASA and to consolidate development efforts and requirements for proper validation and verification and configuration management. The goal is to develop a suite of accepted models under formal configuration management and make them available to all centers. Training and certification on performing hazard analysis using the models, including the associated physics and acceptable risk levels, will be required. This effort should minimize duplication of development effort and provide ranges with expanded capability when necessary to evaluate new hazards. It will also somewhat standardize the analysis process and ultimately make analysts well versed in a particular type of hazard analysis available to other centers.

Developing a Toolbench

With larger and more varied launch programs being introduced, such as expendable launch vehicles, reusable launch vehicles, reentry vehicles, and in particular the Constellation program (see right), greater emphasis is being placed on risk management and the use of rigorously validated and verified risk models.

In 2007, the Constellation Program funded a task to develop an updated debris risk analysis tool. The task is intended to evaluate the current suite of Space Shuttle/expendable launch vehicle launch area and overflight debris risk models and their associated sub-models to determine how they can be improved and integrated into a government owned and operated risk analysis tool.

The “toolbench” will have an open systems architecture that will provide economies in upgrading hardware, modifying existing models, interfacing new models when new or enhanced capabilities are required, and sharing physics and data modules between risk models. The toolbench will be managed with formal processes for verification, validation and acceptance, and configuration management and user training/certification. A requirements document, outlining modeling capabilities, validation and acceptance, and configuration management has been completed.

Initial Focus

Evaluations of existing capabilities and proposals on both system architecture and new physics model development will begin in early 2008. Although initial development will focus on supporting ARES 1 debris risk analysis at the Eastern Range, plans are to expand toolkit capability to include other hazards (such as toxics and distant focusing overpressure), other launch vehicles (expendable launch vehicles), unmanned aerial vehicles, other phases of flight (descent), and other centers and ranges.

Support to Program Operations

Near Field Infrared Experiment (NFIRE)

Kennedy Space Center Range Safety Support of Toxics and Distant Focusing Overpressure Evaluations

On April 24, 2007, an Air Force Minotaur 1 rocket was successfully launched at 2:48 AM EDT from NASA's Wallops Flight Facility in Virginia. The launch took place from the Mid-Atlantic Regional Spaceport's launch pad on the south end of Wallops Island. Click [NFIRE launch video](#) to view the actual launch.

This launch was the second Minotaur 1 launch from Wallops in just over four months. The previous mission on December 16, 2006, carried the Air Force Research Laboratory's TacSat-2 satellite.

The Rocket

The four-stage Minotaur 1 shown below carried the Department of Defense, Missile Defense Agency's near field infrared experiment (NFIRE) satellite. The Orbital Suborbital Program Minotaur 1 launch vehicle consists of an M-55 (51,514 pounds) and SR-19 (13,740 pounds) first and second stages taken from the Minuteman-2. Upper stages consist of an Orion 50XL motor and Orion 38 motor, both of Pegasus heritage.

Although launch vehicles of significant size (including the vehicle used for the TacSat-2 mission) have been launched from Wallops Flight Facility in the past, this was the second time Wallops performed a detailed analysis of toxic and overpressure hazards. A Tier 1, or screening evaluation of the TacSat-2 mission performed by the 45th Space Wing, revealed an in-depth toxics and distant focusing overpressure analysis was required.

The close proximity of the Minotaur 1 launch vehicle (with over 65,000 pounds of solid rocket propellant) to the off-base public was the driving factor behind the need for more detailed analysis. Based on the large number of data requirements, first time evaluation of these hazards required a significant effort.

Based on acceptable risk criteria contained in NPR 8715.5; *Range Safety Program*, pre-launch and day-of-launch risk analysis must be performed for all expendable launch vehicles launched from Wallops Flight Facility.

NFIRE Mission Support

Kennedy Space Center Range Safety has gained a great deal of experience in evaluating toxic and distant focusing overpressure at the Eastern Range and has assisted Wallops in the development, coordination, and real-time support of these hazard evaluations.

For the NFIRE mission, Kennedy Space Center Range Safety support to launch day operations consisted of coordinating with the 45th Space Wing to provide real-time toxic and distant focusing overpressure modeling support and coordinating with ACTA Inc to provide meteorological and technical support.

The 45th Space Wing and ACTA Inc provided significant support to the effort by conducting the real-time analysis as well as training Wallops Range Safety personnel on toxic and distant focusing overpressure modeling techniques.

2007 Launch Schedule

Dryden Flight Research Center Missions 2007

Date	Project Name	Mission	Flight Duration (Hours)	Location	Mission Result
6/23/2007	Ikhana (Predator B)	Ferry Flight	1.6	From Gray Butte/Palmdale, CA to Edwards AFB	Success
07/20/2007	X-48B LSV (Blended Wing Body)	Flight # 1	0.5	Edwards AFB	Success
7/30/2007	X-48B LSV	Flight # 2		Edwards AFB	Success
7/30/2007	Ikhana	Pilot Training Flight # 1		Edwards AFB	Success
7/31/2007	Ikhana	Pilot Training Flight # 2		Edwards AFB	Success
8/02/2007	X-48B LSV	Flight # 3		Edwards AFB	Success
8/03/2007	Ikhana	Pod Checkout Flight # 1		Edwards AFB	Success
8/08/2007	X-48B LSV	Flight # 4		Edwards AFB	Success
8/09/2007	Ikhana	Pod Checkout Flight # 2		Edwards AFB	Success
8/13/2007	X-48B LSV	Flight # 5		Edwards AFB	Success
8/16/2007	Ikhana	Western States Fire Mission Flight # 1		Edwards AFB; Central and Northern CA	Success
8/28/2007	X-48B LSV	Flight # 6		Edwards AFB	Success
8/29/2007	Ikhana	Western States Fire Mission Flight # 2	14	Edwards AFB; CA; NV; UT; ID; MT; WY	Success
9/07/2007	Ikhana	Western States Fire Mission Flight # 3	14	Edwards AFB; CA; OR; WA	Success
9/19/2007	Ikhana	Functional Check Flight	2	Edwards AFB	Success
9/27/2007	Ikhana	Western States Fire Mission Flight # 4	10	Edwards AFB; Central and Northern CA	Success
10/03/2007	Ikhana	Functional Check Flight	2	Edwards AFB	Success
10/04/2007	Ikhana	High Altitude Performance Flight	2.5	Edwards AFB	Success
10/11/2007	Ikhana	Functional Check Flight	3	Edwards AFB	Success
10/24/2007	Ikhana	Western States Fire Mission Flight # 5	9	Edwards AFB; Southern CA	Success
10/25/2007	Ikhana	Western States Fire Mission Flight # 6	9	Edwards AFB; Southern CA	Success
10/26/2007	Ikhana	Western States Fire Mission Flight # 7	9	Edwards AFB; Southern CA	Success
10/28/2007	Ikhana	Western States Fire Mission Flight # 8	9	Edwards AFB; Southern CA	Success

ER and WR Launches 2007

DATE	VEHICLE	MISSION	LAUNCH SITE
17-Feb	Delta II	THEMIS	ER/NASA
8-Mar	Atlas V	STP-1	ER/NASA
25-Apr	Pegasus	AIM	WR/NASA
7-Jun	Delta II	COSMO SkyMed 1	WR/Comm
8-Jun	Shuttle Atlantis	STS-117	KSC
15-Jun	Atlas V	NROL-30	ER/DoD
4-Aug	Delta II	PHOENIX	ER/NASA
8-Aug	Shuttle Endeavour	STS-118	KSC
18-Sep	Delta II	WorldView 1	WR/Comm
27-Sep	Delta II	DAWN	ER/NASA
10-Oct	Atlas V	WGS F1	ER/DoD
17-Oct	Delta II	GPS 2R-17 (M4)	ER/DoD
23-Oct	Shuttle Discovery	STS-120	KSC
10-Nov	Delta IV H	DSP 23	ER/DoD
5-Dec	Atlas V	NROL-24	ER/DoD
8-Dec	Delta II	COSMO-Sky Med 2	WR/Comm
20-Dec	Delta II	GPS 2R-18 (M5)	ER/DoD
Additional Support			
24-Apr	Minotaur	NFIRE	WFF/DoD

Wallops Flight Facility Launches for 2007

Date	Vehicle	Location	Launch Result
1/19	21.138 UE Black Brant VB	Poker Flat Research Range, Alaska	Success
1/19	36.234 UE Black Brant IX	Poker Flat Research Range, Alaska	Success
1/19	41.064 UE Terrier-Orion	Poker Flat Research Range, Alaska	Success
1/19	41.065 UE Terrier-Orion	Poker Flat Research Range, Alaska	Success
2/12	40.020 UE Black Brant XII	Poker Flat Research Range, Alaska	Success
2/14	DRW-4531 BQM-74	Wallops Flight Facility	Success
2/14	DRW-4623 BQM-74	Wallops Flight Facility	Success
2/14	41.061 UE Terrier-Orion	Poker Flat Research Range, Alaska	Success
2/14	41.062 UE Terrier-Orion	Poker Flat Research Range, Alaska	Success
2/14	41.063 UE Terrier-Orion	Poker Flat Research Range, Alaska	Success
2/14	35.037 UE Black Brant X	Poker Flat Research Range, Alaska	Success
2/28	40.019 UE Black Brant XII	Poker Flat Research Range, Alaska	Partial*
4/24	DRW-3741 NFIRE	Wallops Flight Facility	Success
5/22	USAF FALCON V	Wallops Flight Facility	Success
6/21	12.059 GT Terrier MK 12 Improved Orion	White Sands Missile Range, New Mexico	Success
8/3	41.069 UE Terrier-Orion	Andoya, Norway	Success
8/6	41.070 UE Terrier-Orion	<i>Andoya, Norway</i>	Success
8/13	36.220 UG Black Brant IX	White Sands Missile Range, New Mexico	Success
9/6	41.055 Terrier Mk70-Improved Orion	Wallops Flight Facility	Failure
10/30	36.218 UE Black Brant IX	Wallops Flight Facility	Success
11/6	36.241 GS Black Brant IX	White Sands Missile Range, New Mexico	Success
11/14	DRW-4657 BQM-34	Wallops Flight Facility	Success
11/14	DRW-4658 BQM-34	Wallops Flight Facility	Success

Emerging Technology

Autonomous Flight Safety System (AFSS)

The autonomous flight safety system is an independent and autonomous flight termination subsystem intended for expendable launch vehicles. It uses tracking and attitude data from an onboard GPS and inertial measurement unit sensors and configurable rule-based algorithms to make flight termination decisions. The system is a joint Kennedy Space Center and Wallops Flight Facility project.

The autonomous flight safety system testing and development philosophy is a graduated approach, emphasizing bench tests and flight tests of incremental system changes using available resources and clearly defined objectives. Data from each test is carefully analyzed and used to identify the current system's performance and any problems that need to be resolved before changes are made.

The ultimate objectives of the autonomous flight safety system are to increase capabilities by allowing launches from locations that do not have existing range safety infrastructure, reduce costs by eliminating some downrange tracking and communications assets, and increase safety by reducing the reaction time for flight termination decisions.

First Test Flight—White Sands Missile Range 2006

The autonomous flight safety system first flew on the Terrier Improved-Orion, two-stage sounding rocket shown right at White Sands Missile Range on April 5, 2006. A single-chassis, dual-processor, dual-GPS system was used.

Purpose of Flight. The primary purpose of the flight was to demonstrate the key elements of the autonomous flight safety system concept of operations pertaining to pre-launch set-up (loading and verifying the application and configuration files), bench testing, vehicle integration, in-vehicle end-to-end testing, countdown system verification procedures, and flight operations. A secondary purpose was to gather lessons learned which could be codified into the Autonomous Flight Safety System System Level Requirements document currently under revision.

Test. The test incorporated redundant GPS sensors and used two independently programmed processors. One was loaded with a nominal trajectory and the other programmed with artificial rules under which the nominal flight would violate safety parameters and provoke termination commands. The autonomous flight safety system was not connected to actual explosives. The system functioned and reacted correctly during the entire flight from launch to parachute deployment.

Mission Rules. Two different sets of mission rules were developed for this test, one for each processor. The set for Processor 1 (designated as the *nominal* processor) was configured so that a nominal flight would not result in any flight termination actions. The set for Processor 2 (designated as the *errant* processor) included three additional rules so that multiple destruct activations would occur during a nominal flight. *The autonomous flight safety system was not connected to a flight termination system and it could not initiate any destruct actions.*

The prelaunch success criteria of loading and verifying the application and configuration files and verifying that the applications were running correctly using simulated sensor data were satisfied. The rocket behaved nominally and the software performed as expected. The nominal processor did not execute any unplanned destruct actions and the errant processor successfully initiated three destruct actions as planned.

The Ashtec G12 GPS receiver lost lock on liftoff and did not regain it until after the flight was over. The Javad GPS receiver maintained lock throughout the flight. Both processors were operational during the flight and provided navigation and status messages via the vehicle telemetry stream. Navigation and status messages were stored in the nominal processor's nonvolatile (flash) memory for the entire operation, but the errant processor's flash memory chip became partially dislodged during the flight and stopped recording at T+335 seconds. Otherwise, the hardware performed as expected.

Second Test Flight—Kwajalein Reagan Test Site 2007

An autonomous flight safety system developmental test article flew on the SpaceX Falcon 1 expendable launch vehicle from the Kwajalein/Reagan Test Site on March 21, 2007. The primary test item was a single autonomous flight safety system chassis containing redundant flight processors, a custom-built voting circuit known as the *command and switching interlock circuit*, a power supply module, and a GPS receiver. An externally mounted GPS receiver for navigation solution redundancy and a 10-Watt Low-Cost Tracking and Data Relay System (TDRS) Transceiver (LCT2) for a space-based range demonstration were also flown.

The Falcon I, shown right, is a two-stage, liquid oxygen and rocket-grade, kerosene-powered launch vehicle designed to achieve substantial improvements in reliability and cost and to deliver 480 kilograms (1058 pounds) to an orbit of 200 kilometers at 28.5° inclination. The first stage is almost entirely reusable and returns via parachute to a water landing. Lift-off weight for the standard Falcon I is approximately 27,000 kilograms (60,000 pounds), length is about 22 meters (70 feet) and diameter is 1.67 meters (5.5 feet).

Minimum Success Criteria

The minimum success criteria for this test were met and included the following:

- Power-up, configure, verify configuration and test both flight processors and the command and switching interlock circuit during countdown operations.
- Acquire and maintain a navigation solution on the internal GPS throughout the terminal countdown.
- Maintain at least one GPS navigation solution throughout all portions of flight where the GPS antenna axis had a positive elevation angle. Correlate all GPS outages with unfavorable antenna attitudes using the vehicle attitude data.
- Confirm proper application of Green Time destruct rule for portions of the trajectory with insufficient GPS coverage.
- Maintain sufficient telemetry data coverage from launch to orbit insertion (100 kilometer perigee) to transmit valid navigation data from at least one GPS receiver and mission rule evaluation status from at least one processor. Telemetry outages are permissible; however, there must be coverage over 50 percent of the flight time with outages that do not exceed 10 seconds in duration.
- Evaluate the full set of mission rules on at least one processor from launch to orbit insertion.

Test Configuration. The test article was configured with a telemetry link from each of the two flight processors within the autonomous flight safety system chassis. The link from flight processor 0 (FP0) was routed through the Falcon 1 line-of-sight telemetry system. The link from flight processor 1 (FP1) was routed through the LCT2. Despite the previous successful completion of compatibility testing with launch vehicle systems, a concern was raised on launch day that LCT2 could potentially interfere with the vehicle GPS. With insufficient time available to permit additional conclusive testing, a decision was made by the Falcon 1 launch management team to fly with the LCT2 powered off. As a result, detailed mission rule response data was not available from FP1 for post-test analysis.

Test Results. The telemetry data integrity from FP0 was satisfactory throughout the entire flight, with no data dropouts prior to L+6 minutes. From L+6 minutes through the remainder of the propulsive phase of flight, there were 8 telemetry dropouts less than 0.3-seconds in duration. The GPS receiver housed within the autonomous flight safety system chassis maintained a navigation solution throughout the flight with no observed dropouts.

Both GPS receivers maintained navigation solutions throughout the flight with four observed momentary dropouts experienced after the onset of the vehicle anomaly. The autonomous flight safety system sensor redundancy management algorithms were able to properly cross-compare the two solutions and supply navigation data to the onboard range safety algorithm modules throughout the flight. The voting circuit properly responded to commands from the two flight processors throughout the flight.

The autonomous flight safety system properly detected lift-off and enabled the appropriate flight termination mission rules. A test exclusion zone was included in the mission rule set to simulate a flight termination event in the nominally planned vehicle trajectory. Both flight processors properly issued and released ARM and FIRE commands to the voting circuit when the vehicle instantaneous impact point intruded and exited the test exclusion zone. Both processors issued ARM and FIRE functions associated with the anomalous vehicle performance experienced during flight. Using the available telemetry data, it was confirmed that the FP0 termination command was issued due to a violation of a moving-gate rule established to catch erratic flight from “in-plane” vehicle failures.

Post-Flight Analysis. During post-flight analysis, a number of anomalies were observed and investigated. Shortly after launch, an anomaly in the navigation solution issued by the externally housed GPS receiver caused FP0 to improperly flag stage 1 burnout and stage 2 ignition events. Stage 2 ignition was flagged at T+18.0 seconds when it really occurred at T+176 seconds.

The GPS solution anomaly was traced to marginal satellites swapping in and out of track. This was a known vulnerability for this test article, and an attempt was made in the mission rule design to decouple all of the flight termination rules from in-flight detection of staging events to prevent spurious event detections from affecting the processing of mission rules. In the future, acceleration data from one or more inertial measurement units will be used for in-flight ignition and burnout event detection.

Both processors issued ARM and FIRE functions when it was expected that the moving-gate would have overtaken the instantaneous impact point because of anomalous flight conditions. FP1 issued ARM/FIRE commands approximately 163 seconds after FP0 issued its commands for the moving-gate rule. This lack of synchronization was caused by a set-up error in the configuration of the second stage moving-gate rule that resulted in the use of the elapsed time from second stage ignition as the time reference for the tabulated gate coordinates instead of time from launch in combination with the erroneous stage 2 ignition detection by FP0.

Comprehensive Minimum Success Criteria. In spite of these anomalies, all of the established minimum success criteria noted above were met. Moreover, two of the three comprehensive success criteria given below were met:

1. All Minimum Success Criteria are met.
2. Sufficient telemetry data exists to show that all hardware and software configuration items within the autonomous flight safety system RT4 chassis functioned properly through countdown, launch, and the entire propulsive phase of flight. This includes verification of proper functioning of the two flight processors, the command and switching interlock circuit, and the internal GPS.

3. A navigation solution was maintained on any GPS through enough of the propulsive phase of flight to avoid a Green-Time destruct violation.

Criterion 2 could not be met because the LCT2 was the only path for telemetry detailed status data from FP1.

Results of Rocket Tests

The results of these rocket tests has led to improvements in the autonomous flight safety system design concept and the general functional requirements set for autonomous flight termination. Work continues on improving the autonomous flight safety system by making the chassis more rugged, formalizing the requirements and design, and adding a loosely coupled GPS/Inertial Navigation Solution to improve the reliability of the autonomous flight safety system sensor suite.

A prototype of this GPS/Inertial Navigation Solution was flown on an F104 at Kennedy Space Center on November 8, 2007. The equipment was integrated on the F104 and recovered undamaged, but the GPS receiver did not function properly for reasons still being investigated. Consequently, insufficient data was collected to determine how the GPS/ Inertial Navigation Solution system performed. A second set of flights is planned for January 2008.

Joint Advanced Range Safety System

The joint advanced range safety system is a collaborative effort between Dryden Flight Research Center and the Air Force Flight Test Center at Edwards Air Force Base to develop a state-of-the-art mission planning, risk analysis, and risk management tool for range safety. The Range Safety organizations from all Major Range and Test Facility Bases are being asked to support the development, testing, and operation of unmanned aerial vehicles and reusable launch vehicles. It is the vision that the joint advanced range safety system will provide range safety support for these missions.

Primary System Elements

The joint advanced range safety system consists of two primary elements: a mission analysis software tool and the real-time operations tool. The mission analysis software tool quantifies the range safety risk for a given flight path and its associated vehicle parameters using a computerized method. This method will streamline the range safety analysis process by providing a consistent, high fidelity solution in less time than required by present methods of analysis.

Additionally, the real-time operations tool will provide the Range Safety Officer with near real-time assessment of the range safety risks during flight. This capability has many possible applications for the unmanned aerial vehicle or reusable launch vehicle operator, including the following:

- Assessment of unmanned aerial vehicle overflight of populated areas
- Allowing extended flight of an anomalous vehicle
- Recovery of an off-nominal vehicle at an alternate landing site
- Selection of an alternate flight or entry path

Status

The joint advanced range safety system mission analysis software tool is nearing operational status. Training of Dryden Flight Research Center, Air Force Flight Test Center, and 30th Space Wing Range Safety analysts has occurred. Dryden analysts are in the process of comparing test case results run on the mission analysis tool versus the results run by other methods. Other accomplishments include the creation of an interface control document for users who would like to develop their own modules and a new graphics tool to display results.

The joint advanced range safety system mission analysis software tool will not be undergoing an independent software assurance assessment due to lack of funding. The 30th Space Wing is currently leading the effort to begin work on the joint advanced range safety system real-time operations tool and the development of tools for re-entry risk analysis.

The 45th Space Wing is leading an effort to develop tools specific for the launch mission at the Eastern Range. Johnson Space Center is currently working to integrate the Public Entry Risk Assessment tool onto the joint advanced range safety system toolbench. The Center developed the Public Entry Risk Assessment tool in-house to analyze the risk posed by Space Shuttle re-entry trajectories.

Eastern Range (ER) Range Safety Instrumentation Update

The Eastern Range is the launch head at Cape Canaveral Air Force Station, which also supports Kennedy Space Center launches. Range Management activities are hosted at Patrick Air Force Base under the command of the 45th Space Wing. Downrange sites include Jonathan Dickinson Missile Tracking Annex, Wallops Flight Facility, and Antigua, Argentia, and Ascension stations. In the context of space launch operations, the Eastern Range includes all of the surrounding air, sea, and land space that is within the range of any particular launch vehicle. (See the graphic below.) The Eastern Range is not part of NASA but supports NASA activities.

Primary Objective of the Eastern Range

The primary objective of the Eastern Range is to provide for the safety of the public during launch operations. The activities and resources to ensure safety of flight include range instrumentation, infrastructure, and scheduling required to support and ensure that space and ballistic launches and other operations are appropriately supported.

The Eastern Range Range Safety Program uses instrumentation that is comprised of legacy and state-of-the-art technologies to ensure launch mission safety, launch area safety, and launch complex safety. Range instrumentation is primarily at the Florida locations of Cape Canaveral Air Force Station and Patrick Air Force Base. The Eastern Range also uses instrumentation from other Department of Defense and NASA agencies to accomplish its mission.

Information Provided by Instrumentation

During launch operations, Eastern Range instrumentation provides vehicle positioning information from radar, vehicle telemetry, and optic tracking systems. Additionally, telemetry also provides vehicle health and status through its data stream. This range safety critical data is shipped via the range communication CORE network to the range safety display strings located in the Range Operations Control Center at Cape Canaveral Air Station. The Range Operations Control Center is shown at the left.

Range Safety Displays

The current range safety displays are designated as Flight Operations Version One (FOV1) and located at the Range Operations Control Center. The FOV1 system provides an Eastern Range range safety function and monitors launch vehicle performance. FOV1 consists of two independent systems: FOV1-A and FOV1-B. The systems acquire and process instrumentation data from the Eastern Range, NASA, and off-range sites through redundant network paths. Using the instrumentation data, these systems generate flight path and predicted impact point displays similar to the one shown below.

Using these displays, the Mission Flight Control Officer determines risk based on pre-defined mission rules and, if required, destroys any vehicle that violates those rules. The 45th Space Wing Safety Office personnel devise these mission rules to ensure

public safety from any errant launch vehicle incident. This is the primary Eastern Range function.

FOV1 is constantly going through upgrade and development efforts. The fix-it-second development effort was completed in early 2007. The fix-it-third upgrades will be completed in 2008.

Command Destruct System

During launch operations, the 45th Space Wing is responsible for and ensures public safety through the use of a network of ground-based command destruct systems and vehicle-based flight termination systems. The two Eastern Range launch corridors are supported by downrange command transmitter sites that are geographically located along the flight path trajectory. This provides positive vehicle control throughout powered flight or orbit insertion.

The Mission Flight Control Officer monitors real time vehicle performance from the FOV Range Safety displays. (See right)

If a vehicle anomaly violates mission flight rules, the Mission Flight Control Officer initiates flight termination commands to the vehicle flight termination system by activating the central command remoting system (CCRS) located in the Range Operations Control Center.

The central command remoting system generates and formats the digital command messages, then transmits the message to the applicable command transmitter (CT) site.

The site then re-formats the message and uplinks the message to the vehicle. This is accomplished by the use of high power transmitters that generate a radio frequency carrier wave that is received by the vehicle flight termination system (FTS). The graphic below shows how the command destruct system works.

The command destruct ground system is constantly going through upgrade and development efforts. The 45th Space Wing Safety Office monitors all development activity to ensure this instrumentation meets or exceeds system requirements.

Post-Detect Telemetry System

The premier Eastern Range launch vehicle telemetry acquisition system is the post-detect telemetry system. This system provides transport of digital post-detect telemetry data from Eastern Range telemetry sites via the Network CORE System Wide Area Network Interface Units and the microwave and commercial circuits from Jonathan Dickinson Missile Tracking Annex.

Post-detect telemetry system sites include Tel-4 at Kennedy Space Center (shown at left), Jonathan Dickinson Missile Tracking Annex, Wallops Flight Facility, Antigua, and Ascension. The post-detect telemetry data is transported to the launch customer facilities and the Range Operations Control Center (FOV1) for range safety purposes. In 2006, the developer updated post-detect telemetry system software to Version 3.1 to provide resolution of deficiency reports generated before post-detect telemetry system initial acceptance.

INTEL SATCOM System

The INTELSAT SATCOM system now consists of two separate SATCOM strings: A Side and B Side. SATCOM A provides the transport for the post-detect telemetry system telemetry data.

This new digital communication transport service is the Eastern Range secondary telemetry and transport management system circuit transport carrier from the downrange stations of Antigua and Ascension to the Range Operations Control Center. The control center antenna is shown at right.

Wide Area Network Interface Units

The Network CORE Wide Area Network Interface Units facilitate the transport of data to Range Safety and telemetry data end users. The CORE provides the communication backbone at Cape Canaveral Air Force Station. The CORE consists of four rings, two OC-48 (2488 megabits per second) and two OC-12 (622 megabits per second). The communication link to NASA is through the Launch Operations Control Center. The primary nodes are the Range Operations Control Center, XY Facility, Southwest Terminal Building, and the East Terminal Building.

Central Telemetry Processing System

The central telemetry processing system is used for the processing, distribution, and display of Range Safety telemetry data during the powered flight portion of Eastern Range launches. Post-detect data streams into the central telemetry processing system where it undergoes frame synchronization and decommutation. The resulting telemetry parameters are used to generate 4.8 kilobits per second range safety outputs. This 4.8 kilobits per second data is forwarded to the FOV1 system for further processing and display.

Replacing the Cyber 860 Mainframe Computers

Many pre- and post-launch analysis products are produced at the Cape Central Computer Complex. For over 20 years, the Eastern Range has depended on Cyber 860 mainframe computers at the Central Computer Complex to produce launch critical and instrumentation analysis and Range Safety flight analysis. These computers and the code that resides in them are outdated in that the hardware is very costly to maintain and software problems are too difficult to fix. Two projects are in progress to replace the 860 Cyber mainframe computers.

Launch Analysis Production System. The launch analysis production system project is slated to replace Cyber 860 instrumentation analysis. The project is translating instrumentation analysis computer programs originally written in CDC Cyber FORTRAN to C++ programs that can be hosted on a standard personal computer. The project started in April 2005 and is scheduled to have the instrumentation analysis programs functioning by mid-2008. Most of the launch area production system hardware has been installed. Combined developmental and operational testing is underway.

Safety Hazards Analysis and Risk Processing. The safety hazards analysis and risk processing project is slated to replace Cyber 860 flight analysis automation. The project is re-hosting the CDC Cyber FORTRAN flight analysis programs primarily using MATLAB and C++ for computations and Java for the graphical user interface. This system will have open system architecture to allow incorporation of innovations in processor speed and storage capacity without major redevelopment. New commercial off-the-shelf software can be incorporated as “add-on” tools. The architecture will also accommodate the latest built-in analytical tools.

Safety hazards analysis and risk processing is a two-phased project. Phase 1 provides the host computer, backup storage, version control tools, and in initial suite of flight analysis modules. These Phase 1 products will eliminate 45th Space Wing reliance on the Cyber mainframes to produce flight analysis launch support products. Phase 1 software modules will enable flight analysts to process range user and weather data to produce range safety display backgrounds and range safety risk-based products for launch day support. Phase 1 development was completed on schedule in October 2007.

Phase 2 is underway and will provide contractor support for operational acceptance of Phase 1, flight analysis enhancements that were not previously possible due to Cyber 860 limitations and documentation for an organic software maintenance capability. Operational acceptance is scheduled for March 2008. Phase 2 will continue until the end of 2008.

Space-Based Range

Space-based range, formerly called *space-based range demonstration and certification* and *space-based telemetry and range safety*, is a multicenter NASA proof-of-concept project to determine if space-based communications can support the Range Safety functions (tracking data and flight termination signals) while also providing broadband Range User data (voice, video, and vehicle/payload data).

Space-based range is made up of the Range Safety and the Range User systems. The Range Safety system sends tracking data from the vehicle to the ground and receives flight termination commands from the ground. The Range User system sends high-data-rate vehicle telemetry from the vehicle to the ground. Both systems use NASA's Tracking and Data Relay Satellite System (TDRSS).

F15 Flights

Between November 2006 and February 2007, there were 11 space-based range flights on an F15-B at Dryden Flight Research Center. The primary goal for the Range User system was to test a 184-element TDRSS Ku-band (15 gigahertz) phased-array antenna with data rates of 5 and 10 megabits per second. The figure to the right shows the Range User antenna mounted behind the cockpit of an F15. The Range Safety system tested its ability to maintain lock with two TDRSS satellites simultaneously on a highly dynamic aircraft simulating an out-of-control launch vehicle and to transition between receiving forward commands from the launch head and TDRSS.

Because the Range Safety system used four S-band telemetry antennas (two forward and two return, with one set of each on the top and bottom of the aircraft), the antenna patterns were measured while they were mounted on the aircraft at the Benefield Anechoic Facility at Dryden Flight Research Facility.

The Range User antenna was electronically steerable in elevation and mechanically steerable in azimuth. The antenna was 29.5 inches in diameter, 13 inches deep, and weighed 119 pounds. Custom algorithms used the vehicle position and attitude to steer the antenna towards TDRSS. All the Range User flights used TDW (one of the TDRSS satellites) at 174° W longitude.

Data Results

The data was a combination of digitized, compressed black and white cockpit video, Range Safety tracking and transceiver data, and aircraft and antenna controller pulse-code modulated data streams; internal protocol data formatting was used. The antenna controller data stream was sampled at 1 hertz to correlate with the uncorrected error rates measured by the White Sands TDRSS ground station.

The figure below shows the link margins as a function of antenna elevation for a 5 and 10 megabits per second flight. It was not possible to measure link margins greater than 9 decibels, so it can only be said that the link margins were greater than 9 decibels for elevations above 30 degrees.

The following table summarizes the percentage of locked frames for the Range User flights. The pointing error was typically much less than 1 degree. The measured data and video latency was about 0.4 seconds.

Flight	% Locked at WSC	Notes
1	99.91%	5 megabits per second
2	88.16%	5 megabits per second, TDRSS Autotrack Problem
3	99.95%	5 megabits per second
4	98.16%	5 megabits per second, Intentionally exceeded antenna azimuth performance
5	99.78%	5 megabits per second
6	99.33%	10 megabits per second
7	99.89%	10 megabits per second

The Range Safety system used the previously flown S-band transceiver to validate the 840 bits per second forward link and the 10 kilobits per second return link. Several “fly-away” maneuvers were done to test the transition from launch head to satellite for the forward links and showed that there was a reasonably smooth transition between the launch head and TDRSS within 10 to 20 kilometers of the launch head for a launch head power level of -84 dBm. The CA (coarse acquisition) code Global Positioning System receiver performed well and had very few dropouts, even during highly dynamic maneuvers.

Enhanced Flight Termination System Program (EFTS)

The objective of the Enhanced Flight Termination System Program is to develop the next generation flight termination system for the Department of Defense and NASA ranges. The program addresses robust command links for flight termination, including message formats, modulation methods, and encryption.

Previous Status

The Range Safety Group of the Range Commanders Council initiated a study task and ultimately selected the following:

- Continuous phase frequency shift keying as the modulation scheme
- A 64-bit triple data encryption standard for security
- The layout of the 64-bit message for the new system.

The Air Force Flight Test Center then let a contract to build prototype enhanced flight termination receiver decoders and an encoder for the ground transmitter. The receiver decoder and encoder units successfully demonstrated that the enhanced flight termination system would function in flight and in an operational setting.

The Central Test and Evaluation Investment Program is funding the development of the flight termination receiver decoders, encoders, monitors, and encryption units for different range applications, such as unmanned aerial vehicles, space launch vehicles, and missiles. In August 2004, two contracts to develop the enhanced flight termination receiver decoder engineering development units were awarded to L-3 Cincinnati Electronics and Herley Industries. In August 2005, a contract to develop the ground systems (enhanced flight termination system encoder, monitor, and encryption unit) was awarded to L-3 Cincinnati Electronics.

Current Accomplishments

Milestones accomplished this year are described below.

- In early 2007, Qualification Testing was completed on three L-3 Cincinnati Electronics receivers.
- In October 2007, the entire system (ground equipment and receivers) was tested at Eglin Air Force Base onboard an Advanced Mid-Range Air-to-Air Missile (AMRAAM). The system performed nominally and marked the first live test of the entire system.

Future Plans

The Enhanced Flight Termination System Program will continue to work with various entities to achieve the goals of certifying this system. The program also desires to attempt more testing of the system in 2008 at various ranges.

Enhanced Flight Termination System Architecture

The enhanced flight termination system architecture consists of the vehicle and ground systems shown in the diagram below. The enhanced flight termination system was designed so that upon the completion and qualification of all units for both airborne and ground systems, implementation with existing architecture would minimally impact the ranges.

On the airborne side, the enhanced flight termination system uses existing components and systems, where the only new addition would be the new enhanced flight termination system command receiver/decoder. Legacy antennas, couplers, logic units, safety devices, and ordnance will be used along with the new command receiver/decoders and ground equipment.

The ground systems architecture will change somewhat, but the impacts will not be severe. Ranges will have to purchase the new enhanced flight termination system ground equipment (encoders, monitors, and triple data encryption units) and each range can develop the unencrypted 64-bit enhanced flight termination system command frame (command controller) based on its own culture.

The ground system will also implement existing technology and equipment including Range Safety Officer command panels, modulators/exciter, high power amplifiers, and command transmitters.

Enhanced Flight Termination System Equipment

Four of the major components of the enhanced flight termination system—enhanced flight termination receiver, triple data encryption unit, encoder, and monitor—are described below.

Enhanced Flight Termination Receiver

The receiver takes the encrypted messages sent from the command transmitter system (modulator, exciter, power amplifier) and decrypts them into useable commands.

Triple Data Encryption Unit

The triple data encryption unit is embedded within the encoders and encrypts the messages using the Triple Data Encryption Standard. A triple data encryption unit is embedded within each monitor for decryption of the enhanced flight termination system message for analysis.

Encoder

The encoder takes the encrypted message from the triple data encryption unit and adds a certain amount of frame synchronization and parity bits for forward error correction before sending the final message to the Legacy excitors.

Monitor

The monitor is used as an analysis tool for Range Safety by providing an independent verification process for the transmitted enhanced flight termination system signal. The command transmitter system sends the final, encrypted enhanced flight termination system message to the receiver and to the monitor.

After 2007, the Enhanced Flight Termination System Program is one step closer to bringing a new, qualified, improved system to ranges and range users. Milestones still remain as the program continues to get closer to bringing a new system currently under development into operational status. NASA Range Safety will continue to work with the enhanced flight termination system program and support the mission of providing a new advanced method of flight termination that will be low cost and low impact to ranges and range users, while providing a reliable system that will help ensure public safety during launch operations.

Special Interest Items

The Space Florida Customer Assistance Service Program for the Eastern Range

To attract and win new commercial business, improve timeliness, and optimize the cost of doing business, Space Florida initiated the Customer Assistance Service Program for the Eastern Range and identified two experienced, highly regarded contractors to implement their program. The Customer Assistance Program has three phases:

- Phase I — Analysis and Design: “Initial” Universal Document System and Range Safety Mentoring Capability/Services for customers; training plan development and course planning; and conceptual studies for a universal flight safety system. This Phase was completed in 2007
- Phase II — Develop, Test, and Deliver: “Mature” Universal Document System and Range Safety Mentoring Capability/Services for customers; training course development; and feasibility study for selected universal flight safety system concepts. This phase is currently in progress.
- Phase III — Maintain and sustain customer services with continuous process improvement; complete testing, and obtain 45th Space Wing, Range Safety approval of the selected universal flight safety system.

Mentoring

Mentoring includes instruction and training and professional consultant services. Current customers include SpaceX and Orbital Sciences, with several more candidates coming on board in the near future. Services have included:

- Assistance with Universal Document System documentation
- Flight safety system review and advice
- AFSPCMAN 91-710, *Range Safety User Requirements*
- Tailoring assistance
- Compilation of new customer lessons learned
- Liaison with the 45th Space Wing

Training

In Phase II, the final training plan is complete and the following courses, originally developed by NASA Range Safety, will be tailored for commercial customers:

- *Range Safety Overview*
- *Range Flight Safety Analysis*
- *Range Flight Safety Systems*

In addition, one new course, *AFSPCMAN 91-710 Requirements*, is under development. This course contains 10 stand-alone modules that cover the full spectrum of AFSPCMAN 91-710 requirements. Module 1 is an overview of the entire document, and modules 2 through 10 are in-depth reviews of the nine major sections of 91-710. All modules are designed for both engineering and non-engineering staff of commercial customers.

Universal Flight Safety System

The third component of Customer Assistance Service Program for the Eastern Range is the development of the universal flight safety system. This development will pay big dividends for the State of Florida by providing an incentive for commercial customers to come to the Eastern Range. The plan is to develop the universal flight safety system, either at the component level or system level, obtain pre-approval of the components and/or system by 45th Space Wing, Range Safety, and make it available to commercial customers, saving them much of the cost and time for flight safety system development and testing.

The Space Florida contractor will collect and document available universal flight safety system component information to fully populate the "Flight Termination System Component Matrix" developed in Phase I. The information will be divided and color-coded into categories and will contain enough information for customers to select current and future flight termination system components for a variety of launch vehicles.

The contractor will develop a Universal Flight Safety System Concept Feasibility Report recommending one short-term concept and one long-term concept for implementation. They will then prepare a Universal Flight Safety System Concept Implementation Plan for Phase III. This plan will include a detailed concept of operations and schedule. Current NASA systems under development, such as the enhanced flight safety system and the autonomous flight safety system, are included in the trade studies.

In Phase III, the contractor will update the universal flight safety system schedule and concept of operations; provide the required technical expertise during each phase of the flight safety system selection process to include support to identify flight safety system selection components, review proposed test plans, and monitor and review qualification and acceptance testing for each flight safety system selection component. The

contractor will continue to work with Space Florida and its designated customers to receive final certification and approval from the Eastern Range to use each flight safety system selection component and/or integrated system.

The comprehensive training, professional consultations, and universal flight safety system options will greatly ease a new customer's transition onto the Eastern Range and significantly reduce the current time schedules for launch requirements.

NASA Expendable Launch Vehicle Payload Safety Program

NASA Headquarters Office of Safety and Mission Assurance designated a NASA Expendable Launch Vehicle Payload Safety Manager and an Agency Team to establish the NASA Expendable Launch Vehicle Payload Safety Program and develop policy and requirements in support of this safety program. Program policy was placed in the last version of NPR 8715.3, *NASA General Safety Program Requirements*, paragraph 3.13.4.5.

The team's goal is to develop a program with improved structure and processes for ensuring NASA expendable launch vehicle payloads are consistently designed, transported, processed, tested, integrated with the launch vehicle, and launched safely. The Agency Team is updating the expendable launch vehicle payload safety review process and replacing the current NASA-STD-8719.8, *Expendable Launch Vehicle Payload Safety Review Process Standard*, with the two following documents:

- NASA procedural requirements document, NPR 8715.XX *Expendable Launch Vehicle Payload Safety Program*
- NASA Standard, NASA-STD-8715.18, *Expendable Launch Vehicle Payload Safety Design and Ground Operations Requirements*

The new process and requirements will be coordinated and implemented jointly with the Air Force approval process (for launches from Air Force ranges) and will retain the Payload Safety Working Group and a phased safety review approach.

The new NPR 8715.XX, *Expendable Launch Vehicle Payload Safety Program* draft has been reviewed and commented on by each NASA Center Safety and Mission Assurance Director. The NPR has been improved and finalized based on comments from the review and will be submitted in the formal approval process in January of 2008.

The current Draft NASA STD-8719.8 *Expendable Launch Vehicle Payload Safety Design and Ground Operations Requirements* contains NASA's requirements for safeguarding people and resources (including flight hardware and facilities) from hazards associated with payloads that will fly on expendable launch vehicles, including hazards associated with payload related ground support equipment.

This standard infuses and tailors applicable NASA, industry, and Air Force Range Safety requirements into a single standard for NASA expendable launch vehicle payload projects. This methodology was used to ensure a single baseline requirements document that the Payload Project Office will tailor for both Air Force and NASA acceptance and approval. This NASA Standard should be completed by the summer of 2008 and programmatic activities continue.

NASA Range Safety Support for the Space Florida Educational Balloon Release Program

The Space Academy, a joint venture between Space Florida and the NASA/Florida Space Grant Consortium, was specially designed to encourage students to continue their studies in science-based programs at their college or university, through continuing studies, Kennedy Space Center Internships, and science-based research programs. The Academy hosts Florida teachers, undergraduates, middle school, and high school students in a range of scientific and hands-on activities at the Kennedy Space Center Visitors Complex Education Center. The students and teachers represent several academic institutions from across the state of Florida and the nation.

The program focuses on bridging engineering and science gaps that currently exist in academics and in the workforce. In addition to the hands-on activities, the students work on a number of interdisciplinary projects designed to help them become problem-solvers, with real-life space and science-based problems. The students also have the opportunity to meet with top NASA scientists as well as potential Kennedy Space Center employers.

Educational Balloon Release Program

Over the past two years, 22 balloons have been released: 10 in 2006 and 12 in 2007. The releases have taken place from a variety of locations ranging from the Cape Canaveral Air Force Station Weather Station, the Kennedy Space Center Visitors Complex, Kelly Park on Merritt Island, and the Astronaut Hall of Fame in Titusville.

These scientific balloons are designed to climb to an altitude of over 100,000 feet (20 miles), and at that altitude, relay pictures of the curvature of the Earth and the blackness of space back to the students.

The scientific balloons are launched from Kennedy Space Center with the following payloads on board:

- Live camera that is set to relay pictures to a ground receiver and monitor
- Global Positioning System designed to chart the flight pattern of the balloon

Plans are in the works for additional payloads such as ozone monitoring sensors.

Balloon Release Program Safety Requirements

NASA Range Safety works with the 45th Space Wing Safety Office to ensure all requirements and common sense practices are satisfied. In the balloon release program, Space Florida must adhere to four primary requirements.

1. Any individual payload package weighing over 4 pounds must have a surface density of less than 3 ounces per square inch (computed by dividing the total weight by the area of the smallest surface of the package).
2. Any individual payload package must weigh less than 6 pounds.
3. The total payload must weigh less than 12 pounds (Space Florida payloads generally weigh less than 14 ounces).
4. The payload suspension line must have a breaking strength of not more than 50 pounds.

These are the same requirements used for the daily weather balloon releases by the 45th Space Wing at Cape Canaveral Air Force Station Weather Facility. Balloons flown under these requirements are exempt from notification to Federal Aviation Administration control facilities, but Space Florida makes pre-launch courtesy notifications to the Kennedy Space Center Shuttle Landing Facility/Military Radar Unit and to the 45th Space Wing, 1st Range Operations Squadron since the release location is inside restricted airspace under their control.

Once all of these requirements and notifications have been satisfied, the 45th Space Wing Safety Office issues an approval letter with concurrence from NASA Range Safety to Space Florida to conduct their balloon release.

Center Status Reports

Kennedy Space Center Range Safety Representative

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

Constellation Program

The Kennedy Space Center Range Safety Representative participated in multiple meetings and technical exchange sessions in support of developing a draft set of tailored range safety requirements for the ARES 1-X test flight mission.

The mission has to meet both AFSPCMAN 91-710; *Range Safety User Requirements*, and NPR 8715.5; *Range Safety Program* requirements. The 45th Space Wing Safety Office, the Constellation Program Office, and NASA Range Safety worked through the Launch Constellation Range Safety Panel to successfully develop a single tailored document that includes all range safety requirements. The teaming process hopefully sets the groundwork for future Constellation Program range safety requirements document tailoring. The effort also exemplified NASA's philosophy of accepting or sharing responsibility for all aspects of range safety.

The Kennedy Space Center 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 2007, a team consisting of NASA Range Safety, 45th Space Wing Safety Office, and risk model development support contractors completed a requirements document that will pave the way for future risk model development. The document includes preferred modeling capabilities, but also focuses on verification and validation and configuration management requirements. Although the ascent debris hazard assessment capability will be developed first, other hazards such as descent debris, distant focusing overpressure, and toxics risk are also being considered. Actual model development will begin early next year.

The Range Safety Representative also provided continued support to the Launch Constellation Range Safety Panel.

Space Shuttle Program

For the Space Shuttle program, the Kennedy Space Center Range Safety Representative was involved in the development of an update to the Launch Commit Criteria Document which will implement NPR 8715.5 requirements. Following discussions with the Launch Commit Criteria Working Group, a decision was made late in the year to develop a separate section that contains all Shuttle-specific NASA range safety launch commit criteria. Work will continue in 2008.

Launch and entry risk estimates were evaluated for STS-117, STS-118 and STS-120, with mitigation efforts initiated through the Kennedy Space Center Emergency Operations Center when appropriate.

Mitigation efforts were required to minimize the distant focusing overpressure risk for all three missions while STS 120 also required mitigation efforts to reduce debris risk. Efforts included moving personnel from windows to mitigate distant focusing overpressure risk and moving people outside of facilities to mitigate risk from debris.

The Range Safety Representative also provided continued support to the Shuttle Range Safety Panel and supported STS-117, STS-118, and STS-120 launches on console in the Morrell Operations Control Center.

Launch Services Program

For the launch services program, the Range Safety Representative supported a number of NASA expendable launch vehicle campaigns, including Dawn, Phoenix, AIM, and THEMIS. This effort involved attending all the NASA and Air Force Safety readiness reviews and ensuring NASA procedural requirements were being met during the respective launch countdowns. An artist's concept of the five THEMIS satellites being released from their carrier is shown at right.

Agency Activities

For Agency activities, the Kennedy Space Center Range Safety Representative served as a NASA point of contact to the Range Safety Group and supported several committees charged with developing or rewriting nationwide standards on a number of important range safety issues. These topics included developing reusable launch vehicle and unmanned aerial vehicle requirements and a rewrite of RCC 321, *Common Risk Criteria for National Test Ranges* for risk evaluation and approval.

Other Range Safety Activities

Other Range Safety activities that the KSC Range Safety Representative was involved in included the following:

- Documenting approval of range safety non-conformances/variances for all applicable NASA launches
- Supporting discussions regarding flight termination system frequency migration plans and how they affect future NASA missions
- Supporting discussions relative to meeting secure systems requirements found in NPR 2810, *Security of Information Technology*
- Assisting the Agency Range Safety Manager in developing a *Range Safety Operations* course for NASA, the last in a series of NASA Safety Training Center taught courses
- Developing, tracking, and implementing corrective actions from items identified during the Kennedy Space Center Infrastructure, Facilities, and Operations Audit performed by NASA Headquarters
- Providing toxic and distant focus overpressure risk analysis support to Wallops Flight Facility for the TAC SAT-2 Minotaur launch

The past year was a challenge in supporting a number of launch and entry campaigns, providing critical early support to the Constellation Program, and continuing to ensure Kennedy Space Center safely implements NASA Range Safety requirements. The coming year promises to be at least as busy and the Kennedy Space Center Range Safety Representative will continue to provide critical support whenever called upon by NASA programs or to address issues that may arise.

Wallops Flight Facility

Wallops Flight Facility had a particularly active and successful year in 2007. The Sounding Rocket Program conducted 17 missions, highlighted by field campaigns conducted in Poker Flat, Alaska and Norway, along with additional missions launched from Wallops and White Sands Missile Range. The figure at right shows a Poker Flat launch for observations of a pulsating aurora. See the table at the end of this article for details of the 2007 launches.

In addition to its operational missions, the Sounding Rocket Program conducted efforts to bring the Patriot and Multi-Launch Rocket System motors into the program as new low-cost configurations to support science and technology missions.

Balloon Program Office

The Balloon Program Office at Wallops Flight Facility conducted 18 missions during fiscal year 2007. Flight operations were conducted from Fort Sumner, New Mexico; Palestine, Texas; Kiruna, Sweden; and McMurdo, Antarctica. The Wallops Safety Office supported the 2007 Balloon flight program by providing flight safety risk analysis reports for operational implementation for both continental United States and foreign operations 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 6 hours to 35 and ½ days with the longest flight occurring over Antarctica. The Balloon Program Office continued the ultra long duration balloon vehicle development. Flight testing of the ultra long duration balloon is planned for 2008. The balloon is being developed to provide extended duration flight, upwards of 60-100 days, at constant float altitudes.

See the results of the Balloon Program Missions 2007 in the table at the end of this document.

Other Missions

Wallops Flight Facility was involved in a number of other programs, including measuring the changes in the Greenland ice cap, unmanned aerial vehicle demonstrations, hurricane research, and the launch of the Missile Defense Agency near field infrared satellite.

Measuring Changes in the Greenland Ice Cap

The Airborne Science Program conducted a series of missions using the Wallops Orion P-3B aircraft, including an annual campaign to measure changes in the Greenland ice cap.

Unmanned Aerial Vehicle Activities

Wallops also supported numerous unmanned aerial vehicle activities. Wallops worked with Aurora Flight Sciences to flight demonstrate a new ducted fan unmanned aerial vehicle, the GE-80, as a test platform to demonstrate advances in platform-independent science and data systems. These systems are intended to standardize systems used for science applications and streamline integration processes.

Hurricane Research

Wallops continued its hurricane research collaboration with the National Oceanic and Atmospheric Administration using the AAI/Aerosonde unmanned aerial vehicle shown at right.

Aerosonde flew in the eye wall of Hurricane Noel for 7 and ½ hours in winds reaching 80 mph at altitudes ranging from 300 to 2000 feet and provided real-time detailed observations of the near surface, high wind environment.

The Aerosonde mission into Hurricane Noel was the first ever successful flight of an unmanned aircraft into the inner core of a hurricane.

Near Field Infrared Experiment Satellite Launch

In addition to internal NASA sounding rocket and unmanned aerial vehicle missions, the Research Range conducted numerous missions for non-NASA organizations. The Range launched the near field infrared experiment satellite for the Missile Defense Agency on a Minotaur I rocket. It was the second Minotaur mission conducted by Wallops.

New Range Technologies

Wallops continued development of a number of key technologies intended to improve mission capabilities and lower costs.

Low-Cost TDRSS Transceiver

The Wallops Flight Facility-developed low-cost TDRSS transceiver (LCT2) successfully added the receive capabilities to the existing transmitter capabilities. Flight tests will continue in 2008 to demonstrate the full functionality of this dramatically lower-cost system.

Autonomous Flight Safety System

The autonomous flight safety system was successfully demonstrated as a payload on the Defense Advanced Research Projects Agency-sponsored SpaceX Falcon 1 mission conducted from Kwajalein Atoll. Once fully developed and tested, this system offers the opportunity for reduced ground instrumentation by using onboard sensors and preprogrammed safety rules to determine the need for flight termination.

Phased Array Antenna

Work also began on a new phased array antenna design that offers opportunity for significantly higher data rates on suborbital and orbital launch vehicles.

Ku Band Telemetry System

Wallops is also actively developing a high data rate (~200megabytes) Ku Band telemetry system, in an effort sponsored by the Missile Defense Agency. The system will be demonstrated on a sounding rocket mission in mid-2008.

Wallops Safety Office Support

The Wallops Safety Office supported each of these missions through pre-mission analysis and certification, as well as providing operational personnel during launch operations. The Safety Office also contributed significantly to the technology efforts through providing engineering and safety expertise into designs that will enable these tools to meet range safety requirements for flight. The Safety Office also is actively engaged with other NASA and external organizations in the assessment and improvement of analysis tools that allow for streamlined and consistent implementation of safety analysis techniques for mission planning.

Dryden Flight Research Center

The Dryden Flight Research Center, located at Edwards Air Force Base, California, is NASA's primary installation for flight research. Over the past 60 years, projects at Dryden have led to major advancements in the design and capabilities of many civilian and military aircraft. The Center is involved in the following:

- Support of operations for the Space Shuttle
- Development of future access-to-space vehicles
- Conduct of airborne science missions and flight operations
- Development of piloted and unmanned aircraft test beds for research and science missions

Range Safety operations at Dryden are managed by the Range Safety Office. Under an alliance agreement with the Air Force Flight Test Center, the Dryden Center Director established the Range Safety Office to provide independent review and oversight of range safety issues. The Range Safety Office also supports the Center by providing trained flight termination system engineers, Range Safety Risk Analysts, and Range Safety Officers to provide mission and project support. In addition, the office supports the NASA Range Safety Training Program by providing the unmanned aerial system perspective in the development of range safety courses.

Unmanned Aerial Systems and Vehicles

Dryden continues to support the testing of a wide range of unmanned aerial systems and vehicles. The systems and vehicles flown with Dryden's assistance are described below.

Model-Type Unmanned Aerial Systems

The model-type unmanned aerial systems consist of tactical reconnaissance and surveillance vehicles. The primary purpose of the flights was to acceptance test the vehicles before delivery to the United States military. Dryden has supported over 340 hours of operations on six vehicles from three different companies.

Blended Wing Body Low Speed Vehicle

The blended wing body low speed vehicle unmanned aerial vehicle is a dynamically scaled version of the original concept vehicle. The primary goals of the test and research project for this vehicle are as follows:

- Study the flight and handling characteristics of the blended wind body design
- Match vehicle performance with engineering predictions based on computer and wind tunnel studies

- Develop and evaluate digital flight control algorithms
- Assess the integration of the propulsion system to the airframe

Industry studies suggest that because of its efficient configuration, the blended wing body would consume 20 percent less fuel than jetliners of today, while cruising at high subsonic speeds on flights of up to 7,000 nautical miles. To date, the project has conducted six successful flights.

Ikhana

NASA's Ikhana unmanned aerial vehicle is a General Atomics Predator-B modified to support the conduct of Earth science missions for the Science Mission Directorate. The aircraft is capable of mission durations in excess of 24 hours at altitudes above 40,000 feet. On-board support systems include a NASA developed airborne research test system.

The test system can host research flight control algorithms that can test autonomous sensor or autonomous aircraft control concepts. The aircraft is designed to be disassembled and transported in a large shipping container aboard standard military transports.

The vehicle has successfully flown 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 missions successfully over the Southern California wildfires, sending near real-time imagery to the firefighters.

The Range Safety Office has supported flight planning and risk analysis tasks in support of Federal Aviation Administration Certificate of Authorization applications as well as real-time operations support. The vehicle has flown seventeen flights this year with durations lasting as long as 14 hours.

Orion

The Orion Project is part of NASA's Constellation Program. The Orion Project consists of the crew module (shown right) and launch abort system.

Dryden is tasked with conducting a series of flight tests to demonstrate proper operations of the launch abort system and the crew module 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 the White Sands Missile Range in New Mexico.

NASA Headquarters

The Safety and Assurance Requirements Division at the Headquarters Office of Safety and Mission Assurance provides corporate leadership in the definition and implementation of NASA's agency-wide Safety and Mission Assurance policies, procedures, standards, tools, techniques, and training, including the Agency Range Safety and Expendable Launch Vehicle Payload Safety Programs.

The Headquarters Range Safety Representative and other members of the Office of Safety and Mission Assurance participated in two primary activities in 2007 in support of the Range Safety Program:

- An independent audit of the agency and local Range Safety functions at Kennedy Space Center
- A review and update of NPR 8715.5, *NASA Range Safety Program*

The audit went very well with only a few minor findings that are currently being corrected.

A Range Safety Team meeting—including members from Headquarters Office of Safety and Mission Assurance, Kennedy Space Center, Dryden Flight Research Center, Wallops Flight Facility, and Air Force Space Command—was held in Colorado Springs to kick off the 8515.5 update. Action items from this meeting are being worked before the NPR is submitted for formal review in 2008.

Other activities included support to the following:

- Expendable Launch Vehicle Payload Safety Program
- Range Commanders Council Range Safety Group
- Space Shuttle and Constellation Range Safety Panels
- Training development, including a critique of the Range Safety Operations pilot course
- Support to research and development projects such as the joint advanced range safety system, autonomous flight safety system, and enhanced flight termination system

This annual report contains articles about each of the activities listed above.

Johnson Space Center

Space Shuttle Range Safety Panel

During 2007, the Space Shuttle Range Safety Panel dealt with a number of topics related to the Space Shuttle. Included were Shuttle main engine reliability assessment, advanced master events controller spurious output testing, and ceiling and visibility launch commit criteria. Also addressed were command receiver decoder implementation and public entry risk assessment flight rule updates.

Space Shuttle Main Engine Reliability Assessments

During the past several years, NASA and the 45th Space Wing have made significant progress on updating the launch area risk assessment input parameters that are used as part of the process of estimating public risk for each Shuttle launch. One of the input parameters pertains to vehicle failure probabilities and is addressed using the Shuttle probabilistic risk assessment data generated by NASA. The NASA probabilistic risk assessment data include both a failure probability estimate and a time distribution for each identified failure mode. The probability estimate and time distribution for Space Shuttle main engine related failures were reassessed in 2007. Prior NASA studies indicated that a uniform distribution (i.e., constant failure probability as a function of time in flight) was the most appropriate distribution for main engine failures.

The Space Shuttle main engine failure distribution was reanalyzed by both NASA and 45th Space Wing personnel, and the results were discussed at the Range Safety Panel in April 2007. The conclusion from that panel meeting was that the uniform distribution was the most representative distribution based on the current Space Shuttle main engine data and analyses compiled to date. As a result, the launch area risk assessment input parameters pertaining to failure time distributions remained unchanged.

Advanced Master Events Controller Spurious Output Testing

During advanced master events controller testing in the Shuttle Avionics Integration Lab, it was noted that advanced master events controller outputs would spuriously turn on when the controllers are powered down. This raised concern as to whether the spurious advanced master events controller commands could trigger the solid rocket booster range safety safe and arm device to the SAFE position and/or left or right solid rocket booster range safety Power Off (command receiver/decoder off).

Research into the anomalous advanced master events controller condition and the interface circuit design led the Range to conclude that spurious output of the solid rocket booster range safety SAFE is acceptable for all vehicles/missions.

Each advanced master events controller controls 1 of 2 switches in series between the command receiver decoder and the safe and arm device. The switches are non-latching and reset within 50 milliseconds (per command receiver decoder specification) after power is removed. The worst-case circuit analysis shows they actually reset within 8.7 milliseconds.

To impact the safe and arm device, spurious output from both advanced master events controllers would need to occur within 8.7 milliseconds, which was considered non-credible. Additionally, the voltage/duration observed will not reset the switch.

Research into the anomalous advanced master events controller condition and the interface circuit design led the Range to conclude that spurious output to the solid rocket booster range safety system safe and arm is acceptable for all vehicles/missions. The maximum spurious output voltage seen on the STS-123 installed advanced master events controllers was 13.3 Vdc for 300 microseconds. Worst-case circuit analysis showed that spurious master events controller inputs to the command receiver decoder of 32 Vdc for less than 2.6 milliseconds will not latch the command receiver decoder.

Also, worst-case circuit analysis showed that spurious master events controller inputs to the command receiver decoder that are less than 14.4 Vdc (steady state) will not latch the command receiver decoder. So the maximum advanced master events controller voltage output/duration seen to date will not reset the command receiver decoders. Given this data and the understanding of the cause of the condition, the Range has accepted this condition “as is” for all flights provided that testing is done no earlier than 6 months before scheduled launch to ensure the anomalous condition does not degrade further.

Ceiling and Visibility Launch Commit Criteria

The Shuttle ceiling and visibility launch commit criteria was evaluated in an effort to understand how the criteria were established and whether they needed to be updated. The evaluation focused on part of the launch commit criteria that states that, for short duration launch windows, the cloud ceiling at the pad can be no less than 6,000 feet for a cloud deck greater than 500 feet thick. The Shuttle Range Safety Panel requested this evaluation to determine if the launch commit criteria could be lowered to 5,000 feet to be consistent with the “Return to Launch Site” launch commit criteria ceiling limit.

The impact of lowering the ceiling launch commit criteria to 5,000 feet was measured by evaluating the casualty expectation (E_c). The study showed that with a constant delay time between vehicle failure and vehicle breakup, the overall risk remained constant with ceiling altitude. However, as the delay time between vehicle failure and vehicle breakup increased, the risk increased.

A delay time between 7 and 10 seconds resulted in acceptable E_c values; however, a delay time of approximately 15 seconds and above caused E_c violations. Traditionally, 7 seconds is the accepted delay time used for analysis.

In the event that the Mission Flight Control Officers may need to initiate the Range Safety System, the lack of visibility of the vehicle due to a cloud ceiling would lessen the visual cues for the Mission Flight Control Officer and likely increase the delay time.

The Space Shuttle Range Safety Panel concluded that the cloud ceiling altitude did not significantly affect risk. Although lowering the launch commit criteria ceiling limit from 6,000 feet to 5,000 feet may yield acceptable risk values, the panel decided not to pursue the change at this time.

Command Receiver Decoder Implementation

The command receiver decoder replaced both the integrated receiver decoder and range safety distributor on the solid rocket booster range safety system and completed its first flight during the STS-118 mission in August 2007. The solid rocket booster range safety system, otherwise known as the airborne command destruct system, provides personnel and property protection in the event of flight path deviation or inadvertent vehicle breakup. The command receiver decoder was implemented due to supportability and obsolescence concerns for the integrated receiver decoder and range safety distributor previously used for all Shuttle missions.

Two command receiver decoders (System A and B) are required per solid rocket booster (four per flight). Their functions include providing control of the safe and arm device (System A only) in response to Orbiter master events controller or solid rocket booster multiplexer/demultiplexer commands and commanding the safe and arm device to SAFE during flight operations shortly before solid rocket booster separation. The command receiver decoder provides protection to the solid rocket booster retrieval crew by returning the safe and arm device to SAFE and turning off range safety power shortly before solid rocket booster separation.

In addition, the command receiver decoder provides isolation and interconnection for cross strapped ARM and FIRE commands between solid rocket boosters and ARM latching switch INHIBIT/RESET control. The command receiver decoder INHIBIT function protects the Space Transportation System and crew from inadvertent destruct during final launch countdown after ordnance is connected and the safe and arm device is commanded into the ARM position (T-4 minutes 55 seconds to T-10 seconds). The command receiver decoder also provides range safety system status to telemetry and ARMED indication to alert the crew.

The command receiver decoder routes range safety system measurements through the solid rocket booster multiplexer/demultiplexer to the Orbiter transmission system and provides energy output current pulse to fire the NASA standard detonator, initiating the pyro chain needed for airborne command destruct sequence. Before its first flight, the command receiver decoder was given exhaustive qualification testing to ensure compliance with revised loads environments. Additionally, an extensive flight safety review process ensured that the entire community was in agreement with the changes to the flight hardware and risk documentation.

Public Entry Risk Assessment Flight Rule Updates

Updates were made to Shuttle Flight Rule A2-207 to address the entry public risk consideration per the NPR 8715.5, *Range Safety Program*. The updates were a result of updated population numbers using LandScan 2005 and an updated probabilistic risk assessment incorporating late inspection to lower the overall probability of loss of vehicle. As a result of these analyses, it was seen that the current flight rule placards for nominal End-Of-Mission and Compromised Orbiter entries needed to be adjusted. The new flight rule was accepted during a Shuttle Flight Rule Control Board meeting in November 2007.

Launch Constellation Range Safety Panel

In February 2006, the Launch Constellation Range Safety Panel was officially chartered by the Constellation Program and jointly signed by the 45th Space Wing Commander and the program manager. This article addresses the development and implementation of two working groups; Ares I-X tailoring, linear-shaped charge extension, and flight termination system command frequency modifications; and the Orion abort flight test campaign.

Launch Constellation Range Safety Panel Trajectory Working Group

The Trajectory Working Group was the first sub-group to be chartered by the Launch Constellation Range Safety Panel. The primary responsibility of this group is to ensure that each of the range safety trajectory analysis requirements, as specified by the 45th Space Wing, is coordinated among the proper NASA centers.

Consequently, the working group is responsible for technical management of diverse trajectory modeling and simulation tasks and related analysis efforts, as well as for technical oversight of the product review and approval process preceding official delivery of trajectory datasets and vehicle debris catalogs to the 45th Space Wing.

Trajectory Working Group activities were primarily focused on satisfying range safety requirements for a planned launch of the Ares I-X flight test vehicle in April 2009. As a result of these activities, the following official products were successfully completed and delivered to the 45th Space Wing in 2007:

- Ares I-X Preliminary Nominal and Malfunction Turn Trajectories. This dataset included thousands of trajectories for various failure scenarios. The task to generate these trajectories also involved extensive simulation development that was performed to model many different vehicle failure modes.
- Ares I-X Preliminary Debris Catalog. This dataset included mass property, dimension, and ballistic coefficient estimates for various debris pieces and vehicle segments that may pose a potential hazard in the event of vehicle breakup. To complete this task, an assessment of the vehicle breakup sequence was performed as well as an aerodynamic analysis of the various debris pieces.

In addition to the products delivered to the Eastern Range, the working group coordinated another analysis task in support of the Constellation Program's debate as to whether to extend the linear-shaped charge to cover the Ares I-X first stage aft segment. The working group participants conducted an extensive assessment of Ares I-X trajectories and debris fields that showed clear risk benefits were achievable when the first stage linear-shaped charge was extended.

NASA centers providing integral support for these analysis tasks and Ares I-X range safety products included Langley Research Center, Johnson Space Center, Marshall Space Flight Center, and Glenn Research Center. Representatives from Kennedy Space Center and the 45th Space Wing were also regular participants in working group activities throughout the year and provided invaluable advice and technical assistance on many occasions.

Range safety trajectory related activities for the Ares I-X vehicle will carry through to 2008 in support of the final flight plan approval process.

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 2007 in support of the Ares I-X flight test vehicle. In particular, the group coordinated all tasks pertaining to a preliminary Ares I-X range safety probabilistic risk assessment that was provided to the United States Air Force as part of the Ares I-X preliminary flight data plan. The Ares I-X preliminary probabilistic risk assessment was developed by Safety and Mission Assurance personnel at Johnson Space Center, Marshall Space Flight Center, and Langley Research Center.

The results of the probabilistic risk assessment serve as a potential input to future Ares I-X launch area risk assessments. In addition to the probabilistic risk assessment development, the working group also coordinated discussions between NASA and Air Force personnel regarding the selection of assumptions and datasets for use in the Ares I-X risk assessments. The group will continue to coordinate the Ares I-X probabilistic risk assessment-related work in 2008 in support of the Range Safety final flight data plan approval process.

Other Topics Considered by the Launch Constellation Range Safety Panel

Many other topics were addressed past year, including Ares I-X tailoring, linear-shaped charge extension, flight termination system command frequency modifications, and the Orion abort flight test campaign.

Ares I-X Requirements Tailoring

Ares I-X and the 45th Space Wing conducted numerous Technical Interface Meetings during the past year to produce an AFSPCMAN 91-710, *Range Safety User Requirements*, tailored document for the Ares I-X flight test vehicle. During those iterations, the document underwent a metamorphosis in which it finally became the repository of all range safety user requirements for both the Air Force and NASA. Despite many difficult challenges, the High Performance Work Team consisting of representatives from the 45th Space Wing Safety Office, NASA Range Safety, the Launch Constellation Range Safety Panel, and the Ares I-X Flight Test Vehicle Mission produced a revolutionary document that incorporates requirements from both AFSPCMAN 91-710 and NPR 8715.5. The document is currently in the approval process.

Ares I-X Linear-Shaped Charge Extension

As a carry-over task from 2006, the safety community, including both NASA and Air Force Range Safety, engaged the Constellation Program in an attempt to have the Ares I-X Flight Test Vehicle Mission extend the linear-shaped charge currently installed in the Shuttle heritage solid rocket booster so that it would cover the booster aft segment. Because of added budget and schedule risks, the Ares I-X Mission initially opposed the proposal. However, in January the Launch Constellation Range Safety Panel, with the support of the 45th Space Wing, successfully presented their position to the Constellation Program Manager.

As a result, a Technical Interface Meeting was held at the ATK manufacturing facility in Utah. This meeting was supported by representatives from Ares I-X, the Launch Constellation Range Safety Panel, and the 45th Space Wing. During this meeting, a concerted effort was made to understand the cost and schedule impacts that would result from the extension. The preliminary position of the Ares I-X Mission at the onset of the meeting was that it would cause a delay of up to eight months and dramatically increase costs.

During the weeklong meeting, these estimates were reviewed and, with the willingness of the 45th Space Wing to compromise on a qualification program for the extension and some innovative scheduling, the final schedule showed the linear-shaped charge to be available earlier than the need date to support a 15 April 2009 launch with only moderate budget increases.

Ares I-X Flight Termination System Command Frequency Modifications

At the end of 2006, considerable effort went into determining whether the Ares I-X Flight Test Vehicle Mission would be required to migrate to a flight termination system command frequency of 421 megahertz or whether it could still use 416.5 megahertz as does the Shuttle. By the end of 2006, it was widely believed that a policy established by both NASA and the Air Force of staying on 416.5 megahertz would assure that the Ares I-X Mission would not have to migrate to the higher frequency.

However, by the end of the first quarter of 2007, that assumption was less certain. As a result, in 2007, the Air Force negotiated with the National Telecommunications and Information Agency to allow both commercial and NASA launches on the range to continue to use a flight termination system command frequency of 416.5 megahertz. As part of the agreement, the Air Force will seek a Special Temporary Authority for each launch through calendar year 2010.

Orion Abort Flight Test Campaign at White Sands Missile Range

Throughout 2007, Constellation's Orion Project worked with the White Sands Missile Range Flight Safety Office on the Orion Abort Flight Test campaign.

Beginning in 2008, a series of launches will be conducted at White Sands to test the launch abort system of the Orion spacecraft (shown right).

The launch abort system would be used operationally to pull the crew module away from the Ares I launch vehicle following a catastrophic failure of the Ares on the launch pad or during early ascent. Five tests are currently planned at White Sands. Two flights are pad abort tests and the remainder are classified as ascent abort tests where the abort is initiated at a specified test condition during the ascent of a test booster.

An analysis showed that a flight termination system would not be required for the launch abort system. The White Sands Missile Range Flight Safety Office approved this analysis and established a four nautical mile exclusion zone for the pad abort tests. Submitted analysis also showed that Launch Complex 32 would be acceptable for both the pad abort and ascent abort missions. This common pad approach will result in considerable savings to the project. Lockheed-Martin, Northrop-Grumman, Orbital (Chandler), Langley Research Center Engineering, Johnson Space Center Engineering, and Johnson Space Center Mission Operations all contributed to these studies. Range approval allowed pad area construction to begin on 1 October 2007.

The project completed the required tailoring of NPR 8715.5 in support of the Pad Abort-1 flight as well as the required risk management plan. The Range Commanders Council Standards that govern flight safety at White Sands Missile Range were reviewed by the project and no tailoring was identified for the pad abort missions.

The program introduction document to White Sands Missile Range was completed and the operational requirements document is nearing completion. The Pad Abort -1 Flight Safety Operations Plan will be released by the range in response to the operational requirements as the launch date for Pad Abort-1 approaches.

White Sands Missile Range has supplied the required Pad Abort-1 range safety data products and delivery dates, and the project has started work in this area. White Sands generally prefers a failure modes and effects criticality analysis methodology for assessing the test vehicle reliability. The failure modes and effects criticality analysis product is generally used by other range customers and was specified in the range letter defining the products.

NASA and Lockheed-Martin prefer a probabilistic reliability assessment approach since this methodology is used throughout the remainder of the Constellation Program. After a series of meetings on this topic, White Sands Missile Range agreed to the use of a probabilistic reliability assessment for the Pad Abort-1 reliability product. A failure modes and effects criticality analysis may still be required for the abort test booster, which will first be used for the ascent abort 1 mission scheduled for the fall of 2009.

Summary

As always, Range Safety has been involved in a number of exciting and challenging activities and events. Throughout the year, we have strived to meet our goal of protecting the public, the workforce, and property during range operations.

During the past year, Range Safety was involved in the development, implementation, and support of range safety policy. Range Safety training curriculum development was completed this year and several courses were presented. Tailoring exercises concerning the Constellation Program were undertaken with representatives from the Constellation Program, the 45th Space Wing, and the Launch Constellation Range Safety Panel.

Range Safety actively supported the Range Commanders Council and its subgroups and remained involved in updating policy related to flight safety systems and flight safety analysis. In addition, Range Safety supported the Space Shuttle Range Safety Panel and addressed policy concerning unmanned aircraft systems. Launch operations at Kennedy Space Center, the Eastern and Western ranges, Dryden Flight Research Center, and Wallops Flight Facility were addressed.

Range Safety was also involved in the evaluation of a number of research and development efforts, including the space-based range (formerly STARS), the autonomous flight safety system, the enhanced flight termination system, and the joint advanced range safety system. Flight safety system challenges were evaluated.

Range Safety's role in the Space Florida Customer Assistance Service Program for the Eastern Range was covered along with our support for the Space Florida Educational Balloon Release Program.

We hope you have found the web-based format both accessible and easy to use. Anyone having questions or wishing to have an article included in the 2008 Range Safety Annual Report should contact Alan Dumont, the NASA Range Safety Program Manager located at the Kennedy Space Center, or Michael Dook at NASA Headquarters.