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Use of nuclear power sources in outer space

THE UNITED STATES APPROACH TO NUCLEAR LAUNCH ACCIDENT MITIGATION[1]

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ABSTRACT

The United States of America subjects its planned launches of nuclear power source applications to an extensive launch radiological contingency planning process to characterize and mitigate any possible effects of a nuclear launch accident. This process is consistent with the relevant guidance recommended in the "Safety Framework for Nuclear Power Sources Applications in Outer Space", jointly published by the Scientific and Technical Subcommittee and the International Atomic Energy Agency in 2009. For every launch involving nuclear material, the United States creates contingency plans to mitigate accident sequences that could lead to a radiological hazard. A network of remote sensors and monitoring teams are established around the launch area to determine whether a release from an accident has occurred and, if necessary, to characterize the nature of a release. Information from the sensors is collected and interpreted in a Radiological Control Center, which is staffed by national experts in radiological emergencies. These experts may

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[1] This paper is also available, edited and in all official languages of the United Nations, in document A/AC.105/C.1/L.315.

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recommend actions to limit exposure of populated groups in potentially affected areas. A Joint Information Center is established to promptly distribute consistent, accurate and current information to the appropriate governments, international organizations, non-governmental entities and the general public. Numerous exercises are conducted before every launch to practice and ensure that the United States is ready to respond appropriately and promptly in the unlikely event of a launch accident involving nuclear material.

1. INTRODUCTION

The United States has instituted a detailed and thorough approach to launch accident mitigation involving the use of a nuclear power source (NPS). This process is consistent with the "Safety Framework for Nuclear Power Source Applications in Outer Space" (UN/IAEA Safety Framework) [UNCOPUOS, 2009]. This process includes detailed radiological contingency planning (RCP), assessing the situation in the unlikely event of a launch accident involving an NPS, and, if necessary, recommending protective actions and communicating this information to the public and other governments.

A phased approach of coordinated RCP efforts are an integral part of the planning for each NPS space mission using the provisions set forth in the United States National Response Framework [Department of Homeland Security, 2008]. The National Response Framework is a guide on how the United States responds to incidents involving hazardous materials. The Nuclear/Radiological Incident Annex of the National Response Framework specifically addresses nuclear and radiological releases.

The Nuclear/Radiological Incident Annex provides a more detailed description of the policies, situations, concepts of operations, authorities, and responsibilities of the Federal departments and agencies governing the immediate response and short-term recovery activities for incidents involving release of radioactive materials. The Nuclear/Radiological Incident Annex applies to incidents where the nature and scope of the incident requires a Federal response to supplement the State or local incident response.

The National Response Framework/Nuclear/Radiological Incident Annex identifies the National Aeronautics and Space Administration (NASA) as the Federal Coordinating Agency in the event of a launch accident involving an NPS on a NASA mission. NASA is responsible for designating a Coordinating Agency Representative (CAR) to lead this effort, including a planning portion and a response implementation portion both on-site (U.S. Government property) and off-site (Non-U.S. Government property). NASA launches all of its NPS missions from Kennedy Space Center KSC in Cape Canaveral, Florida; as such KSC also develops a supplemental plan to address these requirements for all missions using NPS.

2. RADIOLOGICAL CONTINGENCY PLANNING

The RCP efforts for each mission typically begin with formal coordination between NASA and the Department of Energy (DOE) about three years prior to a scheduled launch. One of the major functions of the RCP process is to identify the requirements basis for the contingency response plan and develop the timelines for development of effective plans and timely procedures for addressing an accident or

incident that could result in a radiological release. "NASA/KSC Radiological Contingency Plan for Major Radiological Source Missions," provides a summary of the RCP requirements and procedures for an NPS mission and references all of the other mission specific plans and procedures. The mission specific support plans are requirements driven and are not limited to, but normally include, the following areas: Data Management Plans, Out-of-Launch Area Contingency Plans, Source Recovery Plans, Data Assessment Plans, Logistics Support Plans, and Field Monitoring. Actual writing and development of the plans is accomplished through an iterative series of drafts and reviews. Measures are taken to ensure each plan is fully vetted prior to final staffing and signature.

A series of approximately seven to ten major inter-agency meetings are held during the RCP process. Numerous other sub-meetings involving specific topics and personnel occur, and tailored validation drills and exercises are also held in support of the mission. The meetings are designed to address, outline and implement the RCP path forward for the upcoming mission. Attendees to the RCP Meetings include representatives from NASA, DOE, the State of Florida, Brevard County (the local jurisdiction where the launch occurs), Department of Defense/U.S. Air Force, Environmental Protection Agency, Federal Emergency Management Agency, National Oceanic and Atmospheric Administration/National Weather Service, Department of State and U.S. Coast Guard.

KSC normally hosts the RCP meetings. Having the meetings at KSC provides for the use of existing mission facilities, which include the Radiological Control Center (RADCC), designed and dedicated to facilitate the RCP Concept of Operations (ConOps) for NPS missions. Additionally, holding the RCP meetings at the actual launch site facilitates coordination efforts with state and local government emergency management representatives at their actual Emergency Operations Centers (EOCs) and facilitates. These RCP coordination efforts with the state and local emergency management representatives acknowledge their key role in the implementation of National Response Framework/Nuclear/Radiological Incident Annex guidance.

The development of radiological contingency plans is based on data and results from the detailed safety analyses and risk assessments developed for each mission as part of the U.S. procedure for approval of NPS launches. Comprehensive efforts are taken in the early RCP process to identify and evaluate all radiological risk that have been identified in studies and/or regulatory safety documents prepared for the mission. These documents are mission specific and include: the Environmental Impact Statement (EIS), Final Safety Analysis Report (FSAR) and Safety Evaluation Report (SER). The risk assessments are consistent with Section 5.3 of the Safety Framework and focus on the radiological materials, launch vehicle, meteorological and other environmental considerations [Bechtel, Lipinski et al., 2011]. The information found in the EIS provides a starting point for obtaining the data regarding possible environmental impacts required for initial RCP efforts to identify and characterize any radiological release in the unlikely event that an accident occurs. Eventually the EIS data will be replaced and updated by the data found in the FSAR.

The radiological source term and risk information found in the FSAR is used to develop atmospheric modelling approaches to obtain expected dispersal plumes of the radiological materials for each mission based on local meteorology information.

Current and historical meteorological data for the KSC launch site is used to model meteorological conditions for the projected launch window and supports the staging and deployment of radiological monitoring and response personnel and equipment. It should be noted that the KSC and its surrounding area is one of the most highly meteorologically monitored and studied areas in the world.

The key objective of the RCP effort is to ensure that all required assets are in place (on-site and off-site) prior to any NPS mission launch. These assets are necessary to ensure a timely response to an accident that could result in a radiological release, and providing for a smooth transition of that initial response into a full Federal response, should the need arise.

As the RCP process moves along and the unique requirements for each mission are established, a list of mission plans and procedures are identified for development. These plans, coupled with the information in the safety documents indicated above, will provide the basis for the tailoring of personnel and equipment requirements to address staffing, monitoring and response contingencies for that particular mission.

The ongoing RCP process provides for the modifications and changes to the plans and procedures throughout the planning effort and the RCP meetings provide an established forum to discuss and modify these documents. Once these plans have been developed, coordinated and approved they are circulated to all involved agencies for familiarization in preparations for mission planning and scheduled pre-launch RCP drills and exercises of RCP personnel, equipment and facilities that will be used to support the mission launch.

The RCP process is designed to address accidents that may result in radiological release, along with resources for providing an initial response, including locating and identifying the radiological materials. The period of support for deployed RCP resources is designed to be a short period, encompassing a couple of days. Additional Federal resources would be deployed upon request. To facilitate this transition and influx of personnel and equipment and to maintain continued operations of the RADCC activities throughout the transition, DOE has its Consequence Management Home Team (CMHT) operational during each NPS Mission launch. The CMHT mission is to provide all of the support required to address the radiological issues from any accident while trained and equipped personnel are deployed to mitigate the consequences of any radiological mishap.

The Federal Radiological Monitoring and Assessment Center (FRMAC) is a Federal asset available on request to respond to nuclear/radiological incidents as described in the National Response Framework/Nuclear/Radiological Incident Annex. Under the National Response Plan (NRP) the DOE has the responsibility to maintain the operational readiness of the FRMAC. The FRMAC is an inter-agency organization with representatives from various federal, state, and local radiological response organizations. The purpose of the FRMAC is to assist the states, local and tribal governments in their mission to protect the health and well-being of their citizens with: (1) verification of radiation measurement and interpretation of radiation distributions based on Environmental Protection Agency (EPA), Food and Drug Administration or local Protective Action Guidelines (PAGs); and (2) the characterization of overall radiological conditions.

A Radiological Contingency Response Review is conducted by NASA with key personnel from each of the agencies that have been involved with RCP efforts for

the upcoming mission approximately 30-60 days before launch. The purpose of the review is to ensure all known requirements have been fully addressed and to obtain a "Ready to support!" response from each agency representative having a support role in the mission.

3. RADIOLOGICAL CONTINGENCY FACILITIES, PERSONNEL AND EQUIPMENT

The RCP support personnel are identified by specific positions that are either on-site at the KSC or off-site in selected Federal, state or local facilities that have been identified and/or established, as necessary, for each particular launch. Three primary RCP Mission support elements are: the CAR Management Group (CMG), the RADCC and the Joint Information Center (JIC). All personnel that support radiological contingency efforts have clearly developed position descriptions and associated checklists, which are reviewed and appropriately revised, as required, for each mission. The personnel, support plans, equipment and facilities are validated via a series of intensive drills and exercises. Substitutes are trained for each position so that in the event that the primary individual is unable to perform their duties, they can fill the position. Substitute personnel are also subject to training, drills and exercises.

The CMG is led by the CAR and is composed of Federal, state and local government representatives. It provides the focal point for on-site and off-site operations, including the coordination, approval and dissemination of information and recommendations involving the status of the radiological materials on the mission.

The RADCC is staffed with federal, state and local government representatives, and includes engineers, scientists, physicians, and other experts from across the United States. The RADCC staff provides a single tailored and trained hub for initially managing any mission accident/incident (on-site and off-site) with a possible release of radiological materials.

The JIC is located in close proximity to the CMG and RADCC and includes engineers and public affairs experts from various federal, state and local governments. The primary purpose of the JIC is to: (1) ensure the timely release of fully coordinated and approved radiological information with focus on public health and safety and protection of the environment, and (2) serve as the focal point for the communications and the exchange of information between CMG/RADCC and the news media and the general public regarding any issues involving the radiological materials on board the mission.

Radiological monitoring (RADMON) teams are field units that have direct communication with a dedicated point-of-contact within the RADCC. The pre-positioned RADMON Teams provide an initial radiological response to an accident to verify whether or not a radiological release has occurred. If applicable, the teams also characterize the release and assist in the determination of the areas of contamination. One of the RADMON Teams deployed for each mission is specifically designed, staffed and equipped to identify the NPS and its components and to take initial steps for its safe and secure recovery.

4. CHARACTERIZING THE LOCATION AND NATURE OF A RELEASE OF RADIOACTIVE MATERIAL

The RADCC collects real time information regarding the telemetry, trajectory and tracking data for the mission launch vehicle. If an accident/incident occurs with the launch vehicle during any phase of the launch to orbit, the RADCC would have access to that information and the predicted impact locations of the spacecraft and associated debris, including the NPS. This information combined with local meteorology can be used to help predict the potential dispersion of any radioactive material and related ground concentrations and radiation doses in the unlikely event of a launch accident.

The Lawrence Livermore National Laboratory's (LLNL) National Atmospheric Release Advisory Center (NARAC) has an extensive, global network of meteorological information available that, if necessary, can be used for modelling atmospheric releases throughout the world. A NARAC scientist is located in the RADCC to provide predictive radiological dispersal plots for a potential launch accident. These plots provide the planning basis for initial deployment and staging of unmanned Environmental Continuous Air Monitors (ECAMs) and the RADMON Teams.

If an accident were to result in a radiological release, NARAC would model the plume and deposition of radiological materials potentially contained in the plume based on meteorological data, input from the network of detection devices and the ground sampling obtained by the RADMON Teams in the field both on-site and off-site.

ECAMs are automated radiation detection equipment that continuously sample ambient air to determine if radioisotopes are present. The air samples are collected at a height of 1.5 m, which is approximately mouth and nose level for an adult human. This is important because inhalation is the primary dose pathway for released NPS radiological material (plutonium-238). ECAMs are optimized for outdoor weather conditions, including wind. ECAMs can detect alpha and beta radiation, and can be programmed specifically to detect certain radioisotopes, such as plutonium-238. The ECAMs can report the concentration of radioisotopes in the air. The ECAMs have their own independent power supply. The ECAMs transmit the data via satellite on a real time basis to the RADCC. In the event of a communications failure, the ECAMs maintain a record of the measurements taken. This information can be read from the ECAM directly and sent to the RADCC via radio, phone, or manual courier as necessary.

The radiological detection equipment and RADMON Team personnel are strategically placed pre-launch in identified positions around the launch area, both on-site (KSC and Cape Canaveral Air Force Station) and off-site (i.e. surrounding communities) based on projected meteorological conditions at launch. Most detection/monitoring equipment is placed in fixed locations so that adequate background levels of radiation can be well understood in advance of a launch and to aid in RCP plans and exercises. Some equipment and personnel are mobile and can be moved hours before launch, as dictated by weather conditions, to best monitor the area.

Initial pre-launch positioning of the mobile ECAMs and RADMON Teams is adjusted based on updated information and a series of NARAC plots starting

approximately 24 hours prior to the scheduled launch down to the final positioning, which is normally two to four hours prior to launch.

The use of strategically placed ECAMS and RADMON teams provide a fast, real time determination of release, or confirm no release of material, in the unlikely event of a launch accident involving an NPS. The data collected by the ECAMs and RADMON teams is interpreted by expert scientists and engineers in the RADCC. The information would be used to help understand the potential population exposure and land contamination in affected areas, should an accident with a radiological release occur.

5. RECOMMENDING PROTECTIVE ACTIONS

The primary focus of the RCP process is protection of the public health and safety and the environment resulting from any release of the radiological materials. Specific RCP meetings and working groups, including state and local government representatives, Federal representatives from NASA, DOE, EPA and other agencies, are held and dedicated to assist the state and local governments develop Protective Action Guidelines (PAG) to fit their particular needs. Mission specific PAGs are coordinated, developed and documented for both on- and off-site.

One such protective action is called “sheltering in place”. To protect launch area personnel, visitors, and residents from any potential hazards involved in an early launch accident, people may be advised to go indoors, close all doors and windows, shut off their heating and air conditioning systems and wait for the passage of a potential radiological or toxic (chemical) plume. This protective action is also recommended for launch accidents not involving an NPS, simply to protect people from possible toxic plumes (e.g. from rocket propellants and/or by-products) generated during a launch accident.

In addition to the PAGs and recommendations, DOE works with local government representatives to provide unique medical training to staff personnel from local area hospitals and medical centres in the launch area. The training focuses on effects of radiological materials, and the handling and treatment of contaminated patients. The training is coordinated with each medical facility identified by local government representatives and is provided approximately six to eight weeks in advance of every NPS mission launch. Instructors for the training is provided by the DOE’s Radiation Emergency Assistance Center/Training Site (REAC/TS) and are medical doctors, health physicists and occupational health professionals, that are all experts in the area of the health effects of radiation and the handling and treatment of exposed patients.

6. DISSEMENATION OF INFORMATION TO THE PUBLIC

Consistent with the Safety Framework, Section 5.4 (e), the United States sets up a JIC to provide a single, unified source of information to the appropriate governments, the news media and the public about the federal radiological response to a launch accident. The timely, effective and efficient flow of information between NASA, the media and the public is integral to a successful response to a launch incident. Similar to the RADCC, the JIC is a group of representatives from federal, state and local agencies.

Prior to launch, the JIC personnel develop, recommend, and execute public information products, plans and strategies in the event of a launch accident. Given that there are many governmental agencies involved in the launch of an NPS, mechanisms are established for inter-agency coordination of public information releases in the unlikely event of a launch accident. Presentations are given to the media (print and television), decision makers, and interested public organizations to help inform the public of the risks and benefits of the mission. The JIC creates pre-scripted accident-specific announcements to facilitate the timely, accurate and consistent release of public information in a launch accident. Pre-scripted announcements are drafted for all credible outcomes of a launch, including accidents occurring during pre-launch, early ascent, sub-orbital and orbital phases of a launch. Specific information related to an accident would be filled in once an accident has occurred. These pre-scripted messages include recommended protective actions the public can take in the unlikely event of a launch accident.

Should an accident occur, the JIC will obtain information from the RADCC to produce and distribute timely information about the launch accident to the media and other audiences. The JIC reviews any public information developed in response to the accident by partner agencies. The JIC also monitors message delivery, media content and public perception of the launch accident and can issue press releases to ensure that the correct and appropriate message and protective actions reach the public. All JIC-generated messages must be approved by the CAR before being publicly released.

The JIC is also responsible for drafting diplomatic cables which are delivered to appropriate governments and international organizations. Prior to launch, diplomatic cables are prepared by the JIC describing the mission, NPS, and risks of the launch. The Department of State sends the cables out to the many embassies and missions worldwide. The JIC writes pre-scripted diplomatic cables, similar to the pre-scripted messages discussed above, so that accurate information can be released to the appropriate governments as quickly as possible should the need arise. The Department of State activates its Event Operations Center during every NPS launch to ensure that in the unlikely event of a launch accident, the diplomatic cables will be released to the appropriate governments as quickly as possible. All of these international messages are approved by the CAR before being released.

7. CONCLUSIONS

The United States of America has set up a thorough and detailed approach to monitoring and mitigating a launch accident involving the use of an NPS. The United States develops a range of plans to deal with potential launch accident scenarios. Dedicated facilities, teams and equipment are in place for every launch involving a nuclear power system to determine if a release occurred. Expert scientists and engineers interpret the data to characterize the release and risk, and then make recommendations to policymakers and the public. The Joint Information Center is in place to prepare accurate and timely information to the public and other governments.

8. REFERENCES

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