

2013

NASA Range Safety
Annual Report

**This 2013 Range Safety Annual Report
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Table of Contents

I. INTRODUCTION	7
II. AGENCY RANGE SAFETY PROGRAM	8
A. Range Safety Training 2013.....	8
1. Range Safety Orientation (SMA-SAFE-NSTC-0074)	9
2. ELV Flight Safety Analysis (SMA-SAFE-NSTC-0086)	10
3. NASA Range Flight Safety Analysis (KSC-SA-NRFSFA).....	12
4. Range Flight Safety Systems (SMA-SAFE-NSTC-0096)	13
5. Range Safety Operations Course (SMA-SAFE-NSTC-0097).....	14
B. Development, Implementation, Support of Range Safety Policy	16
1. Range Commanders Council (RCC) Range Safety Group (RSG).....	16
2. Common Standards Working Group (CSWG).....	18
C. Inter-Center Aircraft Operation Panel (IAOP)	18
III. PROGRAM/PROJECT SUPPORT	20
A. Commercial Crew Program (CCP), Multi-Purpose Crew Vehicle (MPCV), Ground Systems Development and Operations (GSDO)	20
B. Tri-Program Tailoring	20
IV. EMERGING TECHNOLOGY	22
A. Defense Advanced Research Project Agency (DARPA).....	22
B. Updated Software	22
C. Flight Analyst Workstation.....	22
V. STATUS REPORTS	24
A. Ames Research Center (ARC)	24
1. Dragon Eye	24
2. Vision II	25
B. Dryden Flight Research Center (DFRC).....	25
1. Enhanced Flight Termination System	25
2. DFRC/AFTC Range Safety Alliance	25
C. Johnson Space Center (JSC).....	30
1. Human Exploration Range Safety Panel (HERSP)	30
2. MPCV Exploration Flight Test 1 (EFT-1).....	30
3. Exploration Missions (EM) EM-1 and EM-2	31
4. Multi-Purpose Crew Vehicle (MPCV) Ascent Abort 2 (AA-2) Flight Test	31
5. Commercial Crew Program (CCP).....	31
6. Morpheus Activities at JSC.....	32

D. Kennedy Space Center (KSC)	32
1. Rocket University	33
2. Unmanned Aerial System (UAS) Competition.....	35
3. Morpheus Operations	36
4. KSC Aviation Working Group (KAWG)	38
5. Launch Operations Support.....	38
6. Range Safety Launch Support Policy	39
E. Langley Research Center (LaRC)	39
1. LaRC Small Unmanned Aerial System (sUAS) Facilities	39
2. LaRC Range Safety and sUAS Operation Oversight	40
3. FY 2013 sUAS Flight Projects	40
F. Marshall Space Flight Center (MSFC)	44
1. Aero-M Small Unmanned Aerial System (UAS)	44
2. Mighty Eagle.....	45
3. Space Launch System Program (SLSP).....	46
G. NASA Headquarters (HQ).....	47
H. Stennis Space Center (SSC).....	47
1. Engine Testing	47
2. NASA-US Navy Mobile Construction Battalion 11/Underwater Construction Team (UCT) 1 Combined Underwater Surveying and Tactical Training.....	48
3. Application for Air Range Information and Notification (AARIN).....	48
4. Special Use Airspace	49
5. Unmanned Aircraft Systems (UAS)	49
I. Wallops Flight Facility (WFF)	50
1. Range and Mission Management Office	50
2. Sounding Rocket Program Office	53
3. Balloon Program Office	54
4. WFF Aircraft Office	55
5. WFF Mobile Range - Kwajalein Launch Campaign.....	57
SUMMARY	58

Table of Figures

FIGURE 1: TOTAL NUMBER OF CLASSES AND STUDENTS TAUGHT.....	8
FIGURE 2: 2013 NRS PROGRAM FUNDED COURSES.....	8
FIGURE 3: RANGE SAFETY ORIENTATION COURSE OUTLINE.....	10
FIGURE 4: CURRENT ELV FSA COURSE OUTLINE	11
FIGURE 5: KSC NASA FSA COURSE OUTLINE	12
FIGURE 6: RANGE FLIGHT SAFETY SYSTEMS COURSE OUTLINE	14
FIGURE 7: RANGE SAFETY OPERATIONS COURSE OUTLINE.....	15
FIGURE 8: FLIGHT ANALYST WORKSTATION SCREEN CAPTURE	23
FIGURE 9: DRAGON EYE.....	24
FIGURE 10: VISION II	25
FIGURE 11: BLENDED WING BODY LOW SPEED VEHICLE	26
FIGURE 12: NASA GLOBAL HAWK.....	27
FIGURE 13: NASA'S IKHANA UAS	28
FIGURE 14: BOEING PHANTOM EYE	28
FIGURE 15: DREAM CHASER.....	29
FIGURE 16: LOCKHEED MARTIN X-56A.....	29
FIGURE 17: PREPARATION FOR MPCV EXPLORATION FLIGHT TEST 1	30
FIGURE 18: MISSION CONTROL ROOM	31
FIGURE 19: AA-2 ABORT TEST BOOSTER AND MPCV LAUNCH ABORT VEHICLE.....	31
FIGURE 20: MORPHEUS TEST FLIGHT	32
FIGURE 21: ROCKET U NEAR-SPACE ENVIRONMENTS BALLOON	34
FIGURE 22: ROCKET U ROCKETRY PROGRAM LAUNCH FROM KSC	34
FIGURE 23: KSC TEAM LAUNCHING GENESIS UAS.....	35
FIGURE 24: JSC TEAM FLYING HELICOPTER UAS AT THE SLF	35
FIGURE 25: MSFC TEAM MEMBER WITH HEXACOPTER UAS AT THE SLF.....	36
FIGURE 26: MORPHEUS 1.5B TETHERED FLIGHT AT KSC	37
FIGURE 27: MORPHEUS 1.5B FREE FLIGHT TEST AT KSC	37
FIGURE 28: EASTERN AND WESTERN RANGE SUPPORTED BY KSC IN 2013.....	38
FIGURE 29: AIRSTAR PHASE V, REMOTE INTERNAL PILOT AND GLASS COCKPIT CONFIGURATION LOCATED INSIDE THE MOBILE OPERATIONS STATION WITH CONOPS BEYOND VISUAL RANGE.....	41
FIGURE 30: AIRSTAR BAT-4 EXPERIMENTAL TEST-BED.	41
FIGURE 31: MULTIPLE UAS CONOPS USING TWO FLIC TESTBEDS	42
FIGURE 32: AERO-M HEXACOPTER UAV OWNED BY MSFC.....	43
FIGURE 33: EDGE 540T 33% SUBSCALE VEHICLE BEING OPERATED AT 31VA ABERDEEN AIRFIELD, SMITHFIELD, VIRGINIA.	43
FIGURE 34: EDGE 540T 33% SUBSCALE VEHICLE DESIRED CON-OP	44
FIGURE 35: AERO-M SMALL UNMANNED AERIAL SYSTEM	44
FIGURE 36: MIGHTY EAGLE FLIGHT TEST	45
FIGURE 37: SLS 70-METRIC TON INITIAL CONFIGURATION	46
FIGURE 38: ARTIST'S CONCEPTION OF AN SLS LAUNCH	46
FIGURE 39: ENGINE TEST SSC.....	47
FIGURE 40: US NAVY MOBILE CONSTRUCTION BATTALION 11/UNDERWATER CONSTRUCTION TEAM (UCT) 1 COMBINED UNDERWATER SURVEYING AND TACTICAL TRAINING	48
FIGURE 41: PUMA UAS	49
FIGURE 42: ANTARES ON THE PAD	50
FIGURE 43: ANTARES IN HORIZONTAL INTEGRATION FACILITY (HIF).....	51

FIGURE 44: ANTARES LAUNCH52
FIGURE 45: VIEW OF MINOTAUR V LADEE LAUNCH FROM NEW YORK CITY52
FIGURE 46: MINOTAUR V LAUNCH.....53
FIGURE 47: SUPERTIGER LAUNCH.....55
FIGURE 48: LDS LAUNCH TOWER55
FIGURE 49: NASA GLOBAL HAWK ON APPROACH56
FIGURE 50: SECOND SOUNDING ROCKET LAUNCH FROM ROI-NAMUR ATOLL,
REPUBLIC OF THE MARSHALL ISLANDS57
FIGURE 51: SAMARIUM VAPOR CLOUD IN THE IONOSPHERE.....57

I. INTRODUCTION

Welcome to the 2013 edition of the NASA Range Safety Annual Report. Funded by NASA Headquarters, this report provides an Agency overview for current and potential range users. This report contains articles which cover a variety of subject areas, summaries of various activities performed during the past year, links to past reports, and information on several projects that may have a profound impact on the way business will be conducted in the future.

Specific topics discussed in the 2013 NASA Range Safety Annual Report include a program overview and 2013 highlights, Range Safety Training, Independent Assessments, support to Program Operations at all ranges conducting NASA launch/flight operations, a continuing overview of emerging range safety-related technologies, and status reports from all of the NASA Centers that have Range Safety responsibilities.

Every effort has been made to include the most current information available. We recommend this report be used only for guidance and that the validity and accuracy of all articles be verified for updates. As is the case each year, we had a wide variety of contributors to this report from across our NASA Centers and the national range safety community at large, and I wish to thank them all.

On a sad note, we lost one of our close colleagues, Dr. Jim Simpson, due to his sudden passing in December. His work advancing the envelope of autonomous flight safety systems software/hardware development leaves a lasting impression on our community. Such systems are being flight tested today and may one day be considered routine in the range safety business. The NASA family has lost a pioneer in our field, and he will surely be missed.

In conclusion, it has been a very busy and productive year, and I look forward to working with all of you in NASA Centers/Programs/Projects and with the national Range Safety community in making Flight/Space activities as safe as they can be in the upcoming year.

Alan G. Dumont
NASA Range Flight Safety Program Manager

II. AGENCY RANGE SAFETY PROGRAM

A. Range Safety Training 2013

To date, the NASA Range Safety (NRS) team has conducted 55 training courses with participants from NASA, Department of Defense (DoD), Federal Aviation Administration (FAA), and NASA contractors. Figure 1 shows the total number of classes and students taught since the inception of the NRS training program in 2004.

Courses	# Classes	# Students
Range Safety Orientation	26	684
ELV Flight Safety Analysis	9	155
NASA Range Flight Safety Systems	2	37
Flight Safety Systems	13	194
Range Safety Operations	5	30

FIGURE 1: TOTAL NUMBER OF CLASSES AND STUDENTS TAUGHT

Due to Federal Budget constraints this year, the NASA Safety Training Center (NSTC) was unable to fund any Range Safety classes. Therefore, the three range safety classes taught in 2013 were funded by the Agency Range Safety Program. The Range Safety Operations (RSO) course was conducted at Wallops Flight Facility (WFF) and two NASA Range Flight Safety Analysis (NRFSA) classes were conducted and videotaped at Kennedy Space Center (KSC) for inclusion in the online System for Administration, Training, and Educational Resources for NASA (SATERN) training courses catalog. The dates of these courses are listed below in Figure 2.

Course	Date	Location
NASA Range Flight Safety Analysis	4-8 Feb	KSC
NASA Range Flight Safety Analysis	25-29 Mar	KSC
Range Safety Operations	29 July-2 Aug	WFF

FIGURE 2: 2013 NRS PROGRAM FUNDED COURSES

While the NRS team has provided excellent training for the Range Safety Community, the Agency routinely looks for ways to improve course content as well as methods of delivery. The following are descriptions of the Range Safety courses. The NSTC catalog denotes updates and improvements where applicable.

1. Range Safety Orientation (SMA-SAFE-NSTC-0074)

The Range Safety Orientation Course is designed to provide an understanding of the Range Safety mission, associated policies and requirements, and NASA roles and responsibilities. It introduces the students to the major ranges and their capabilities, defines and discusses the major elements of range safety (flight analysis, flight safety systems, and range operations), and briefly addresses associated range safety topics such as ground safety, frequency management, and unmanned aircraft systems (UASs). The course emphasizes the principles of safety risk management to ensure the public and NASA/range workforces are not subjected to risk of injury greater than that of normal day-to-day activities.

The Range Safety Orientation Course is designed to inform the audience of the services offered by the Range Safety organization, present timeframes that allow adequate interface with Range Safety during Program/Project startup and design in an effort to minimize potential delays and costs, and recommend ways of making the working relationship with Range Safety the most beneficial for the Range User. This course includes a visit to Range Safety facilities at Cape Canaveral Air Force Station (CCAFS)/KSC when presented at the Eastern Range. If you wish to discuss presenting the class at your location, please contact the NSTC staff or the NRS Manager, Alan Dumont, via email at Alan.G.Dumont@nasa.gov.

Target Audience:

- Senior, program, and project managers
- Safety, Reliability, Quality, and Maintainability professionals with an interest in range safety activities
- New Range Safety Personnel

Range Safety Orientation

Day 1	Day 2
<ul style="list-style-type: none">• Intro & Range Safety Missions• Range Safety Organization• Policies, Standards, Directives• Launch & Test Facilities• Flight Analysis• Flight Termination Systems• Tracking & Telemetry• Range Safety Operations	<ul style="list-style-type: none">• Ground Safety• Frequency Management• UAS Operations• The Way Ahead• Hangar AE Tour• Morrell Operations Center Tour• Summary• Critiques

FIGURE 3: RANGE SAFETY ORIENTATION COURSE OUTLINE

2. ELV Flight Safety Analysis (SMA-SAFE-NSTC-0086)

The original Flight Safety Analysis (FSA) course, based primarily on United States Air Force (USAF) procedures at the Eastern Range, was not taught in 2013. However, it will continue to be offered for DoD and FAA customers on an as-requested basis. It includes NASA, DoD, and FAA requirements for FSA; a discussion of range operations hazards, risk criteria, and risk management processes; and in-depth coverage of the vehicle containment and risk analysis methods performed for expendable launch vehicles (ELVs) at the Eastern Range.

Prerequisite: Completion of SMA-SAFE-NSTC-0074, Range Safety Orientation, or equivalent experience – engineering degree and a familiarity with range safety.

Target Audience:

- NASA, FAA, and DoD Range Safety Analysts in training
- Range safety personnel in other disciplines
- Program/project managers and engineers who design potentially hazardous systems to operate on an Air Force Space Command (AFSPC) range
- Personnel who conduct hazardous operations on an AFSPC range

An outline of the ELV Flight Safety Analysis course structure is shown in Figure 4.

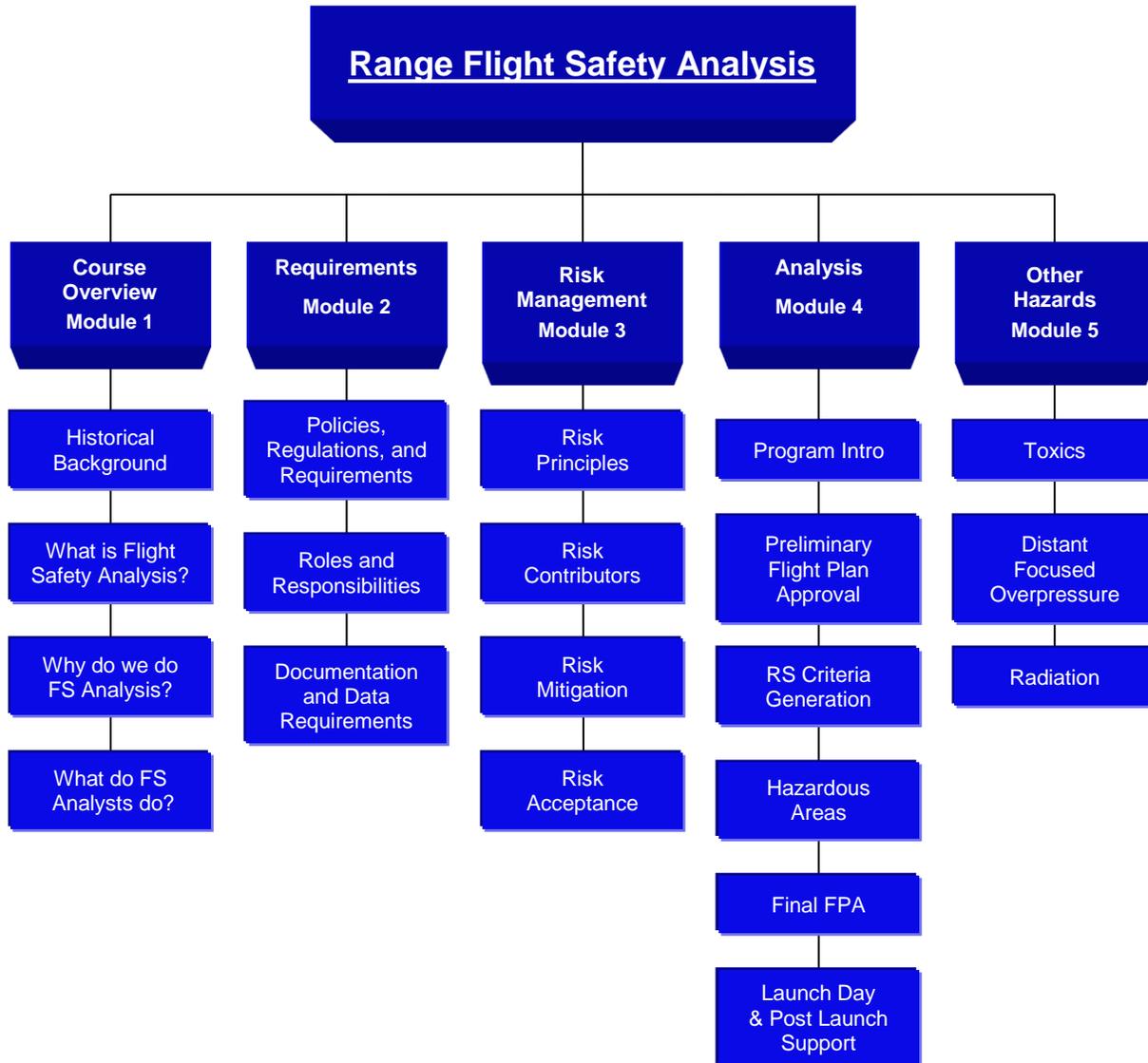


FIGURE 4: CURRENT ELV FSA COURSE OUTLINE

3. NASA Range Flight Safety Analysis (KSC-SA-NRFSA)

NRS was pleased to finalize and debut the new NRFSA Course in 2013. The new course was developed with contributions from several NASA centers including KSC, WFF, Goddard Space Flight Center (GSFC), and Dryden Flight Research Center (DFRC).

The NRFSA course is designed to give the student a fundamental understanding of NASA Range Flight Safety with its associated policies and guidelines, requirements, and analysis processes as applied to a wide variety of Agency vehicles. The course provides a broad understanding of Range Flight Safety considerations pertinent to NASA from the perspective of the NASA ranges.

While touching on FAA and DoD requirements, this course focuses on NASA requirements and highlights unique Range Safety processes used at several NASA ranges. It presents NASA, DoD, and FAA requirements for flight safety analysis and examines how these requirements interact. The course also includes a discussion of range operations hazards, risk criteria, and risk management processes and of the containment and risk management analyses. In addition to discussing ELV methods [also known as guided launch vehicles (GLVs)], the new NASA-centric FSA course covers methods used for unguided launch vehicles (ULV) (also called sounding rockets) as well as UASs, Reusable Launch Vehicles (RLVs), balloons, and other unique flight vehicles flown at NASA Centers. Figure 5 outlines the new NRFSA course structure.

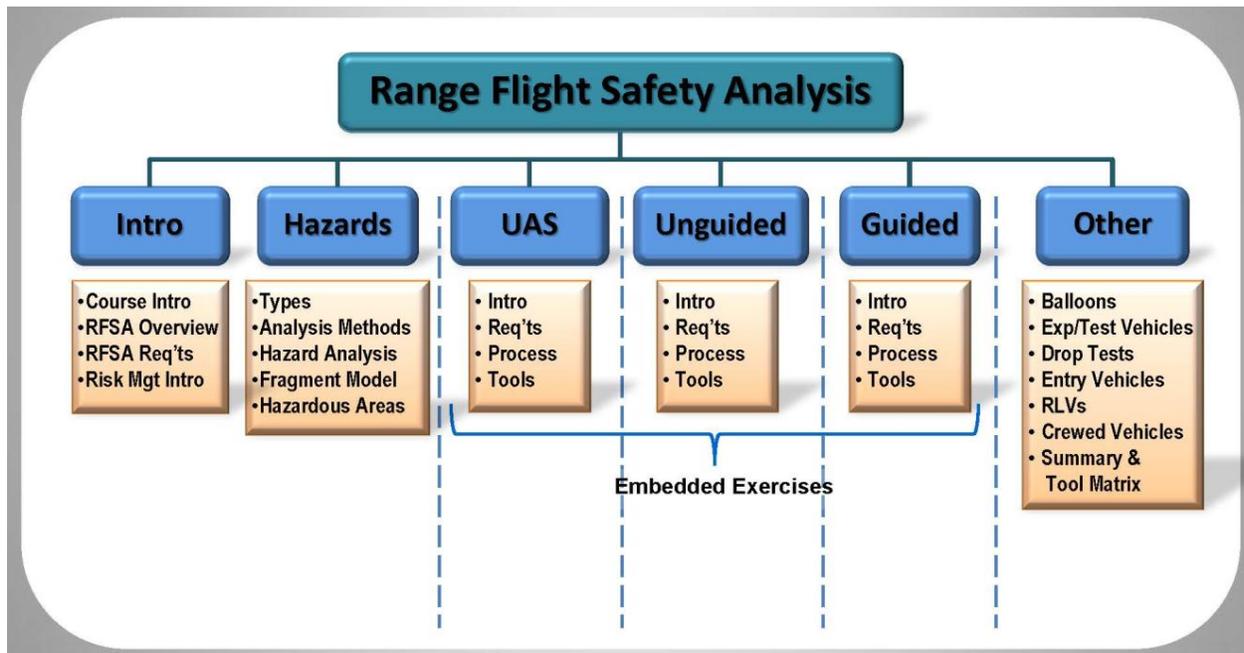


FIGURE 5: KSC NASA FSA COURSE OUTLINE

The NRFSA course contains a general overview of range flight safety issues, including the history and development of range safety practices in the United States, overarching NASA range safety requirements, and an introduction to risk management. The course concentrates on debris hazards and analyses but includes an overview of toxic, blast, and radiation, as well as analysis methods for examining each of these hazards. The course presents an overview of

hazard analysis methods and fragmentation model development with an emphasis on containment (deterministic) methods as a first line of defense and the use of risk assessment (probabilistic) in protecting against unavoidable hazards. Class demonstrations and exercises are used throughout the course (as shown in Figure 5) to present key aspects of FSA in a way that helps students absorb the information in a more practical manner.

The course was videotaped for incorporation into SATERN while it was presented at KSC during the week of March 25-29, 2013. The videotape will form the foundation of an online SATERN course. The online version of this course will be available to SATERN users before the end of 2Q FY14.

Prerequisite: Completion of NSTC Course 0074, Range Safety Orientation, or equivalent experience engineering degree and a familiarity with range safety.

Target Audience:

- NASA, FAA, and DoD Range Safety analysts in training
- Range Safety personnel in other disciplines
- Program/project managers and engineers who design potentially hazardous systems to operate on a NASA range
- Personnel who conduct hazardous operations on a NASA range

4. Range Flight Safety Systems (SMA-SAFE-NSTC-0096)

The Flight Safety Systems (FSS) Course describes FSS responsibilities and Flight Termination System (FTS) design, test, performance, implementation, analysis, and documentation requirements. The course also includes a review of UAS flight termination systems, balloon universal termination packages, and the Enhanced Flight Termination System (EFTS). The FSS class concludes with a description of the Autonomous Flight Safety System (AFSS) and a tour of the Naval Ordnance Test Unit (NOTU) facilities when the class is held at KSC.

The course was videotaped for incorporation into SATERN on August 21-22, 2012 at KSC. NRS reviewed the raw video files, aligned the video and course materials, and incorporated in-class exercises to prepare the course for online delivery via SATERN. The online version of this course was made available in May 2013. The course outline is provided below in Figure 6.

Range Flight Safety Systems

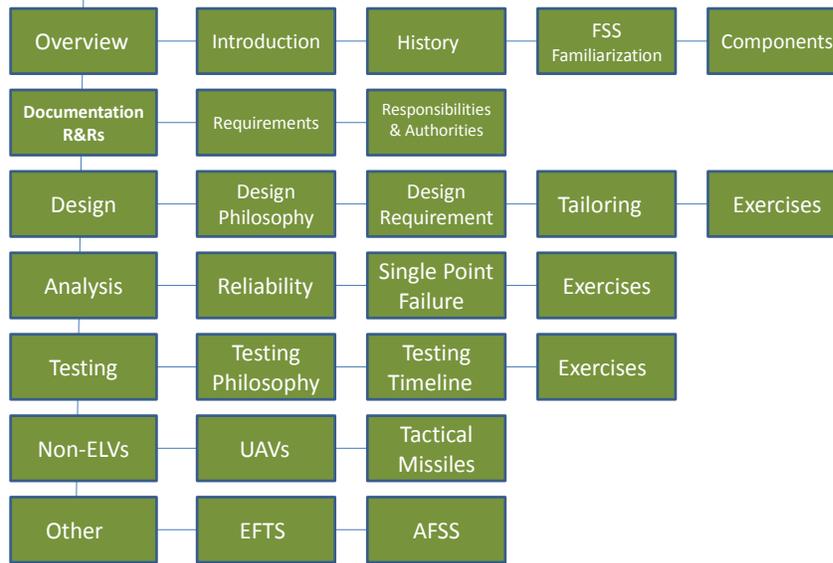


FIGURE 6: RANGE FLIGHT SAFETY SYSTEMS COURSE OUTLINE

Prerequisites:

1. Completion of NSTC 0074, "Range Safety Orientation," or equivalent level of experience or training, is required.
2. Completion of NSTC 002, "System Safety Fundamentals," or NSTC 008, "System Safety Workshop," is recommended.

Target Audience:

- NASA, FAA, and DoD 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

5. Range Safety Operations Course (SMA-SAFE-NSTC-0097)

To ensure mission success and safe operations for the Range, a formal process has evolved within the Range Safety community to provide range safety operations. This course addresses the roles and responsibilities of the Range Safety Officer (RSO) for range safety operations as well as real-time support, including pre-launch, launch, flight, re-entry, landing, and any associated mitigation. Mission rules, countdown activities, and display techniques are presented. Additionally, tracking, telemetry, and vehicle characteristics are covered in detail. Finally, post operations, lessons learned, and the use and importance of contingency plans are presented. Students will receive hands-on training and exercises to reinforce the instruction and will be provided with a WFF range tour of the instrumentation sites used to support a rocket

launch such as radars, telemetry and command systems to include fix and mobile assets. Figure 7 outlines the Range Safety Operations course structure.

Range Safety Operations

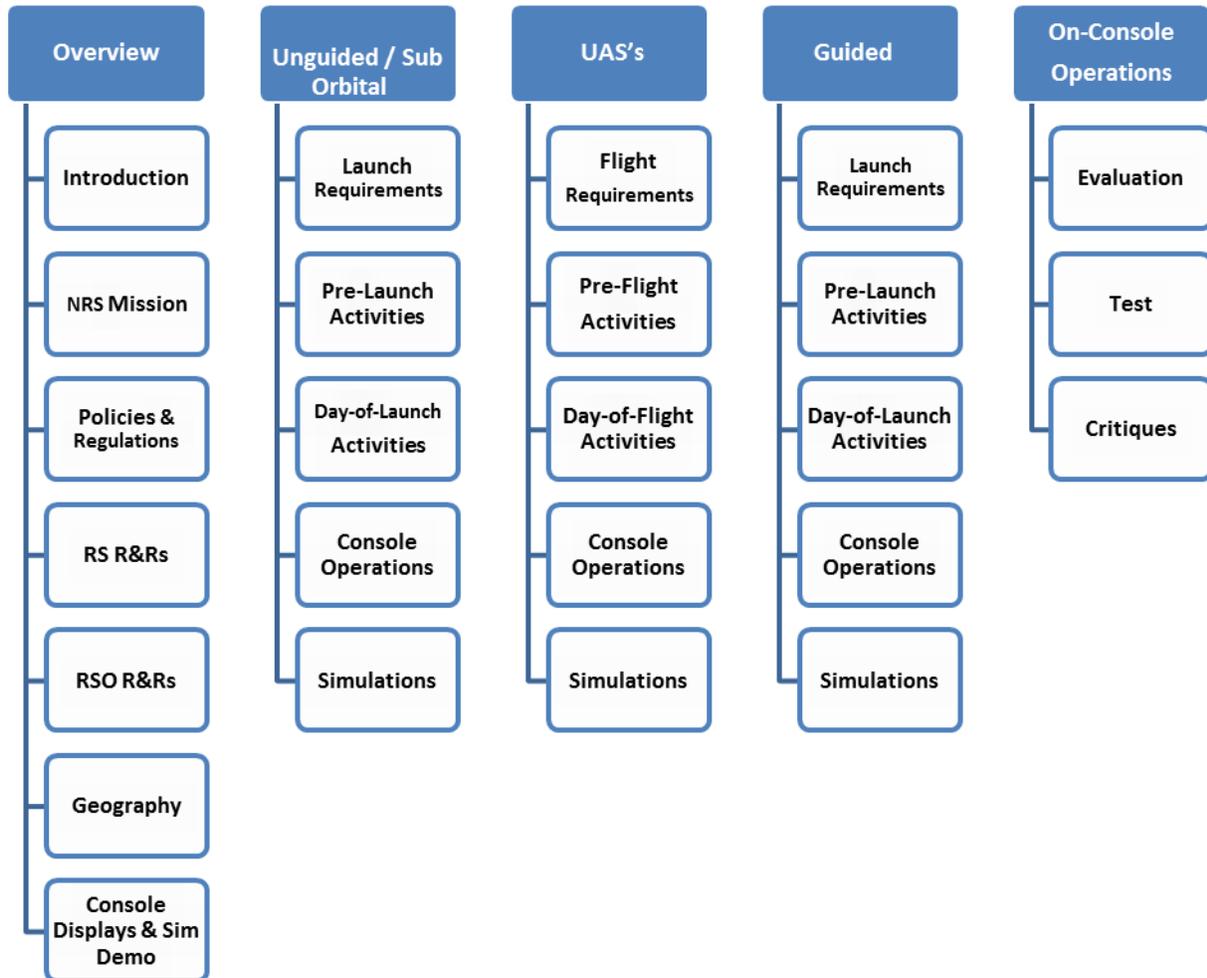


FIGURE 7: RANGE SAFETY OPERATIONS COURSE OUTLINE

This course is only presented at WFF and is limited to six participants. The course material was updated this year and taught July 29 through August 2, 2013. The six participants came from different NASA Centers: two each from KSC and WFF and one each from Stennis Space Center (SSC) and Langley Research Center (LaRC). The two-person instructor team was made up of a WFF RSO and the NASA Range Safety Manager. In the future, we hope to mentor another instructor to have additional flexibility in the teaching arena. The long term plan is to reduce cost and increase course availability with the goal of having WFF personnel instruct this course.

The NASA Range Safety Office will continue to review and control the course content to ensure its applicability across all Centers.

Prerequisites:

1. Completion of NSTC course 0074, "Range Safety Orientation," or equivalent experience and/or training, and a background in range safety.
2. Completion of NSTC course 0086, "Range Flight Safety Analysis," or equivalent experience and/or training.
3. Completion of NSTC course 0096, "Flight Safety Systems," or equivalent experience and/or training.

Target audience:

- Persons identified as needing initial training for future/current job as RSO with NASA or RSO management
- NASA, FAA, and DoD Range Safety Personnel working Range Safety Operational Systems issues

If you wish to attend any of the courses offered, please contact your Center training manager, or refer to the NSTC web site course catalog located at: <https://saturn.nasa.gov/elms/learner/catalog/>.

B. Development, Implementation, Support of Range Safety Policy

1. Range Commanders Council (RCC) Range Safety Group (RSG)

The Range Commanders Council (RCC) was founded in 1951 in order to provide a way for DoD test ranges to communicate and discuss common problems.

The RCC Range Safety Group (RSG) continues to provide a forum in which ranges can standardize, develop, and improve on a variety of subjects and processes related to range safety. NASA participates in this forum on a regular basis and became an official voting member in 2008. Range Safety representatives from NASA Headquarters (HQ), KSC, DFRC, SSC, and WFF actively support the RSG and its subcommittees on a regular basis. Vandenberg Air Force Base (VAFB) is currently the Flight Termination Systems Committee (FTSC) Chair with KSC acting as the Co-Chair. FAA Headquarters is currently the Risk Committee (RC) Chair, and NAVAIR Pt. Mugu is the Directed Energy Committee Chair. White Sands Missile Range (WSMR) became the RSG Chair in 2013.

One RSG meeting was held during 2013: the 112th Range Safety Group Technical Interchange Meeting (TIM). Due to federal budget constraints this year, the 112th RSG meeting was held via Defense Connect Online (DCO) and telecon. The meeting was spread over the afternoons of June 4-5, 2013. While this was a challenge and did not allow for the face to face interactions which normally benefit these proceedings, the 112th RSG Meeting remained a productive forum. The RSG Main Committee, FTSC, and RC met to discuss current issues and reviewed ongoing tasks.

a. Main Committee

In the main committee, range reports from each of the ranges participating in the RSG were presented to the group. NASA headquarters briefed the Main Committee on lifting device standards at test ranges. At the conclusion of the RSG, each committee briefed the Main Committee on accomplishments from the sub-committee meetings, and go-forward plans for future RSGs.

b. Flight Termination Systems (FTS) Committee

The current main task for the FTSC is the rewrite of RCC-319-12, Flight Termination Systems Commonality Standard. The FTSC reviewed various change comments the FAA, NASA, and DoD members for the new revision of RCC 319-12. The discussion mainly involved the change proposals for all sections of the RCC-319 document in an effort to reach a consensus as a committee. While discussions of various sections of RCC-319 were conducted during this meeting, the FTSC has asked the RCC for an extension on the due date for the rewrite of RCC 319-12.

Additionally, the FTSC discussed FTS component failures at the various ranges to identify crossover between ranges. Beneficial discussions took place between WFF, DFRC, WSMR, and the 30th Space Wing (30 SW) regarding component failure and component vendors. The FTSC continues to conduct weekly telecons to continue discussing comments and revising RCC 319-12.

c. Risk Committee (RC)

The agenda for the RC included the following presentations: "Status and Plan for Ship Protection Task," by Dr. Erik Larson; "Benchmark Flight Safety Analyses," by Dr. Paul Wilde; and "Significant Figures in Expected Casualty (EC) Results for Decision-makers," by Dr. Paul Wilde.

The Ship Protection task is just getting started. Its goals are to reduce conservatism, provide practical, logical framework for defining surveillance and Notice to Mariner (NTM) region, identify alternatives to manned aircraft surveillance, and define vulnerability models that match potential vessel hazard mechanisms. Funding has been established for this task, and an approach has been developed for creating the recommended changes.

The Benchmark Flight Safety Analyses task goals are to develop guidelines and provide data to compare model results to actual results and to facilitate comparisons between results computed by various models and actual data. This will aid the RCC in establishing the credibility of risk model predictions and provide a means to identify model uncertainty while establishing confidence in flight safety analysis results. Progress has been made using data from the [International Association for the Advancement of Space Safety](#) (IAASS) workshops which produced results on three cases: one upper-stage, one satellite random reentry, and one launch with European overflight. This effort is seeking more empirical data.

The presentation of Significant Figures in EC Results for Decision-makers tried to make a case for the FAA to use only one significant figure as the default for reporting EC results to a decision-maker. The presentation provided a background, discussion of epistemic uncertainties, and an example. There was some discussion of the applicability and the safety

impact of the proposal during the RC meeting, so RSG RC members will continue to review and discussed these issues into the next RSG meeting.

For more background and information on the Range Commanders Council and the Range Safety Group, [click here](#).

2. Common Standards Working Group (CSWG)

The Common Standard Working Group (CSWG) functions to implement provisions of U.S. Space Transportation Policy directing coordination between the USAF, FAA, and NASA to establish common public safety requirements for space transportation. NASA formally joined the CSWG in 2010, and a revised CSWG Charter was signed by all three agencies in 2012. The CSWG activities and products prescribed in the Charter are focused on protecting the public from hazards associated with space launch and reentry events. A primary objective is to develop, document, and maintain common safety standards that provide a stable framework for the U.S. space launch industry while minimizing implementation and administrative burdens. Each agency has designated a co-chair to the CSWG. The NASA Co-Chair is currently located within the WFF Range Safety Organization. The CSWG co-chairs met by phone periodically throughout 2013 and continued to establish and manage various CSWG sub-working groups as needed to implement the objectives of the CSWG Charter.

During the past year, the CSWG made significant progress on developing a consistent approach for determining the Probability of Failure (PoF) for new launch vehicles. This PoF is a critical input to safety risk assessments and other range safety analyses. The CSWG sub-working group developed new PoF guidelines and standards using a statistical approach and worldwide historical launch vehicle data. The FAA contracted for an independent peer review of the new approach. The draft standard underwent a final review by all three agencies at the end of 2013 and is expected to be published early in 2014.

C. Inter-Center Aircraft Operation Panel (IAOP)

NASA Range Safety supports NASA HQ assessments on a regular basis, including Institutional/Facility/Operational (IFO) audits and Inter-Center Aircraft Operations Panel (IAOP) reviews.

The IAOP provides peer review and objective management evaluation of the procedures and practices being used at the operating Centers to ensure safe and efficient accomplishment of assigned missions and goals. The review teams also identify deficiencies in, or deviations from, Agency-wide policies, procedures, and guidelines. The primary focus of the Agency Range Safety Program during IAOP reviews is on the application of range safety requirements and techniques to NASA operations involving UAS. The intersecting aviation safety and range safety requirements that apply to NASA UAS operations dictate the need for close coordination between the NASA aviation and range safety offices. To facilitate a coordinated review process, NASA Range Safety personnel participate in IAOP reviews at NASA Centers that conduct and/or host UAS operations. At this time those Centers include: Ames Research Center (ARC), DFRC, LaRC, and GSFC)/WFF. KSC, Johnson Space Center (JSC), and Marshall Space Flight Center (MSFC), are new players in this arena, and SSC has also expressed interested in flying or hosting such operations. Range Safety findings during IAOP reviews and associated Center corrective actions are documented and tracked using IAOP systems and processes established by the NASA aviation office.

NASA Range Safety participated in two IAOP reviews, one at DFRC in February and another at KSC in May 2013.

During the DFRC review, it was noted that noncompliance documentation had not been updated to capture recent revisions in NPR 8715.5. A template was provided to DFRC to help develop a standalone form for Range Safety noncompliances. In addition, it was noted that a recurring training plan for key Range Safety personnel had to be developed, and a Risk Assessment process needed to be documented for small UASs. Lastly, one of the Range Safety Analysts was commended for her role in helping to develop the UAS module of a new Agency course covering Flight Safety Analysis.

During the KSC review, it was noted that the risk assessment process only captured spaceflight activities and needed to be updated to include UAS activities. In addition, it was noted that the noncompliance process also needed to include UAS activities. Lastly, it was recommended to add Range Safety personnel to handle increased UAS activities.

Range operations other than UAS operations are subject to IFO audits led by the NASA Safety Center (NSC) and also supported by NASA Range Safety. Such operations include space launch/entry, scientific balloon, and sounding rocket operations. At this time, those centers with such range operations include KSC and GSFC/WFF. Range Safety findings during IFO audits and associated center corrective actions are documented and tracked using IFO systems and processes established by the NSC. No IFO audits were supported in 2013.

III. PROGRAM/PROJECT SUPPORT

A. Commercial Crew Program (CCP), Multi-Purpose Crew Vehicle (MPCV), Ground Systems Development and Operations (GSDO)

The Commercial Crew Program (CCP) is an innovative partnership to help the aerospace industry in the United States develop space transportation systems that can safely launch astronauts to the International Space Station (ISS) and other low-Earth orbit (LEO) destinations. The CCP partners are currently Boeing, Sierra Nevada Corporation, and SpaceX.

The Orion MPCV (Multi-Purpose Crew Vehicle) is based on the Orion design requirements for traveling beyond LEO. Orion will serve as the exploration vehicle that will carry the crew to space, provide emergency abort capability, sustain the crew during the space travel, and provide safe reentry from deep space return velocities. The spacecraft will launch unmanned on top of a Delta IV launch vehicle currently planned for 2014 from CCAFS. The mission has been designated as Exploration Flight Test-1 (EFT-1).

The Ground Systems Development and Operations (GSDO) program is a KSC program established to develop and use the complex equipment required to safely handle rockets and spacecraft during assembly, transportation, and launch. GSDO will help prepare KSC to process and launch the next generation of rockets and spacecraft in support of NASA's exploration objectives by developing the necessary ground systems, infrastructure, and operational approaches.

NRS has been actively supporting each of these programs throughout the year, and will continue to do so in a timely and professional manner. For more information on these programs, the KSC Range Safety Representative and/or NASA Range Safety Manager will fill you in on their current contributions to those efforts.

B. Tri-Program Tailoring

NRS supported the Range Safety tailoring group effort for NASA's Tri-Programs [Space Launch Services (SLS), GSDO, and Orion programs]. The group consisted of representatives from MSFC, KSC, JSC, USAF 45th Space Wing (45 SW), and various private contractors. These groups met to tailor multiple volumes of Air Force Space Command Manual (AFSPCMAN) 91-710 and NASA Procedural Requirements (NPR) 8715.5A. The following AFSPCMAN volumes were tailored: Volume 1, Range Safety Policies and Procedures; Volume 4, Airborne Flight Safety System Design; and Volume 8, Airborne tracking System Design, Test, and Documentation Requirements. Corresponding requirements from NPR 8715.5A were folded into the applicable volumes to make a joint tailored document. This tailoring effort was done in support of the working groups for the Human Exploration Range Safety Panel (HERSP).

NRS supported the Volume 1 tailoring effort by participating in several telecons and face-to-face meetings between JSC and KSC to help establish the roles and responsibilities of NASA and the USAF in support of the Tri-Programs. Tailoring efforts are still in work.

NRS support of the Volume 4 tailoring effort took place with the groups' visits to KSC, along with multiple telecons throughout the year. The 45th SW requested separate presentations from NASA and contractor teams to further explain the teams rationale for tailoring requests concerning certain requirements. The items that were being discussed during these sessions

consisted of battery requirements for the SLS core stage, ordnance pyro delay, preflight testing requirement, booster Linear Shape Charge severance margin, core FTS configuration, system independence, stray current monitoring, and 72 hour end-to-end testing. Tailoring efforts are still in work.

Support for Volume 8 tailoring efforts also took place over various face-to-face meetings and telecoms. The tailoring group reviewed and discussed the requirement matrix of Airborne Tracking Systems provided by the 45th SW to determine applicable requirements and thresholds. The group completed the tailoring efforts for Volume 8 in August 2013.

IV. EMERGING TECHNOLOGY

The Autonomous Flight Safety System (AFSS) is a joint project with GSFC/WFF and KSC. The AFSS is an independent and autonomous onboard flight termination subsystem intended for expendable launch vehicles. It replaces the traditional ground-based human-in-the-loop system and uses tracking and attitude data from onboard sensors and configurable rule-based algorithms to make flight termination decisions. The ultimate objectives of the AFSS are to increase capabilities by allowing launches from locations without range safety infrastructure, to reduce costs by eliminating some downrange tracking and communication assets, and to reduce the reaction time for flight termination decisions.

A. Defense Advanced Research Project Agency (DARPA)

The NASA AFSS team worked with Northrop Grumman on their Safety and Mission Planning for Air Launch (SAMPAL) project for DARPA Airborne Launch Assist Space Access (ALASA) program that is designed to produce a rocket capable of launching a 100-pound satellite into low Earth orbit for less than \$1 million on short notice. The Joint Advanced Range Safety System (JARSS) and AFSS are tightly integrated into SAMPAL. JARSS automatically generates the AFSS flight safety rules and the configuration file. The rules are tested as the mission is planned. The AFSS algorithms verify the final mission data load and perform mission analysis. Additional simulations validated the AFSS algorithms. The NASA team also provided advice on various hardware designs and implementation.

B. Updated Software

The NASA AFSS team is working closely with the 30th Space Wing to modify the original NASA AFSS safety software so it is compliant with the Motor Industry Software Reliability Association (MISRA) standard. This effort is also supported by the 45th Space Wing, DARPA ALASA, and Millennium Engineering and Integration Company (MEI). This updated software is known as the Operational Responsive Space (ORS) Fork because the modifications began as part of an ORS project. This software will undergo additional testing with the goal of providing improved AFSS safety software for government and private users.

The goals are to provide the following by September 2014.

- MISRA-compliant AFSS safety software
- Automated unit testing code
- System level testing using representative launches with documented failure scenarios
- Demonstration that this code will compile and run on a typical embedded processor

C. Flight Analyst Workstation

The Flight Analyst Workstation is an integrated flight analyst software suite using the NASA AFSS code and the JARSS environment to make the AFSS mission rules configuration files and visualize the trajectory, boundaries and AFSS decisions; all running on a single PC. The target user is the flight analyst preparing for a launch using AFSS to be able to visualize and verify the AFSS rules and performance. A screen capture of the workstation is available in Figure 8. The blue circle in the center right shows a destruct limit violation. The red lights in the left panels indicate a destruct condition.

The safety rules file can be made using the configuration file maker developed in 2012. MEI is the primary contractor and the project is supported by WFF and the 45 SW and 30 SW. Funding is provided by NASA KSC GSDO and the DARPA ALASA project. The alpha-version was delivered in September 2013. A beta version with many more features for post-test analysis, data logging, and sensor emulation will be delivered by the end of FY14. The long range plan is to migrate to the ORS Fork software when it is available.

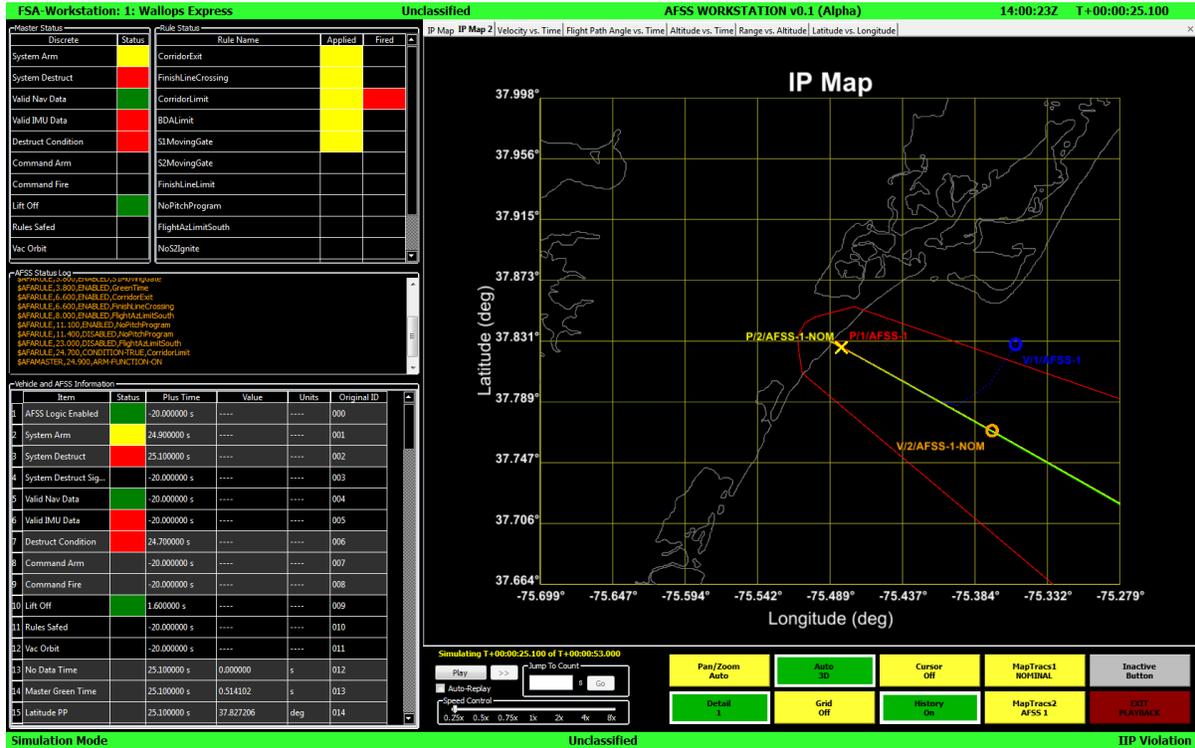


FIGURE 8: FLIGHT ANALYST WORKSTATION SCREEN CAPTURE

V. STATUS REPORTS

A. Ames Research Center (ARC)

1. Dragon Eye

Dragon Eye flights took place at Fort Hunter Liggett, CA (January 28-29, 2013) and Turrialba Volcano, Costa Rica (March 10-15, 2013).

The Dragon Eye (Figure 9) is a 6-pound UAS with a 3.75-foot wingspan. It flies fully autonomously and performs surveillance missions using miniature electro optical/infrared (EO/IR) cameras in the nose section. It is hand or bungee launched and performs belly landings, giving it the ability to be operated from unimproved sites. ARC acquired 70 of these systems and modified several of the noses to carry sensors to measure the constituents in volcanic plumes.



FIGURE 9: DRAGON EYE

Initial flight testing was performed in restricted airspace at Fort Hunter Liggett, CA to allow the team to gain experience with the system in a safe airspace environment. These UASs are cheap and expendable, but some of them demonstrated erratic flight behavior, and many crashed. A number of good flying airframes were identified, and these were used to perform the mission to sample the plume of the Turrialba Volcano in Costa Rica. Range safety was easily achieved given the remoteness of the location, and the Costa Rican Civil Aviation Authority provided a streamlined approval process.

2. Vision II

Vision II flew a mission to Key West, FL (May 9-18, 2013).

The Vision II (Figure 10) is a 130-pound UAS with a rotor diameter of 10.5 feet. It is powered by a 14 horsepower turbo shaft turbine engine running Jet-A fuel. The aircraft was configured to carry a high resolution hyper-spectral camera to take images of sea grass near Sugarloaf, FL and coral near Cheeca Rocks, FL.



FIGURE 10: VISION II

During the mission, Vision II took off from shore and flew out over the ocean to the research sites with the Pilot in Control (PIC) and RSO chasing it in a boat. The slow speed capability of the Vision II made this approach to range safety practical. Imaging passes were repeated at altitudes ranging from 50 to 250 feet before returning to the shore to land and refuel.

B. Dryden Flight Research Center (DFRC)

Located at Edwards Air Force Base, California, DFRC is NASA's primary installation for flight research and flight testing. Projects at Dryden over the past 67 years have led to major advancements in the design and capabilities of many civilian and military aircraft. In the past, DFRC has also conducted tests in support of the Agency's space programs.

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

Range Safety at Dryden was established by the Dryden Center Director under an alliance agreement with the Air Force Test Center (AFTC) to provide independent review and oversight of Range Safety issues. Range Safety supports the Center by providing trained FTS engineers, Range Safety risk analysts, and Range Safety Officers to provide mission and project support primarily for UAS Projects.

1. Enhanced Flight Termination System

The DFRC/AFTC Range Safety Alliance has an operational EFTS transmitter site. The EFTS transmitter site has successfully been used to support four UAS Projects. Modifications are being planned to address the needs of upcoming flight Projects. Dryden also continues to support flight Projects with Inter-Range Instrumentation Group (IRIG) Flight Termination systems.

Dryden has supported other Ranges by assisting in the verification process for their respective fixed EFTS transmitter sites.

2. DFRC/AFTC Range Safety Alliance

Dryden Range Safety continues to provide FTS support to AFTC. Dryden is also providing assistance to the AFTC Range Safety Office as it completes a major reorganization.

Dryden Range Safety continues to support the testing of UASs. The UASs that were flown with Dryden assistance include:

a. Small UASs

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

Dryden currently operates two radio controlled model aircraft named Dryden Remotely Operated Integrated Drone (DROID). One of the vehicles is used for low-cost flight research while the other is used as a UAS trainer for Dryden's UAS Pilots.

b. Blended Wing Body Low Speed Vehicle

The Blended Wing Body (BWB) Low Speed Vehicle (LSV) UAS, also known as X-48 LSV, is a dynamically scaled version of the original concept vehicle. The X-48 LSV Project is a partnership between NASA, Boeing, USAF Research Laboratory, and Cranfield Aerospace. The primary goals of the test and research project are to study the flight and handling



FIGURE 11: BLENDED WING BODY LOW SPEED VEHICLE

characteristics of the BWB design, match the vehicle's performance with engineering predictions based on computer and wind tunnel studies, develop and evaluate digital flight control algorithms, and assess the integration of the propulsion system to the airframe. The BWB testing will address several key goals of NASA's Environmentally Responsible Aviation (ERA) Project, namely noise reduction, emissions reduction, and improvement in fuel economy. Industry studies suggest that because of its efficient configuration, the BWB 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 92 successful flights in the X-48B configuration and 30 successful flights in the X-48C configuration, all with LSV #2. LSV #2 achieved the 100th flight milestone in October 2012. On April 09, 2013, the X-48 LSV airframe flew its last flight, ending the 6-year flight test project.

c. NASA Global Hawk

Dryden has acquired two former USAF Advanced Concept Technology Demonstration (ACTD) Global Hawk UASs. These pre-production Global Hawks were built by Northrop Grumman for the purpose of carrying reconnaissance payloads. The vehicles are now supporting NASA's Science Mission Directorate by providing a high altitude, long endurance airborne science platform. The vehicle has an 11,000 nautical mile range and 30+ hour endurance at altitudes above 60,000 feet mean sea level (MSL). NASA Global Hawk supported two Earth Science

campaigns during 2013, each of which was a month in duration. During the first campaign, NASA 872 successfully supported the Airborne Tropical Tropopause Experiment (ATTREX 2013) that flew over the Pacific Ocean in February. NASA 872 logged 152 flight hours in support of the ATTREX campaign. Both NASA Global Hawks supported the successful second Earth science campaign of the year, the Hurricane and Severe Storm Sentinel (HS3 2013), based out of Wallops Flight Facility and flown over the Atlantic Ocean. During HS3 campaign, the vehicles collectively logged a total of 282 flight hours during the month of September.



FIGURE 12: NASA GLOBAL HAWK

NASA Global Hawk is scheduled to support ATTREX 2014 by conducting Earth Science flights over the Pacific Ocean in the early part of next year. The vehicle will be basing out of Guam.

Dryden Range Safety has supported flight planning and risk analysis tasks in support of FAA Certificate of Authorization (COA) applications.

d. Ikhana

NASA's Ikhana UAS is a General Atomics Predator-B modified to support the conduct of Earth science missions for the Science Mission Directorate. Ikhana has been registered with the FAA and given the tail number N870NA. The vehicle and ground control station have undergone upgrades that standardizes the vehicle to match the rest of the Predator-B fleet. The project has taken delivery of a science payload pod in addition to purchasing a mobile ground control station. The mobile ground control station is expected to be operational early next year. Ikhana also features a turret mounted imaging system, ideal for range surveillance.



FIGURE 13: NASA'S IKHANA UAS

This year, Ikhana successfully completed a series of customer sponsored payload flights. The project has also signed an agreement to partner with a commercial customer to flight test and demonstrate the TAMDAR (Tropospheric Airborne Meteorological Data Reporting) monitoring system. The system enhances aviation safety by providing icing and turbulence data, in addition to other meteorological data. Flights are scheduled to begin early next year.

Dryden Range Safety has supported flight planning and risk analysis tasks in support of FAA Certificate of Authorization (COA) applications.

e. Boeing Phantom Eye

Phantom Eye is an autonomous, hydrogen-powered, high-altitude, long endurance vehicle built by Boeing to develop future UAS technology opportunities. The vehicle completed its first flight in June 2012. Phantom Eye has flown four successful flights this year and a total of five successful flights to date. The objective for the upcoming flights is to reach a cruising altitude of 65,000 feet MSL.



FIGURE 14: BOEING PHANTOM EYE

f. Sierra Nevada Corporation (SNC) Dream Chaser Engineering Test Article (ETA)

Sierra Nevada Corporation (SNC) Dream Chaser Engineering Test Article (ETA) is an unmanned, unpowered, full scale prototype designed to demonstrate and flight validate space transportation technologies developed for a reusable crew transport. The ETA was built as a semi-autonomous, unmanned pathfinder for the manned Dream Chaser Flight Test Article. Dream Chaser is one of the vehicles competing in NASA's Commercial Crew Development Program. The vehicle is based on the NASA HL-20 lifting body design. Dream Chaser ETA successfully flew for the first time on October 26, 2013.

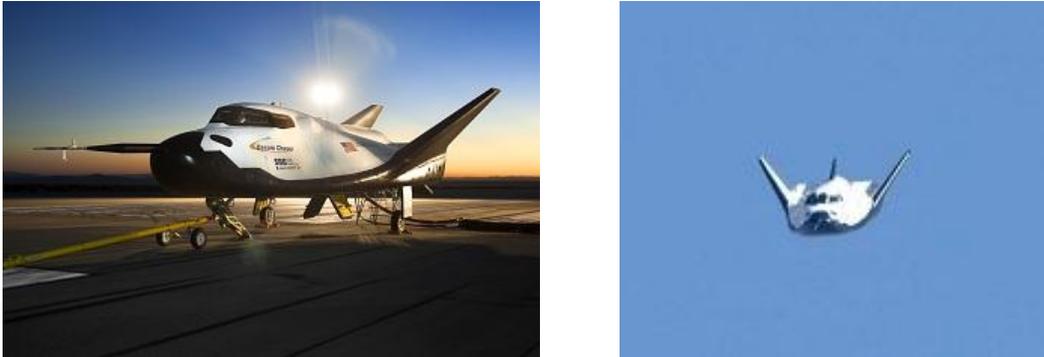


FIGURE 15: DREAM CHASER

g. Lockheed Martin X-56A

The X-56A is low speed, subscale vehicle designed to test lightweight flexible wing/fuselage technologies. First flight occurred in July 2013. X-56A has flown a total of eight successful flights this year, which completed the baseline, stiff wing flights. Flexible wing flights are scheduled to begin early next year.



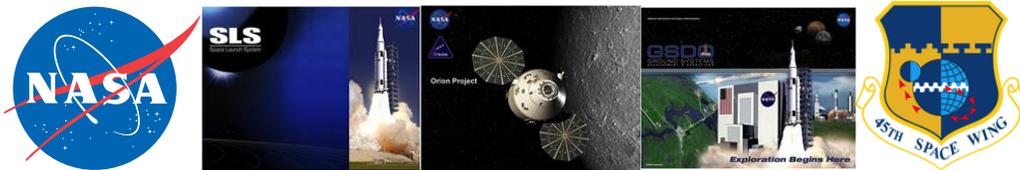
FIGURE 16: LOCKHEED MARTIN X-56A

C. Johnson Space Center (JSC)

1. Human Exploration Range Safety Panel (HERSP)

The Human Exploration Range Safety Panel (HERSP) continued to manage range safety activities for SLS, MPCV/Orion, and GSDO Programs within the Human Exploration and Operations Mission Directorate. Co-chaired by NASA and the USAF 45 SW and with strong representation across all three NASA programs, the JSC Astronaut Office, Safety and Mission Assurance, NASA Range Safety, and Air Force Range Safety, the HERSP works technical issues through its three associated working groups: Flight Analysis, Flight Safety System, and Range Ground Operations.

Building upon the Program Introduction for Orion/SLS Exploration Missions (EM) that was presented to the USAF 45 SW in 2012, the HERSP continued its efforts towards tailoring requirements and planning public safety analyses for these flights. The requirements tailoring spans eight volumes, ultimately resulting in agreements between NASA and the USAF regarding policies and procedures, roles and responsibilities, and design/test plans across several aspects of ground operations, the SLS Flight Safety System, and SLS/MPCV trajectory design.



2. MPCV Exploration Flight Test 1 (EFT-1)

JSC continued to provide range safety expertise to the broader EFT-1 team, supporting safety meetings and reviewing analysis products, as focus has shifted towards operations for the upcoming flight test. In addition, JSC personnel continued to collaborate with the FAA to facilitate steps in the commercial licensing process and develop a better understanding of the unique licensing aspects of this flight.



FIGURE 17: PREPARATION FOR MPCV EXPLORATION FLIGHT TEST 1

3. Exploration Missions (EM) EM-1 and EM-2

In 2013, JSC began focusing considerable attention on the upcoming Exploration Missions. With crew scheduled to be flown on EM-2, several key crew safety issues have been considered. For instance, the Aborts and Range Safety communities worked together to begin assessments on FTS Delay. Ultimately, the objective of this effort is to ensure public safety while providing sufficient time for the crew to escape the vehicle if a scenario requiring flight termination presents itself. The community also began discussing other key operational issues that will need to be addressed as flight controllers in Mission Control work with their USAF Mission Flight Control Officer (MFCO) counterparts during future crewed missions.



FIGURE 18: MISSION CONTROL ROOM

4. Multi-Purpose Crew Vehicle (MPCV) Ascent Abort 2 (AA-2) Flight Test

The MPCV Flight Test Management Office has identified range safety as a discipline of focus for advancing Ascent Abort 2 (AA-2). Planning and preparation for the upcoming requirements tailoring and trajectory evaluations was a significant focus in 2013. The range flight safety analysis completed for this flight test will be extremely valuable in defining analysis expectations and methodologies that will be employed for future MPCV analyses for EM missions.



FIGURE 19: AA-2 ABORT TEST BOOSTER AND MPCV LAUNCH ABORT VEHICLE

5. Commercial Crew Program (CCP)

The range safety approach for CCP will be different from the traditional NASA programs such as the Space Shuttle. The plan is for range safety to be handled in two phases. During the

development and testing phase, the missions will be flown as NASA missions with a good deal of involvement by NASA. Once CCP transitions into the services phase, the missions will be executed under FAA licenses, and NASA's role will be to maintain insight of the range safety activities.

Given that CCP plans to launch under FAA license, and since these will be the first FAA-licensed launch to include astronauts on the vehicle, NASA has been working very closely with the FAA on a wide range of topics of mutual interest to ensure the success of CCP. Many of these topics are also of interest to the USAF, and the three agencies are in the initial stages of standing up a tri-agency steering group called the Launch and Entry Steering Group (LESG) chaired jointly by the FAA, USAF, and NASA. This group will provide a forum for the three agencies to establish consistent policies regarding range safety, crew safety, and public safety for CCP. The LESG charter is currently being circulated among the agencies for comment and approval with a goal of having the first meeting in 2014.

6. Morpheus Activities at JSC

After last year's failed free flight of the Morpheus 1.5 Vertical Test Bed, the engineers at JSC built a version 1.5B of the vehicle. The new vehicle incorporated a number of upgrades including improved cabling standards and a better isolated navigation sensor platform. Morpheus 1.5B successfully conducted 5 hot fire tests including 3 that were over the newly built flame trench, and 13 tether tests that included engine performance, software mode, backup Inertial Measurement Unit (IMU), Autonomous Landing and Hazard Avoidance Technology (ALHAT), and lateral motion testing. On November 7, 2013, the team conducted a tethered ground take-off and landing test using a specially rigged crane. Total engine burn time during these tests was ~712 seconds.

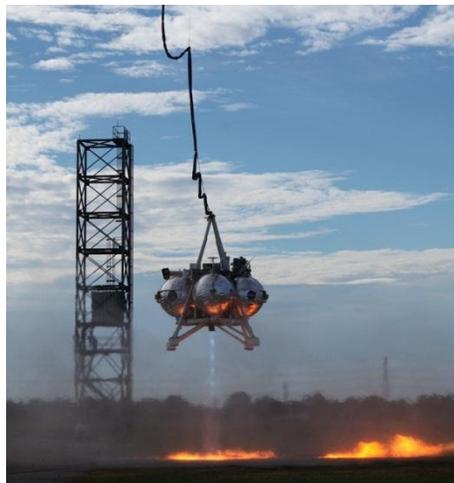


FIGURE 20: MORPHEUS TEST FLIGHT

Videos of Morpheus test flights at KSC are available [here](#) and [here](#).

D. Kennedy Space Center (KSC)

In addition to hosting the NASA Range Safety Staff, KSC has its own Center Range Safety Representative. The KSC Range Safety Representative is tasked with implementing NASA policy and keeping the NASA Range Safety Manager informed of all KSC activities related to

range safety. Over the course of the past year, KSC Range Safety supported a multitude of range safety activities including design and range safety requirement tailoring support to new projects and programs and support to ELV launch operations at multiple locations. The following articles provide a brief summary of these activities.

1. Rocket University

Rocket University (Rocket U) develops flight-systems engineering skills and expertise by exposing NASA engineers to coursework and hands-on activities involving many aspects of flight systems engineering. Rocket University has partnered with different NASA Centers, several universities, and external partners to provide mentoring and expertise to the program.

NRS ensures the Rocket U program meets the range safety requirements of NPR 8715.5A, FAA 14 CFR Part 101, Memorandum of Agreement (MOA) KCA-4397, and AFSPCMAN 91-710 when operating balloons, UASs, and rockets on or off KSC property.

a. Unmanned Aerial System (UAS) Program

Rocket U's UAS program develops UAS skills by conducting flight operations with a 12-pound winged UAS, named Genesis, in a section of the restricted airspace on KSC property. These tests include three major flight modes:

- Phase A: Operate Aircraft in Remote Control mode only; loss of communication verification; UAS launcher tests complete.
- Phase B: Semi-autonomous operations in which the aircraft remains within visual range; demonstrate successful transition from manual to autopilot and perform autopilot tuning...
- Phase C: Fully autonomous operation in which the aircraft will demonstrate waypoint navigation and the imaging of objects of interest (e.g., wildlife) in the flight operations area.

Working with NRS, the Rocket U team was able to accomplish Phase A and B. The NRS team helped define the programs flight test plan, flight test envelope, and review operational documents. NRS provided approval for flight along with the KSC Flight Operations team to certify the Genesis UAS to fly over KSC property. The NRS team provided support and guidance to the UAS team by reviewing presentations and operational plans to fly their UAS at KSC. The RSO function during UAS flights was performed by the qualified KSC UAS Pilot with support from NRS. NRS supported the three successful flights of their Genesis UAS from a camera site North of Pad 39B.

b. Balloon Program

In 2013, NRS supported four Rocket U Near-Space Environments Balloon operations. The role of the NRS team in supporting the balloon program is to review and independently validate the program's flight trajectory analysis. The NRS team also reviews vehicle design and mission parameters to ensure mission objectives can be accomplished without increasing the risk to the KSC workforce and the general public. During the review process, NRS ensures regulations and requirements from the USAF, 45 SW, the FAA, and NASA Range Safety are met.



FIGURE 21: ROCKET U NEAR-SPACE ENVIRONMENTS BALLOON

The four small-scale balloon releases between April and June 2013 that NRS supported were geared to supporting the Maraia balloon release taking place in New Mexico in August 2013. The Rocket U team's objective was to release a small scale version of the Maraia capsule to record aerodynamic effects of the capsule falling through the atmosphere. NRS worked with the balloon program to verify and redesign the release mechanism which had failed in previous missions.

c. Rocketry Program

Rocket U's Rocketry Program builds a broader understanding of flight systems engineering and development by designing, building, analyzing, testing, and flying High Powered Rockets. This year NRS has supported four (update with new launches as they happen) launches from KSC. KSC must comply with the MOA KCA-4397 between NASA and the 45 SW which allows NRS the responsibility of ensuring public, workforce, and property safety on KSC during these launches if the launches are contained within KSC's boundaries. The NRS group reviews and comments on each team's Concept of Operations (ConOps), launch procedures, flight safety Hazard Analysis (HA), launch and landing area predictions, failure mode analysis, and launch trajectory models. Each team must complete all documentation before getting permission to launch.

NRS physically supports each launch campaign with a GO/NO-GO" call to the Rocket U Chief Engineer prior to each launch attempt. The NRS team works with each team to calculate and verify landing predictions



FIGURE 22: ROCKET U ROCKETRY PROGRAM LAUNCH FROM KSC

based on launcher elevation angle launch azimuth, wind speed, and wind direction. NRS does this to ensure maximum probability of the rocket landing in an unpopulated area away from the launch team, spectators, or facilities in the area. NRS also developed an Amateur High Power Rocket checklist for future Rocket U teams along with outside business wanting to use KSC for testing their amateur rockets.

The NRS team supported four launch attempts for a one-stage amateur rocket with a “K” motor and the team also supported one launch attempt for an amateur two-stage rocket using “G” motors.

2. Unmanned Aerial System (UAS) Competition



FIGURE 23: KSC TEAM LAUNCHING GENESIS UAS

team was tasked to gain an airworthiness certification for their vehicle from their respective centers.

NRS worked with Rocket University’s UAS program, the KSC Aviation Working Group (KAWG), and KSC Flight Operations to review and approve the various competitors’ UAS submissions prior to any team flying at the SLF. NRS attended the Flight Readiness Reviews (FRR) for the MSFC, JSC, and KSC teams as they presented their UAS’s respective capabilities and functionalities to the judges. Some of NRS’s responsibilities were to work with the various UAS centers ensuring KSC’s concerns were being addressed during airworthiness approval processes at different NASA centers. NRS also worked to ensure containment steps were addressed by each team. NRS also ensured proper mitigation steps were in place in the event of an UAS anomaly ensuring KSC personnel and property would remain undamaged. The RSO function during all UAS flights at KSC was performed by the qualified KSC UAS Pilot with support from NRS.

NASA’s inaugural AS competition was held at KSC from September 10-12, 2013. Flight operations took place at KSC’s Shuttle Landing Facility (SLF) on September 11, 2013. Teams from KSC, MSFC, and JSC provided their own UASs for the competition, while personnel from DFRC, LaRC, and ARC supported as judges for the competition. The purpose of this competition was to have various NASA centers design or modify a UAS to operate in autonomous mode while performing search patterns over a mock crash site to identify wreckage and survivors. Each



FIGURE 24: JSC TEAM FLYING HELICOPTER UAS AT THE SLF



FIGURE 25: MSFC TEAM MEMBER WITH HEXACOPTER UAS AT THE SLF

3. Morpheus Operations

JSC brought their Morpheus lander vehicle back to KSC in late November 2013 for flight test operations and to demonstrate the capability of the ALHAT instrument. KSC constructed a hazard field at the end of the SLF runway to help simulate a lunar landing environment for Morpheus operations. JSC developed a Morpheus Range Safety Plan for flight operations at KSC which covered everything from vehicle description to flight ops to Contingency Management System (CMS) functions. This document was coordinated with the KSC Range Safety Representative and concurred on by the NASA Range Safety Manager. It was also approved by the KSC Center Director and the Morpheus Project Manager. The RSO function for operations at KSC was performed by JSC personnel due to their familiarity with the Morpheus vehicle and training with Morpheus tethered test operations at JSC. The RSO worked with the KSC Range Safety Representative to establish boundaries and conditions for CMS activation.

Operations began with a successful tethered flight to verify all systems were functional after transport from JSC. This was followed by a short free flight test to 15 meters in altitude. This test was the first test from the newly constructed transportable concrete launch pad with the integrated flame trench. This was constructed to help reduce liftoff environments which were determined to be a cause of the test failure for the Morpheus vehicle at KSC in 2012. Then, one additional free flight was conducted which expanded the altitude to 50 meters and the distance travelled to 47 meters. This concluded the first flight campaign at KSC. JSC plans to conduct additional flight campaigns at KSC during early 2014.



FIGURE 26: MORPHEUS 1.5B TETHERED FLIGHT AT KSC



FIGURE 27: MORPHEUS 1.5B FREE FLIGHT TEST AT KSC

4. KSC Aviation Working Group (KAWG)

The KAWG met several times during 2013 to discuss several new projects with proposals to conduct flight operations at KSC and to discuss the KSC airworthiness process. There was a KSC project reviewed by the KAWG for quad-copter and hexacopter operations at KSC. This proposal was allowed to move forward and eventually received KSC airworthiness board approval. Also, there was a project for the BBC to do some documentary filming over KSC in an airship. This operation was allowed to move forward as well. KSC Range Safety participated in these meetings and gave concurrence for these operations to concur.

5. Launch Operations Support

NASA/KSC Range Safety supported 13 launches this year. There were eleven launches from the Eastern Range (two NASA-sponsored expendable launch vehicle and nine non-NASA launches supported for KSC risk assessment). The remaining launches were NASA-sponsored expendable launch vehicles from the Western Range at VAFB.

In order to ensure the requirements of NPR 8715.5 are met during pre-launch, launch, and post launch operations, NRS personnel worked side-by-side with our Department of Defense counterparts in the Murrell Operations Center (MOC) at CCAFS and in the Western Range Operations Control Center (WROCC) at VAFB for the NASA sponsored launches. NRS personnel ensured any range safety-related activities that could have an impact on NASA launch criteria were communicated to the NASA Safety and Launch Service Program decision makers to ensure safe flight and compliance with requirements identified in NASA Range Safety directives.

Eastern Range and Western Range				
Mission	Vehicle	Launch Site	Launch Date	Responsible Org
TDRS-K	Atlas V	CCAFS	1/30/13	NASA
LDCM	Atlas V	VAFB	2/11/13	NASA
CRS-2	Falcon 9	CCAFS	3/1/13	Commercial
SBIRS-GEO2	Atlas V	CCAFS	3/19/13	DoD
GPS IIF-4	Atlas V	CCAFS	5/15/13	DoD
WGS-5	Delta IV	CCAFS	5/24/13	DoD
IRIS	Pegasus XL	VAFB	6/27/13	NASA
MUOS-2	Atlas V	CCAFS	7/19/13	DoD
WGS-6	Delta IV	CCAFS	8/7/13	DoD
AEHF-3	Atlas V	CCAFS	9/18/13	DoD
MAVEN	Atlas V	CCAFS	11/18/13	NASA
SES-8	Falcon 9	CCAFS	12/3/13	Commercial
THIACOM	Falcon 9	CCAFS	12/30/13	Commercial

FIGURE 28: EASTERN AND WESTERN RANGE SUPPORTED BY KSC IN 2013

We look forward to 2014 and supporting the numerous ELV launches at both the Eastern and Western Ranges.

6. Range Safety Launch Support Policy

a. KSC Flight Risk Assessment Process

In response to an IAOP by NASA Headquarters, KSC Range Safety updated the KSC Space Flight Risk Assessment Process. This process specifically covered NASA sponsored Space flight launch operations from KSC or CCAFS and needed to be updated to reflect the current and future flight operations that will take place on KSC. The title was changed to KSC Flight Risk Assessment Process and includes all flight or launch operations on KSC or CCAFS. The main reason for updating this process was to ensure that the risk assessment process on KSC included UAS operations which just began at KSC during 2013.

b. MOA between KSC and 45 SW for Eastern Range Related Operations

In 2012 the 45 SW and KSC started a working group to help better identify the types of operations that could be occurring on KSC in the future and what level of review/approval would be needed by the 45 SW for those activities. This culminated in 2013 with an MOA signed by the KSC Center Director and the 45th SW Commander. The types of operations on KSC that were specified in the MOA were UAS, amateur rockets and balloons that are covered by CFR Part 101, and vertical lift and landing rockets. These operations were broken down into four criteria sets:

- 45 SW Notification or Approval not required
- 45 SW Notification only
- 45 SW Coordination and Approval is required [Letter Program Introduction (PI) only]
- 45 SW Coordination and Approval is required (Formal PI required)

Definitions and guidelines were provided for each of these types of operations and the applicable criteria set. This agreement provides KSC Range Safety with the ability to review and approve certain types of flight operations occurring on KSC where the risk is contained on KSC. The MOA was signed by the KSC Center Director and the 45 SW Commander in June 2013.

E. Langley Research Center (LaRC)

1. LaRC Small Unmanned Aerial System (sUAS) Facilities

The sUAS Range Safety Office's sUAS Operations Working Group, which began in 2011, continued to expand and develop during FY 2013. The genesis of the sUAS Operations Working Group was to implement and coordinate consolidation activities in terms of sharing common recourses, to provide pilot and observer training, and to integrate operations policy requirements from Headquarters, the Center, and other organizations including the FAA, DoD, and the Department of Homeland Security (DHS).

Range safety training was a major focus for the working group this fiscal year. The RSO developed and implemented a training plan to certify Designated Range Safety Officers (DRSOs), the personnel authorized by the NASA LaRC RSO to oversee the range safety of a specific UAS operation. Qualifications for DRSOs include demonstrated knowledge, experience, and decision making involving Center safety which may include the operation of

various labs, projects, manned flight, simulators, and facilities (i.e., wind tunnels). Five DSROs completed this training.

In addition, the LaRC RSO attended the Range Safety Operations Course that was held at Wallops Flight Facility. Completion of this course complies with the continuous training requirement and certification for RSOs in accordance with NPR 8715.5.

2. LaRC Range Safety and sUAS Operation Oversight

During fiscal year 2013, the LaRC Range Safety Office provided oversight for sUAS flight operations in both the National Air Space (NAS) and in Restricted Air Space. NASA LaRC Range Safety continued to work closely with the FAA's UAS Program Office and with the respective organizations that manage Restricted Air Space. The primary goal of this effort was twofold: 1) to maintain safety of flight for the public, public property, and test personnel, and 2) to ensure that NASA Range Safety requirements were in alignment with NPR 8715.5, NASA Range Flight Safety Program. LaRC currently maintains COA to fly in the NAS at Allen C. Parkinson [Fort Pickett Army Airfield Blackstone (BKT)], 31VA Aberdeen, Smithfield, and at 42VA Virginia Beach, Military Aviation Museum, Virginia.

This year, an MOA was signed between NASA and FAA Headquarters providing a new COA notification process for obtaining streamlined access to class G uncontrolled airspace in the NAS for all NASA UASs that have a gross weight equal to or less than 55 pounds. Since this is a NASA Agency agreement, it is available to all NASA centers that currently have a flight operation. The MOA eliminates the requirement for obtaining a COA for every type of UAS flown by NASA in the 55 pound and under category. As identified in the implementation plan, the FAA named the Unmanned Aircraft System Integration Office as the office of primary responsibility. The Office of Strategic Infrastructure, Aircraft Management Division has the primary responsibility for NASA. It is important to note that policy and oversight for the self-certification of UAS airworthiness and the UAS pilots fall under the guidance of NASA Aircraft Operations Manual, NPR 7900.3, Chapter 5. This MOA will be reviewed annually and is effective until cancelled at any time by either party upon notification in writing. The agreement came about as a result of a working group made up of representatives from LaRC, ARC, DoD, DHS, and the FAA. This activity took place over the previous year culminating with signature approvals from both agencies in March 2013. LaRC is currently using the MOA for sUAS operations at 31VA Aberdeen, Smithfield and at 42VA Virginia Beach, Military Aviation Museum, Virginia.

The Range Safety Office also supported several deployments to Finnegan UAS Air Field at Fort A. P. Hill, Virginia (operations in Restricted Air Space). A total of 23 deployment days were logged at LaRC range facilities during FY2013.

3. FY 2013 sUAS Flight Projects

a. AirSTAR

The Airborne Subscale Transport Aircraft Research (AirSTAR) project continued working on Phase V of the project (see Figure 29). Even though there were no flight tests during FY 2013, a COA was obtained for operations beyond line of sight at Allen C. Parkinson Army Airfield located in Blackstone, Virginia at Ft. Pickett. Take-off and landing will be in the NAS at Allen C. Parkinson. Once airborne, the BAT-4 (Figure 30) will transition into the Ft. Pickett restricted airspace. Plans are also being made to make the first beyond line of sight flights at WFF.

Similarly, a COA is currently in process of review by the FAA to allow take-off and landing from the WFF main base in the NAS and then immediately transition into the range or R6604 restricted airspace for flight research testing. Operational area is within 10 miles and 15,000 feet.



FIGURE 29: AIRSTAR PHASE V, REMOTE INTERNAL PILOT AND GLASS COCKPIT CONFIGURATION LOCATED INSIDE THE MOBILE OPERATIONS STATION WITH CONOPS BEYOND VISUAL RANGE.

CHARACTERISTICS
 Wing Span: 13 ft. (4 m)
 Length: 8 ft. (2.4 m)
 Assembled Size: 13 ft. x 8 ft. x 3 ft.
 4 m x 2.4 m x .9 m
 Weight*: 125 lbs. (56 kg)
 Propulsion: 110cc 2-stroke engine
 Fuel: Gasoline/oil mix (40:1)
 * Full Fuel, 20 lb. Payload, TASE 150/200 Gimbal

PERFORMANCE
 Speed Range: 40 to 70 knots
 Duration*: 6 to 12 hours
 Ceiling*: 10,000 feet
 Range: 300 miles (fuel limited)
 Max Payload: 20 lbs. (9 kg)
 * Payload Dependent

FIGURE 30: AIRSTAR BAT-4 EXPERIMENTAL TEST-BED.

b. Flight Controls Testbeds (FLiC)

In April of 2013, the Automated Flight Controls Lab conducted UAS flight tests at Finnegan UAS Army Airfield at Ft. A. P. Hill, Virginia. The purpose of these tests was to validate a multiple UAS CONOPS to support optical identification strategies of collision avoidance research pertinent to UASs (Figure 31).

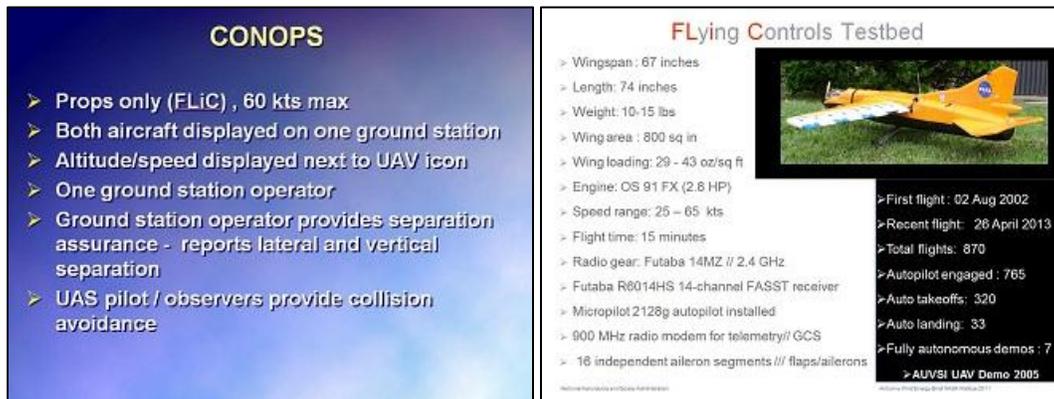


FIGURE 31: MULTIPLE UAS CONOPS USING TWO FLIC TESTBEDS

Even at modest relative speeds of 40 to 60 knots, it is challenging for UASs to fly in close proximity using camera-based, autonomous collision avoidance which requires the detection of a possible collision and execution of an appropriate maneuver to avoid it within a few seconds or less. The Automated Flight Laboratory here at LaRC and Boston University is currently engaged in a collaborative effort to design biologically-inspired, neuromorphic optic flow algorithms to avoid collisions and embed these algorithms in small-sized, low-weight, and low-power customized hardware solutions in UAS.

Data obtained from these multiple operation flight tests are also being used in the preparation of an FAA “safety case” for obtaining a COA to operate multiple UAS in the NASA for the purpose of extending UAS collision avoidance activities as part of the UAS in the NAS integration project.

c. NASA UAS Challenge

The LaRC Flight Operation and Range Safety Office provided guidance and support for the NASA Challenge which took place at Kennedy Space Center in September 2013. LaRC provided review and approval during the development of operating procedures, approving pilot training, analysis of range safety/system hazards, and the review and approval for the airworthiness of an AERO-M hexacopter unmanned aerial vehicle (UAV) owned by Marshall Space Flight Center (Figure 32). The inter-center challenge, a competition between NASA space flight centers, KSC, MSFC, and JSC highlighted hands-on learning and practical experience for project/system engineers to apply the NASA systems engineering process and requirements described in NPR 7123.1. Since the project selected for the challenge involved flying UAVs, additional requirements needed to be met. In preparation for the challenge, the project team at MSFC completed flight testing with their AERO-M hexacopter in restricted airspace managed by the Redstone Army Airfield Flight Operations Huntsville in Madison County, Alabama.



FIGURE 32: AERO-M HEXACOPTER UAV OWNED BY MSFC

d. REC Lab

The Rapid Evaluation Concept (REC) Lab continues to utilize a fleet of all-electric Edge 540T 33% subscale vehicles as a sUAS research vehicle test-bed (Figure 33). The research flights test automation algorithms which perform separation assurance and traffic conflict resolution, in situ resource aware mission re-planning, and onboard resource and systems health monitoring and prognostics. Many of these research algorithms have been tested in pure simulation environments, and fielding these algorithms in realistic environments allows testing to account for assumptions made in the various simulation environments. It should be noted that the automated conflict detection systems and resolution software under study are totally separate from the main flight control software and systems that are required for the PIC to operate the UAS safely in the NAS defined for “nominal operational conditions.” Efforts are underway to transition from a single Edge 540T operation with simulated traffic to a multi-UAV operation in the NAS (Figure 34). An FAA “safety case” is being drafted as an attachment to the COA application for multi-UAV operation testing.



FIGURE 33: EDGE 540T 33% SUBSCALE VEHICLE BEING OPERATED AT 31VA ABERDEEN AIRFIELD, SMITHFIELD, VIRGINIA.

The Aero-M is designed to fly to altitudes up to 150 feet, at up to 20 mph operational velocity, and for flight times up to 35 minutes. The vehicle is equipped with an on-board FTS and manual flight control capability that can override autonomous flight mode for contingency. To compete at KSC, the design and as-built configuration of Aero-M were certified for flight by completing a series of integrated tests at MSFC West Test Area. The Aero-M received Flight Safety Release in May 2013 through the Langley Research Center Airworthiness Safety Review Board which was supported by KSC and the NASA Range Safety Office.

2. Mighty Eagle

The Mighty Eagle was originally built in 2009 as Cold Gas Test Article to validate thruster configuration and flight velocity controlled algorithm. The Cold Gas Test Article was modified with additional capability and longer flight duration (up to 1 minute) during 2010 and 2012 under Lunar Lander Project, and became known as Warm Gas Test Article or Mighty Eagle since then.

The Mighty Eagle can fly autonomously with manual command/abort capability. It has a custom avionics controller using a flight-like RAD750 Processor; sensor suite of IMU, altimeter, and optical camera; peroxide propulsion system using nitrogen as pressurant; throttle capable central thruster for gravity offset; 16 attitude control thrusters; and 3 descent thrusters.

During FY 2013, the Mighty Eagle has performed four flights at MSFC West Test Area demonstrating a hazard avoidance system designed by MSFC engineers based on a commercial off-the shelf (COTS) stereo camera. The stereo camera is a good option in developing a low-weight, low-power, and low-cost hazard avoidance system for small robotic missions because it can detect large boulders at close range given adequate lighting conditions.



FIGURE 36: MIGHTY EAGLE FLIGHT TEST

The duration of each Mighty Eagle flight test was about 38 seconds, and the mission profile was ascending up to an altitude of 30 meters and 45 meters translating distance at different speeds. Because the MSFC-designed hazard avoidance system is an open loop currently, the flight test objectives were limited to taking images and processing the imaging data to generate a disparity map of surveyed terrain. From the flight tests, the Mighty Eagle team identified the need for further improvement of the in-house developed algorithm for image processing as well as the maximum capability of the COTS stereo camera.

3. Space Launch System Program (SLSP)

During FY 2013, the SLSP has been diligently working with Eastern Range USAF 45 SW in tailoring the AFSPCMAN 91-710 Volume 4 (Flight Termination System Design Requirements) and Volume 8 (Tracking and Telemetry Design Requirements). The current plan is to complete tailoring of both Volumes by spring of 2014. The SLSP has also been supporting the tailoring of AFSPCMAN 91-710 Volume 1, 2, 3, 5, and 6 being led by the MPCV Program and GSDO Program under HERSP.

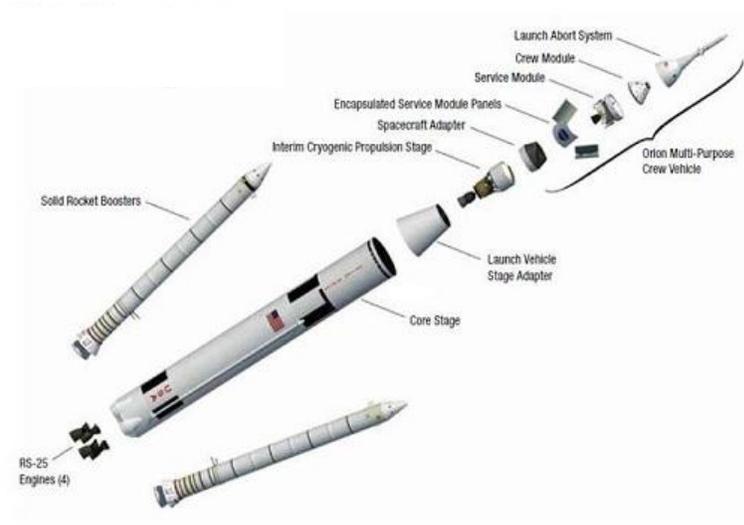


FIGURE 37: SLS 70-METRIC TON INITIAL CONFIGURATION



FIGURE 38: ARTIST'S CONCEPTION OF AN SLS LAUNCH

In November 2012, the SLSP participated in the Tri-Program (SLS, MPCV, and GSDO) Introduction (PI) to USAF 45th SW for Exploration Missions. The outcome of PI is 45 SW Statement of Capability affirming SLSP as a future range user and commitment of USAF 45 SW resources for the Exploration Missions (EM-1 and EM-2) launch plans.

In June 2013, SLSP released the baseline of FTS architecture and hardware list in the SLS-SPEC-140 SLSP FSS description as a product for the June 2013 Preliminary Design Review (PDR).

Since then, SLSP coordinated with HERSP, USAF 45 SW, and Exploration System Development (ESD) in providing the SLS Program memorandum supporting the Human Exploration Operations Mission Directorate waiver request to the National Security Agency (NSA) on EFTS requirement.

G. NASA Headquarters (HQ)

The Safety and Assurance Requirements Division (SARD) at HQ Office of Safety and Mission Assurance (OSMA) provides corporate leadership in the definition and implementation of NASA's Agency-wide Safety and Mission Assurance policies, procedures, standards, tools, techniques, and training. The HQ Range Safety Representative is located within SARD and serves as the HQ Executive for the Agency Range Flight Safety Program and ELV Payload Safety Program.

2013 marked a year of transition for the HQ Range Safety Representative. Mike Dook left the position at the end of 2012 to serve as Deputy for Range Flight Safety at the NASA Wallops Flight Facility. Sandy Hudson took over as HQ Range Safety Representative in early 2013. Sandy has held range safety positions in NASA and the Department of Defense. She brings a wealth of experience and knowledge to the position.

The HQ Range Safety Representative participates in Agency Range Safety Program activities and is responsible for facilitating the development and promulgation of Agency Range Safety-related policy and requirements. During the past year, the HQ Range Safety Representative participated in a Range Operations Training Course at Wallops Flight Facility and participated in a number of ELV Launches. The HQ Range Safety Representative continued as a member of the ELV Payload Safety Agency Team. The Agency Team continued work on Revision A to NPR 8715.7, Expendable Launch Vehicle (ELV) Payload Safety Program. This Revision will update the ELV payload safety process and reflect the new NASA-STD 8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements that was published in 2011.

Other activities included updating the NASA Explosives Safety Program and support to the Commercial Crew Program's coordination with the FAA on issues of commercial launch licensing and applicability of the FAA public safety regulations to future commercial crew launches.

H. Stennis Space Center (SSC)

Several significant activities have taken place in calendar year 2013 on the SSC range, and new developments are on the horizon.

1. Engine Testing

As a safety precaution to general aviation in the immediate airspace, Restricted Airspace R-4403 is activated during engine testing. During 2013, the test stands operated 5 projects resulting in approximately 128 hot fire tests for a total of 5,920 seconds. R-4403 was activated for 17 tests, like the engine test shown in Figure 39.



FIGURE 39: ENGINE TEST SSC

2. NASA-US Navy Mobile Construction Battalion 11/Underwater Construction Team (UCT) 1 Combined Underwater Surveying and Tactical Training

SSC and the United States Navy Mobile Construction Battalion 11/Underwater Construction Team 1 (UCT-1) combined the performance of NASA-required underwater surveying with the UCT-1 pre-deployment tactical training requirement. The UCT-1 training combined operational and tactical missions to provide a realistic pre-deployment training/certification opportunity for the war fighter. During the operational training portion, the UCT-1 performed diving operations (underwater inspections and surveying) in support of SSC construction projects combined with tactical scenarios integrated into the diving operations. The tactical portion included the use of military vehicles, weapons and the discharging of blank rounds. The UCT-1 training objectives were met and the mission was a success for the U.S. Navy and SSC. The multi-agency integration represented excellent fiscal stewardship and realistic pre-deployment training that benefited both cooperating agencies.



FIGURE 40: US NAVY MOBILE CONSTRUCTION BATTALION 11/UNDERWATER CONSTRUCTION TEAM (UCT) 1 COMBINED UNDERWATER SURVEYING AND TACTICAL TRAINING

3. Application for Air Range Information and Notification (AARIN)

SSC uses an electronic range request system called Application for Air Range Information and Notification (AARIN) to track and communicate flight operations to key SSC personnel. AARIN allows the Range Safety Manager to de-conflict air operations and ground testing activities at the Center. Aerial access to the Center is requested in AARIN. The AARIN system was developed to allow pilots onsite and offsite of SSC the opportunity to request access to SSC airspace. Seventeen requests to use SSC airspace were submitted to the AARIN system, nine of which were approved, seven were denied, and one request is being evaluated.

4. Special Use Airspace

SSC and the Naval Special Warfare Command (NSWC) have submitted a request to the FAA to modify the special use airspace associated with SSC, specifically modifications to R-4403. The purpose of this action is to provide containment capabilities conducive to protecting the general aviation community while maintaining priority of engine testing and supporting tenant missions at the Center. Additionally, protection to the surrounding communities from noise and aerial impacts (i.e., turbulence) is critical to maintaining engine testing capabilities at SSC. For mission success within the Federal City and to protect the public including the general aviation community from future testing, special use airspace R-4403 is being modified.

5. Unmanned Aircraft Systems (UAS)

The SSC Range Safety Program reviews and evaluates the compatibility of each proposed UAS or Unmanned Aerial Vehicle (UAV) on a case-by-case basis. Currently, the DoD Special Operations Command (SOCOM) is the only agency operating UAVs at SCC. While SOCOM applies for the COAs, maintains the vehicles, and operates the UAVs, the SSC Range Safety Manager provides de-confliction between the Special Forces flights and NASA missions. The COA or Waiver for SOCOM is Puma 2012-ESA-29-COA-R.

Puma certificate 2012-ESA-29-COA-R is effective from July 20, 2012 through July 19, 2014. Operation of the Puma AE UAS in Class G airspace at or below 1000 feet AGL, except in the northern airspace area under the Picayune Class E airspace where the Puma will remain at or below 500 feet Above Ground Level (AGL). Night flight is acceptable.



FIGURE 41: PUMA UAS

I. Wallops Flight Facility (WFF)

WFF continues in its longtime role as NASA's principal facility for the management and implementation of suborbital science research programs. In addition, WFF has become a premier site for the operation of medium-class space launch vehicles. The research and responsibilities of Wallops are centered on the philosophy of providing a fast, low-cost, highly flexible, and safe response to meet the need of aerospace technology interests and science research.

The WFF Safety Office supports ground safety and flight safety analyses to ensure NASA safety rules and criteria are met. The WFF Safety Office also supports ground operations in preparation for flight and provides on-console support for flight operations as necessary. When other national ranges are involved with WFF missions, the WFF Safety Office provides documentation and operational support as required by the other range.

Listed below are various project/programs that the WFF Range Safety Organization supported in 2013.

1. Range and Mission Management Office

NASA/WFF Range Safety personnel supported multiple missions conducted by the WFF Range and Mission Management Office (RMMO) in 2013. The manifest included 5 Expendable Launch Vehicle (ELV) missions, 1 Department of Defense (DoD) Tracking Exercise, F-35 and X-47B flight testing, and 1 reimbursable mission for runway water ingestion (mandatory testing for FAA aircraft certification). The RMMO supports sounding rocket launches at WFF with fixed instrumentation as well as mobile range instrumentation for sounding rocket launches at other sites. The following provide some details of the ELV launches from WFF.

a. ANTARES

After one of the largest launch infrastructure buildups and vehicle development efforts in



FIGURE 42: ANTARES ON THE PAD

the history of the Wallops Research Range, 2013 marked the beginning of Antares launch operations. Antares (Figure 43) is a medium-class space launch vehicle built by Orbital Sciences Corporation (OSC) and is named after a red supergiant star in the Milky Way Galaxy. This brand-new launch vehicle was developed as part of the Commercial Orbital Transportation Services (COTS) contract for resupplying the ISS. The WFF Range supported two Antares launches in 2013.

The first-ever successful launch of the Antares vehicle on April 21, 2013 (A-ONE mission) was the culmination of an enormous multi-year effort. Antares perfectly placed a payload simulator into a short orbit and demonstrated its ability to carry the Cygnus spacecraft that will resupply the ISS. Range services provided for the Antares A-ONE mission included precision tracking radar, telemetry operations, range timing and communications, radio frequency monitoring, surveillance radar operations, range air and sea surveillance, NASCOM, weather forecasting, meteorological operations, optical systems, range scheduling services, range safety, and postproduction deliverables for prelaunch and launch operations.

One unique aspect of this mission was the teaming effort between WFF Optical Systems Group and a team from Kennedy Space Center. Together, these two teams produced the largest amount of photographic and video data ever collected by one mission. One key to successful range support for the A-ONE mission was the establishment and maintenance of downrange mobile tracking stations in Coquina, N.C. and Bermuda. These stations incorporate mobile power, telemetry, radar, and command.



FIGURE 43: ANTARES IN HORIZONTAL INTEGRATION FACILITY (HIF)

The second Antares launch of 2013, known as ORB-D1 (Figure 44), took place on September 18, 2013. This was the first Antares vehicle to actually carry the new Cygnus spacecraft which ferried approximately 1,800 pounds of supplies to the ISS. Following the successful launch of the Lunar Atmosphere and Dust Environment Explorer (LADEE), WFF had only 11 days to turn over and prepare the range for ORB-D1. This short turnover-time required intense project

management to facilitate the complex and interwoven schedules of two separate medium-class launch vehicles.

A bright future is forecast for Antares as two to three launches are scheduled for 2014.

Editor's Note: At the time of publication, the next Antares mission, ORB-1, launched on 9 Jan 2014.



FIGURE 44: ANTARES LAUNCH

b. LADEE

Aboard a Minotaur V expendable launch vehicle, LADEE lifted off from Pad 0B at WFF on September 6, 2013. After a near-flawless count and with perfect weather conditions, LADEE soared into a clear, beautiful sky on the first minute of the launch window. This spectacular night launch was visible up and down the east coast (Figure 45).

LADEE was sent to the moon to gather information about the fragile lunar atmosphere before further exploration disturbs it. This ground-breaking feat was the culmination of years of effort from multiple agencies



FIGURE 45: VIEW OF MINOTAUR V LADEE LAUNCH FROM NEW YORK CITY

across the country. LADEE was the first-ever interplanetary mission from WFF on the first Minotaur V launch vehicle ever flown (Figure 46). The LADEE project also spurred some major upgrades to Wallops Range facilities. The two biggest upgrades were the development of a new Launch Control Center and a new clean room facility.

The LADEE launch trajectory created particular challenges for WFF Range Safety as the near due east path brought hazard areas close to Chincoteague Island and other populated areas to the north of Wallops Island. The Range worked closely with local authorities to clear the needed areas and to establish safe viewing sites for the tens of thousands of spectators who came to witness this historic launch.

The LADEE mission was a great success for the entire Wallops Range team and might pave the way for future interplanetary missions from WFF.



FIGURE 46: MINOTAUR V LAUNCH

2. Sounding Rocket Program Office

NASA/WFF Range Safety personnel supported 23 missions conducted by the WFF Sounding Rockets Program (SRPO) in 2013. The launch manifest consisted of 2 technology development/demonstration missions, 2 undergraduate student outreach missions (Rock-Sat X and Rock-On), 17 science missions, and 2 reimbursable missions for the Department of Defense. Launch sites included Wallops Island (6 launches), Poker Flat Research Range (1 launch), Reagan Test Site (4 launches), and WSMR (12 launches). The following provide some details of the launches from WFF.

a. Lithium Canister Test

WFF launched a two-stage Terrier Mk70 Improved Orion sounding rocket January 29, 2013. This mission was flown to test the lithium deployment system, in particular the Lithium Canister Design to be used for future missions – Daytime Dynamo and Equatorial Vortex Experiment (EVEX). The experimental payload included two canisters, each using a different lithium loading technique. This successful mission was an exercise in timing as the launch needed to occur in twilight conditions because lithium requires solar illumination to be visible. At the same time, conditions on the ground needed to be sufficiently dark so that the lithium releases could be seen against the sky background.

b. Cosmic Infrared Background Experiment (CIBER)

The Cosmic Infrared Background Experiment (CIBER) successfully flew aboard a Black Brant XII sounding rocket June 5, 2013, from WFF's Pad 1 50K launcher. The purpose of this mission was to investigate the spectral and spatial properties of the extragalactic near-infrared background, and the mission required acquisition of multiple targets. This was the fourth flight that WFF supported under the CIBER banner but the first at the Wallops Range. Previous flights for CIBER were conducted at White Sands Missile Range, New Mexico in 2009, 2010, and 2012. After each flight, the experiment payload was recovered for post-flight calibrations and reflight. The principal investigator decided the payload would not be recovered for this fourth and final mission in order to use a more powerful sounding rocket to fly over the Atlantic

at a higher elevation. The experiment payload safely splashed down in the Atlantic Ocean more than 400 miles off the Virginia coast.

c. RockOn

In the early morning hours of June 20, 2013, a Terrier Mk12 Improved Orion sounding rocket took flight from the WFF's Pad 1 50K launcher. Approximately 30 students and faculty worked on multiple payloads for this mission. Several science experiments were onboard the vehicle including an experiment to determine if the intensity of ultraviolet radiation changes with altitude and an experiment to develop an ozone density profile in the atmosphere.

The RockOn workshop is intended to provide exposure to university undergraduate students and their instructors to space-based science missions. The long-term goal of the RockOn workshop is to provide a minimally subsidized, self-sustaining, annual training program for the university community. This year, the following universities participated:

- Carthage College
- Eastern Shore Community College
- Embry Riddle Aeronautical University
- Miami University
- Mitchell Community College
- The Naval Academy
- Temple University
- University of Nebraska

The RockOn workshop is a collaborative effort by the Colorado Space Grant Consortium (CSGC), the Virginia Space Grant Consortium (VSGC), and the Wallops Flight Facility.

d. Daytime Dynamo

A joint science project between NASA and the Japan Aerospace Exploration Agency (JAXA) was conducted to study a global electrical current called the "Dynamo" which sweeps through the ionosphere. WFF facilitated this study by launching two sounding rockets a mere 15 seconds apart. As luck would have it, WFF celebrated the nation's 237th birthday with its own aerial show as the two vehicles took flight in the morning hours on Independence Day, 2013. The first vehicle, a Black Brant V, carried a payload that collected data on the neutral and charged particles in the ionosphere. The second rocket, a Terrier Mk70 Improved Orion, released a long trail of lithium gas to track how the upper atmospheric wind varies with altitude. These winds are believed to be the drivers of the Dynamo currents.

3. Balloon Program Office

NASA/WFF Range Safety personnel supported 11 missions conducted by the Balloon Program Office (BPO) during 2013. Flight operations were conducted from Fort Sumner, New Mexico; McMurdo, Antarctica; and Kiruna, Sweden in support of Space Science payloads as well as testing for a new launch technique. The Super Trans-Iron Galactic Element Recorder (SuperTIGER) experiment, launched on December 8, 2012, is measuring the abundance of rare elements heavier than iron among the flux of cosmic rays from our galaxy. SuperTIGER set a new duration record for the Balloon Program at over 55 days aloft (Figure 47).



FIGURE 47: SUPERTIGER LAUNCH

The BPO in collaboration with the Jet Propulsion Laboratory (JPL) also conducted tests of a new launch method in preparation for the Low Density Supersonic Decelerator (LDSD) mission in 2014. The launch method utilizes a static launch technique employing a static launch tower. The LDSD Launch Tower (Figure 48) was successfully tested during the Fort Sumner, New Mexico campaign. The next step will be to integrate a Star 48 rocket motor and the LDSD deployable aeroshell aboard the balloon for launch from the Pacific Missile Range Facility (PMRF) in Hawaii. Further plans include up to three additional flights in 2015 from PMRF.

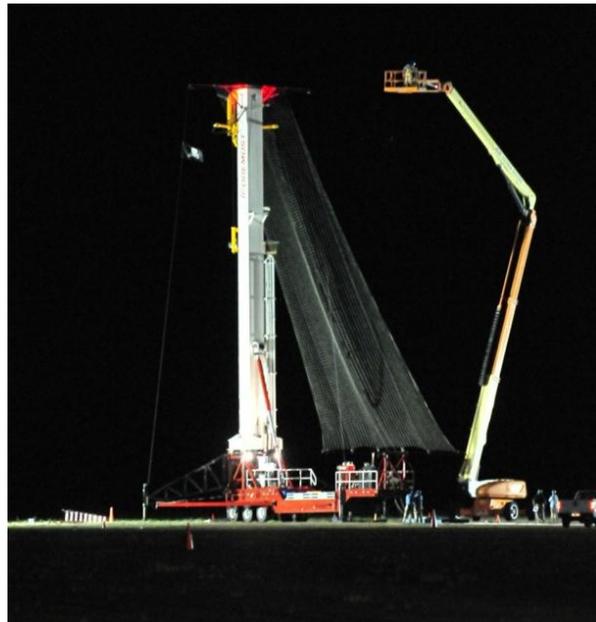


FIGURE 48: LDSD LAUNCH TOWER

4. WFF Aircraft Office

The WFF Aircraft Office supported multiple airborne science missions during 2013 involving manned aircraft. The Wallops Safety Office supports these missions through review of hazardous systems being flown on those aircraft and participation in the airworthiness review process.

The Aircraft Office also supported UAS work, including the Hurricane and Severe Storm Sentinel (HS3) mission and acts as a divert field for UAS missions from the Naval Aircraft Warfare Center, Patuxent River, MD.

The Purpose of the HS3 mission is to obtain critical measurements in the hurricane environment in order to identify key factors and their role in storm intensity change. Two NASA Dryden Global Hawk (GH) UAS aircraft (Figure 49) were especially equipped with sensors to gather science data about hurricanes in the Atlantic Basin. One aircraft (GH N872NA, also called 872 and AV-6) has three sensors selected to fly around the perimeter of hurricanes and is known as the “Environmental GH.” The other aircraft (GH N871NA, also called 871 and AV-1) has three sensors selected to fly through the top of hurricanes and is known as the “Over-Storm GH.” Each aircraft typically flies flight durations of up to 26 hours and can fly up to 28 hours under ideal conditions. These two GHs have flown more than 500 flight hours since being acquired by NASA Dryden and are considered operational UAS aircraft.

2013 marked the second year in the five-year HS3 project, with about ten Global Hawk science flights per year. The Global Hawk aircraft operating from the Wallops Airport fly to the Gulf of Mexico, Caribbean, the western Atlantic, and the central and eastern Atlantic.



FIGURE 49: NASA GLOBAL HAWK ON APPROACH

The Aircraft Office also supports all range missions requiring active range surveillance with helicopter and fixed wing assets. The Wallops Safety Office provides the analysis and requirements for the ship surveillance areas.

5. WFF Mobile Range - Kwajalein Launch Campaign

WFF continued to enable worldwide research with its mobile range that consists of radar, telemetry, command and control and communications systems. These systems can be shipped to any launch location in the world.



This past year, the WFF mobile range was dispatched to the South Pacific to collect data on the Earth's ionosphere to study radio frequency propagation as well as space weather and its impact on communication and navigation systems. WFF Range Safety developed the ground and flight safety plans for this campaign and provided on-site operational safety support. Between May 1 and May 9, 2013, two pairs of sounding rockets were launched. Each pair was launched nearly simultaneously during the successful Kwajalein launch campaign. These suborbital vehicles flew from Roi-Namur Atoll, Republic of the Marshall Islands (Figure 50). Two rockets supported the Equatorial Vortex Experiment, or EVEX – a NASA mission – and two supported the Metal Oxide Space Cloud experiment, or MOSC, which was a DoD mission.

FIGURE 50: SECOND SOUNDING ROCKET LAUNCH FROM ROI-NAMUR ATOLL, REPUBLIC OF THE MARSHALL ISLANDS

The EVEX mission studied space weather in the ionosphere, specifically the circulation of ionized gas, the intensity of which is believed related to post-sunset ionospheric storms that can impact satellite communication and navigation systems and signals. As part of the mission and during rocket flights, red and white vapor clouds formed to allow the scientists to observe the winds in the upper atmosphere. The MOSC payloads released a Samarium vapor creating a red cloud of charged particles in the ionosphere (Figure 51). Researchers from the Air Force Research Laboratory studied the cloud as it dispersed and its impact on radio transmissions sent from multiple locations. MOSC was launched with the assistance of the Department of Defense Space Test Program.



FIGURE 51: SAMARIUM VAPOR CLOUD IN THE IONOSPHERE

SUMMARY

Range Safety participated in a number of exciting and challenging activities and events in 2013 involving the development, implementation, and support of range safety policies and procedures.

Advancing our effort to provide training at various levels of Range Safety, NASA Range Safety has conducted over 55 training courses for NASA, DoD, FAA, and NASA contractor personnel. Almost 1,100 students have participated to date. While Federal Budget constraints did not provide NSTC funding, the Agency Range Safety Program was able to fund one Flight Safety Operations course from WFF and two NASA Range Flight Safety Analysis classes from KSC. The two NASA Range Flight Safety courses taught at KSC this year were videotaped and will be made available through SATERN to enhance our ability to provide training.

Range Safety representatives took part in a number of panels and councils, including participation in the Inter-Center Aircraft Operation Panel and the 112th Range Safety Group TIM with the Range Commanders Council Range Safety Group and its subcommittees. VAFB is the FTSC Chair with KSC acting as the Co-Chair. FAA Headquarters is currently the Risk Committee (RC) Chair, and NAVAIR Pt. Mugu is the Directed Energy Committee Chair. White Sands Missile Range (WSMR) became the RSG Chair in 2013.

NASA/KSC Range Safety worked side-by-side with DoD counterparts to support 13 launches this year consisting of 11 Eastern Range launches (2 NASA-sponsored ELV and 9 non-NASA launches supported for KSC risk assessment) and 2 Western Range launches of NASA-sponsored ELV vehicles. NASA Range Safety supported the first two successful launches of the Antares medium-class space launch vehicle and the successful launch of LADEE aboard a Minotaur V from Wallops Flight Facility. JSC brought Morpheus back to KSC for flight test operations and to demonstrate the vehicle's autonomous landing and hazard avoidance instrument. The NASA Range Safety Manager and KSC Range Safety Representative coordinated planning documentation while JSC performed the RSO function for the successful test.

Range Safety also participated in the evaluation of several emerging technologies. The NASA AFSS team worked with Northrop Grumman on their SAMPAL project for the DARPA ALASA program that is designed to produce a rocket capable of launching a 100-pound satellite into low Earth orbit for less than \$1 million on short notice. The Joint Advanced Range Safety System (JARSS) and AFSS are tightly integrated into SAMPAL. The NASA AFSS team also worked closely with the 30th Space Wing to modify the original NASA AFSS safety software so it is compliant with the MISRA standard.

We hope you found the 2013 Range Safety Annual Report to be usable and informative. As we move into 2014, we look forward to the opportunities and challenges of ensuring the safety of NASA activities and operations.

Anyone having questions or wishing to have an article included in the 2013 Range Safety Annual Report should contact Alan Dumont, the NASA Range Safety Manager located at the Kennedy Space Center.