NASA & the Radiation Emergency Assistance Center/Training Site: A Valuable Partnership

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Abstract

The National Aeronautics and Space Administration (NASA) is preparing for the launch of the Mars 2020 Rover, Perseverance, in July or August of 2020. Perseverance is outfitted with a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). Although this generator is necessary for the powering and heating of the rover on Mars, the plutonium contained within could present a danger to humans in the unlikely event of a launch anomaly. Therefore, NASA has partnered with the Radiation Emergency Assistance Center/Training Site (REAC/TS) to train relevant personnel and provide on-site assistance. This partnership is aligned with REAC/TS' mission to improve the response to radiation incidents and utilizes its capabilities of training and providing expert guidance. This partnership is essential to the success of the Perseverance launch because it prioritizes human health and safety.

NASA & the Radiation Emergency Assistance Center/Training Site: A Valuable Partnership

In a 2010 address at the Kennedy Space Center, President Barack Obama announced his ambitious goal to send humans to Mars by the mid 2030's. The proposed mission would require advanced technologies in navigation and propulsion and improved life-sustaining technologies to protect the crew members. President Obama acknowledged these barriers that would accompany a crewed mission to Mars, and he issued a challenge for NASA: "So I'm challenging NASA to break through these barriers. And we'll give you the resources to break through these barriers. And I know you will, with ingenuity and intensity, because that's what you've always done" (Dunbar, 2010). This challenge and the newly allocated six billion in funding helped to catalyze NASA's Mars Exploration Program. In 2012, NASA administrator Charles Bolden announced the 2020 launch of a new Mars rover (Dunbar, 2012). The launch of the 2020 rover would conclude a decade of Mars exploration with missions such as Curiosity and Insight and move technology toward the 2030 crewed mission goal that was outlined by President Obama (Dunbar, 2012).

As the July/August 2020 launch date approaches, mission specifications have been finalized. The Perseverance Rover is being launched with overarching goals: to research the geological composition of the red planet, consider and search for evidence of past habitability, collect geological samples, and inform the design of a crewed mission by collecting data and testing new technologies ("Mars 2020," 2019). The rover will be sent to the Jezero Crater and will be operational for a minimum of one Mars year (687 days) ("Mars 2020," 2019). Between the 2012 announcement of the mission and the scheduled 2020 launch date, NASA scientists and

engineers have been working to design and assemble the 2,260 pound rover ("Mars 2020," 2019). In addition to NASA's own work, they have partnered with universities such as MIT and other assets such as the Oak Ridge Institute for Science and Education (ORISE) to ensure the mission is successful. Within ORISE, the Radiation Emergency Assistance Center/Training Site (REAC/TS) is working to ensure success of the mission's launch phase. As the Perseverance rover will derive its energy from a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) that contains plutonium dioxide, NASA is taking precautions in case the launch does not occur as planned and the radioactive plutonium compound escapes from the rover ("Preparing to Launch," n.d). Although such an event is unlikely, the consequences would be dangerous to spectators, personnel on site, and residents in the area surrounding the launch. REAC/TS is a critical partner to NASA due to their capability to prepare for and assist in the aftermath of radiation incidents. As this partnership prioritizes safety by mitigating the effects of a radioactive launch incident, it promotes a successful 2020 Perseverance rover launch.

Radiation Emergency Assistance Center/Training Site (REAC/TS)

The Radiation Emergency Assistance Center/Training Site (REAC/TS) is located at the Oak Ridge Institute for Science and Education (ORISE) in Tennessee. It is managed and sponsored by three larger organizations, the United States Department of Energy (DOE), the National Nuclear Security Administration (NNSA), and Oak Ridge Associated Universities (ORAU). Therefore, a review of REAC/TS should be preceded by a review of the DOE, NNSA, and ORAU.

REAC/TS Parent Organizations: Department of Energy and National Nuclear Security Administration

The US Department of Energy (DOE) was created by the Department of Energy Organization Act of 1977 ("A Brief History," n.d.). It merged the government's responsibilities of managing the energy sector and completing defense projects such as the Manhattan project into one department ("A Brief History," n.d.). In modern times, its mission has remained largely the same: "to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions" ("About Us," n.d.). As a result of this diverse mission, the DOE is a parent agency to many sub departments such as the National Nuclear Security Administration (NNSA). The NNSA is specifically tasked with promoting national security by maintaining the US nuclear stockpile, supplying the US Navy with nuclear propulsion systems, reducing the threat of nuclear weapons from other nations, and assisting in the recovery from post-radiation disasters ("About NNSA," n.d). Much like its parent agency, the DOE, the NNSA is highly structured to ensure each facet of their mission is successfully executed. REAC/TS is a facility of the DOE's NNSA.

REAC/TS Parent Organization: Oak Ridge Associated Universities

REAC/TS is managed by the Oak Ridge Associated Universities (ORAU) on behalf of the DOE and NNSA. The ORAU is a non-profit and a collaboration of over one hundred universities from across the United States such as the University of Miami, Purdue University, and Oregon State University ("ORAU Consortium Members," n.d.). The group was established in 1946 as the Oak Ridge Institute of Nuclear Studies (ORINS) and conducted research regarding the use of radioactive treatments for cancer ("Our History," n.d.). They became the ORAU in

1966 to convey the significance of the multiple universities comprising the group ("Our History," n.d.).

The consortium's goal is to mobilize academic resources on behalf of the government and in service of the public good ("Mission, Vision & Values," n.d.). The ORAU is heavily involved in community relations through donations for United Way and the Second Harvest Food Bank, grants to promote STEM education, and a sponsorship of Dolly Parton's Imagination Library ("Community Relations," n.d). In addition to community outreach, ORAU remains involved with radiation study. Their experts help to conduct epidemiology studies related to occupational hazards such as radiation, act as consultants for companies working to meet radiation guidelines, and improve emergency preparedness ("Expertise," n.d.). Through ORAU's mission and efforts in the community, it is evident that their overarching purpose is to use their resources, such as radiation research and donations, to benefit individuals in their surrounding community and across the nation.

The ORAU manages the Oak Ridge Institute for Science and Education (ORISE) to execute their mission goals. REAC/TS is part of ORISE, and it is directed by Dr. Carol Iddins. (Schwinge, 2019). Specifically, REAC/TS' mission is to promote an effective response to disasters involving radiation or nuclear materials (Schwinge, 2019). This mission statement is a specific aspect of its parent organizations' broader goals. Therefore, as a smaller organization working on behalf of the DOE, NNSA, and ORAU, REAC/TS has a more narrow focus, allowing for specialization and a more efficient execution of tasks. This division of work allows the larger organization to accomplish their diverse array of goals effectively.

Radiation Emergency Assistance Center/Training Site (REAC/TS) Capabilities

The Radiation Emergency Assistance Center/Training Site (REAC/TS) has a variety of resources that allow it to fulfill its goal of improving the response to radiation accidents. Broadly, these resources include response assistance, training, and maintenance of information ("Nuclear Incident Response," n.d.). First, REAC/TS sponsors a 24/7 hotline at 865-576-1005 ("Radiation Emergency," n.d.). This hotline receives approximately 55 calls per year (Ricks et al., 1999). When a medical provider treating a patient involved with a radiation incident contacts this hotline, they will be asked to provide basic information about the incident such as whether it was an exposure or contamination problem, what isotope was involved, and whether the patient was wearing a dosimeter ("Radiation Emergency," n.d.). As experts gain insight into these details, they may ask for further clarification and then provide treatment advice to the provider. Furthermore, REAC/TS also provides in-person assistance. Depending on the nature and severity of the incident, experts may be deployed to the site of the radiation incident with medical equipment ("Radiation Emergency, " n.d.). A deployment team would consist of a combination of physicians, nurses, health physicists, and paramedics ("Emergency Response," n.d.). These resources have been utilized on a global scale. For example, REAC/TS experts assisted in the response to the Chernobyl reactor explosion in 1986 (Smith, 2016). They have also assisted in Mexico and Brazil when citizens were exposed to cobalt-60 and cesium-137, respectively (Smith, 2016).

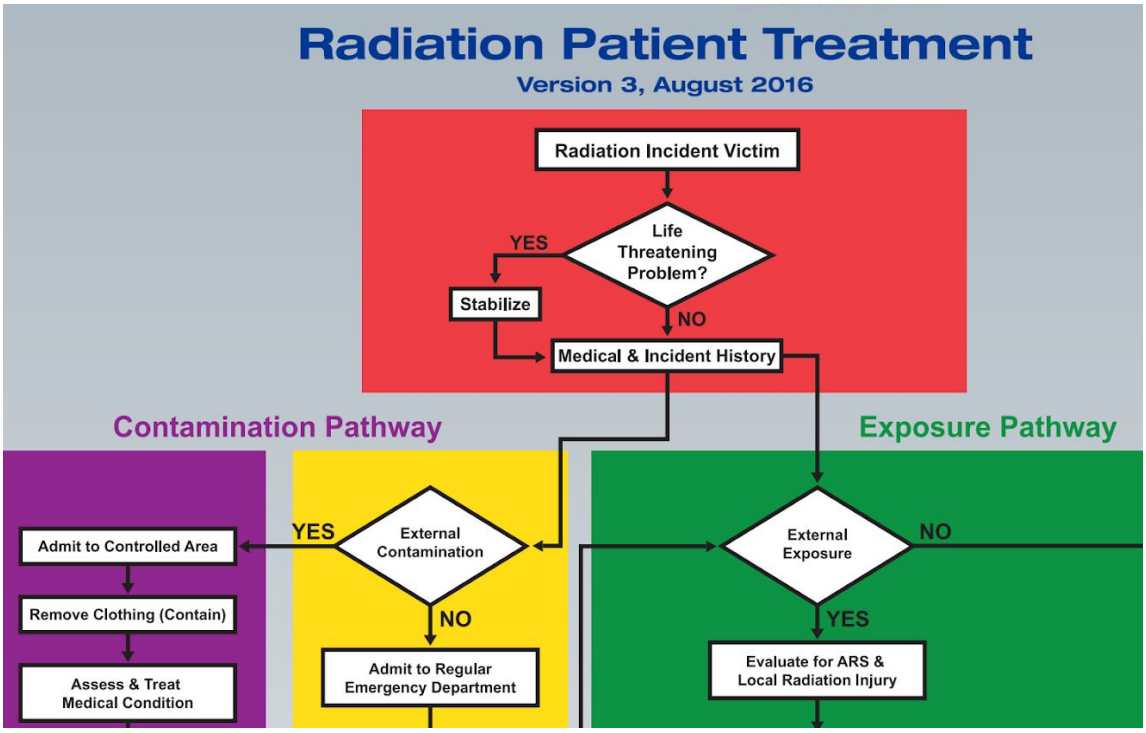
In addition to the previously outlined resources, REAC/TS' Cytogenetic Biodosimetry Laboratory is also critical in the response to radiation incidents. The primary purpose of this laboratory is to assess the level of radiation an individual has received ("Cytogenetic

Biodosimetry," n.d.). This is essential in the treatment of patients as providers will be better able to tailor their care depending on the severity of radiation ("Cytogenetic Biodosimetry," n.d.). It also informs the allocation of response resources: patients with higher levels of radiation exposure should receive more treatment resources ("Cytogenetic Biodosimetry," n.d.). In order to determine this data, the laboratory utilizes their knowledge that exposure to radiation affects a human's genetic material. Specifically, the lab considers dicentric chromosomes, which is an irregularity occurring when radiation causes a split and a fusion of chromosomes ("Cytogenetic Biodosimetry," n.d.). Higher counts of dicentric chromosomes indicate higher amounts of radiation.

Secondly, REAC/TS provides an array of educational resources to train medical providers in the response to radiation incidents. They have developed an online video series with titles such as "Ground and Air Medical Transport of Radiologically Contaminated Patients" ("REAC/TS Resources," n.d.). Furthermore, they provide online pamphlets for reference. One such pamphlet is titled "Radiation Patient Treatment Algorithm," and its flowchart design allows providers to easily follow a course of treatment for their patient depending on factors such as whether the incident was an contamination or exposure event (Figure 1). In addition, REAC/TS sponsors training courses for providers. In the course of a year, they have worked with the Knox - East Tennessee Healthcare Coalition to host three training days providing a survey of health physics and emergency response ("REAC/TS shares," n.d.). Although these workshops were held in Tennessee, they have a global impact as individuals from countries such as Finland and Romania attended ("REAC/TS shares," n.d.). REAC/TS also provides courses in Radiation Emergency Medicine, Advanced Radiation Medicine, and Health Physics in Radiation

Emergencies ("Continuing Medical," n.d.). These courses are accredited by both the American College of Emergency Physicians and the American Academy of Health Physics ("Continuing Medical," n.d.). If the provided training courses do not fit an organization's needs, the Education Coordinator may help to provide more specialized courses for training ("Continuing Medical," n.d.).These have been widely utilized; in the first forty years of REAC/TS, more than 9,000 providers have taken one of their courses (Smith, 2016).

Figure 1: Portion of Radiation Patient Treatment Algorithm Pamphlet



(Retrieved from orise.orau.gov)

Finally, REAC/TS maintain three registries: U.S. and Non - U.S. Radiation Accident Registry, Diethylenetriaminepentaacetic Acid (DTPA) User Registry, and the Prussian Blue Registry ("Emergency Response," n.d.). The radiation accident registry logs radiation incidents by drawing on sources such as the World Health Organization, state health departments, and calls to the hotline (Ricks, 1999). By tracking this data, REAC/TS may better understand the

nature and cause of the majority of radiation incidents and seek to reduce them. Next, the DTPA and Prussian Blue registry are used to track individuals after they have received treatment for radiation ("Medical Countermeasures," 2018). This registry allows REAC/TS to follow-up with these patients and assess the success of the DTPA or Prussian Blue treatments they received.

During the 2020 launch, NASA is primarily utilizing REAC/TS' training resources and expert assistance. First responders in the area surrounding Cape Canaveral are completing training, and REAC/TS experts will be on-site during the launch ("Preparing to Launch," n.d.). These measures are precautionary for the unlikely event that the plutonium housed in the rover escapes. NASA's utilization of these resources ensures that, in this event, first responders and physicians would be able to care for individuals exposed to the radioactive plutonium. If a radiation incident occurred, NASA would also utilize another REAC/TS' resource: the registries. These registries would be used to log the event and track patients post-treatment.

REAC/TS and NASA: the Launch of the Perseverance Rover

The Perseverance rover utilizes a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) as power. This generator utilizes heat derived from decaying plutonium-238 to create electricity for the rover (Bechtel, 2013). Specifically, the heat from 10.6 pounds of Pu-238 heats one side of a thermocouple junction while the other side remains cool from the low temperature on Mars (Bechtel, 2013; "Electrical Power," n.d.). This temperature differential allows for an electrical current to be produced within the closed circuit of the thermocouple, as first discovered by Thomas Seebeck in the 1820's (Bechtel, 2013). In addition to generating electrical power, the MMRTG also keeps the rover's technology warm in the low Mars temperatures (Bechtel, 2013)

The design of the MMRTG prioritizes durability and safety. It has a lifetime of 14 years and has been used on multiple previous NASA missions such as Curiosity, Apollo, and Viking ("Electrical Power," n.d.). To ensure safety, the DOE created the plutonium in a breakage-resistant, ceramic-like form and encased it in a protective structure ("Electrical Power," n.d.). These precautions are necessary because plutonium is radioactive and emits alpha particles ("Plutonium," 2018). Plutonium is primarily dangerous to humans if it is inhaled, ingested, or enters the body through a wound. Of main concern is inhalation; in this case, the substance could travel from the lungs into the circulatory and lymphatic systems and settle in organs such as the liver, which could eventually lead to cancer ("Plutonium," 2018).

Therefore, the primary radiation threat to humans during the 2020 Perseverance launch is the inhalation of aerosolized Pu-238. This could occur if a launch anomaly occurred and the MMRTG was compromised. In this scenario, an individual close to the site could receive 210 millirem of radiation ("Electrical Power," n.d.). Although a launch anomaly is unlikely, first responders and physicians in the area must still be knowledgeable about how to manage patient exposure to plutonium radiation. As stated by Dr. Jenkins, a health physicist from REAC/TS, "... due diligence says you prepare…" ("Preparing to Launch," n.d.). As a result, NASA has partnered with REAC/TS to provide expert knowledge and training regarding Pu-238. Furthermore, during launch, REAC/TS experts (a physician and a health physicist) will be onsite to provide additional guidance if an anomaly were to occur ("Preparing to Launch," n.d.).

REAC/TS expertise contributes to a successful launch of the Mars 2020 rover. By helping the surrounding community prepare for launch, they are prioritizing the safety and health of NASA employees and spectators who will be close to the launch location. Inevitably, there are

risks associated with launching a MMRTG. Regardless of the precautions taken, there is always the low possibility that a launch anomaly could occur, and it must be accounted for. REAC/TS partnership with NASA is integral to the risk mitigation plan. Specifically, the precautionary measures allow NASA to fulfill risk mitigation by "minimizing the consequences of occurence" ("Guidelines for Risk Management," 2017). By accounting for risk in the mission timeline, REAC/TS is supporting a successful launch of the Mars 2020 Perseverance rover.

In conclusion, REAC/TS carries out a specific goal to help fulfill the larger missions of its parent organizations: the DOE, NNSA, and ORAU. In order to improve the medical response to radiation incidents, REAC/TS conducts research and provides training and expert advice. Their impact is widespread and has national and international impacts. REAC/TS' expertise will benefit NASA during the launch of the Perseverance rover which utilizes a MMRTG with radioactive plutonium. This partnership is primarily precautionary as it prepares the local community for a launch anomaly, but regardless, is critical to NASA's risk mitigation. Therefore, REAC/TS' partnership with NASA is helping to ensure the progress of space exploration in a manner that ensures the health of residents on Earth. As this partnership prioritizes safety, it is integral to the success of the 2020 Mars rover launch.

References

A Brief History of the Department of Energy. (n.d.). Retrieved March 15, 2020, from https://www.energy.gov/management/office-management/operational-management/history/brief-history-department-energy

About NNSA. (n.d). Retrieved March 15, 2020, from https://www.energy.gov/nnsa/about-nnsa

About Us. (n.d.). Retrieved March 15, 2020, from https://www.energy.gov/about-us

Bechtel, R. (2013, October). Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). Retrieved March 18, 2020, from https://mars.nasa.gov/internal_resources/788/

Cytogenetic Biodosimetry Laboratory. (n.d.) Retrieved March 17, 2020, from https://orise.orau.gov/reacts/cytogenetic-biodosimetry-laboratory.html

Dunbar, B. (2010, April 15). President Barack Obama on Space Exploration in the 21st Century. Retrieved March 15, 2020, from https://www.nasa.gov/news/media/trans/obama_ksc_trans.html

Dunbar, B. (2012, December 4). NASA Announces Robust Multi-Year Mars Program; New Rover to Close Out Decade of New Missions . Retrieved March 15, 2020, from https://www.nasa.gov/home/hqnews/2012/dec/HQ_12-420_Mars_2020.html

Community Relations. (n.d.). Retrieved March 15, 2020, from https://www.orau.org/about/community.html

Continuing Medical Education. (n.d.). Retrieved March 17, 2020, from https://orise.orau.gov/reacts/continuing-medical-education/index.html

Electrical Power. (n.d.). Retrieved March 18, 2020, from https://mars.nasa.gov/mars2020/mission/rover/electrical-power/

Emergency Response to Radiation Incidents. (n.d.). Retrieved March 17, 2020, from https://orise.orau.gov/reacts/emergency-response-to-radiation-incidents.html

Expertise. (n.d.). Retrieved March 15, 2020, from https://www.orau.org/index.html+

Guidelines for Risk Management. (2017, October 16). Retrieved March 18, 2020, from https://www.nasa.gov/sites/default/files/atoms/files/s3001_guidelines_for_risk_management_-_ver_g_-_10-25-2017.pdf

Smith, D. (2016, October 25). Historically Speaking: REAC/TS - 40 years of excellence in radiation emergency medicine. Retrieved March 17, 2020, from https://www.oakridger.com/opinion/20161025/historically-speaking-reacts---40-years-of-excellence-in-radiation-emergency-medicine

Mars 2020. (2019, December). Retrieved from https://mars.nasa.gov/files/mars2020/Mars2020_Fact_Sheet.pdf

Mission, Vision & Values. (n.d.). Retrieved March 15, 2020, from https://www.orau.org/about/mission.html

Nuclear Incident Response. (n.d.). Retrieved March 17, 2020, from https://www.energy.gov/nnsa/nuclear-incident-response

ORAU Consortium Members. (n.d.). Retrieved March 15, 2020, from https://www.orau.org/university-partnerships/consortium-members.html

Our History. (n.d.). Retrieved March 15, 2020, from https://www.orau.org/about/history.html

Plutonium. (2018, December) Retrieved March 18, 2020, from https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/plutonium.aspx

Preparing to Launch: REAC/TS supports NASA in Mars 2020 Mission. (n.d.). Retrieved March 15, 2020, from https://orise.orau.gov/reacts/features/reacts-supports-nasa-in-mars-2020-mission.html

Radiation Emergency Assistance Center/Training Site (REAC/TS). (n.d.). Retrieved March 15, 2020, from https://orise.orau.gov/reacts/index.html

REAC/TS celebrates 40 years as international leader in emergency medical response. (2016, July 1). Retrieved March 15, 2020, from https://www.energy.gov/nnsa/articles/reacts-celebrates-40-years-international-leader-emergency-medical

REAC/TS Resources (n.d). Retrieved March 17, 2020, from https://orise.orau.gov/reacts/resources/index.html

REAC/TS shares unique radiation emergency medicine expertise with the world. (n.d.). Retrieved March 17, 2020, from https://orise.orau.gov/reacts/features/reacts-shares-unique-radiation-emergency-medicine-expertise-with-the-world.html

Ricks, R., Berger, M., Holloway, E., & Goans, R. (1999). REAC/TS Radiation Accident Registry: Update of Accidents in the United States. Retrieved March 17, 2020, from http://www.irpa.net/irpa10/cdrom/00325.pdf

Schwinge, A. (2019, January 19). Director named at Radiation Emergency Assistance Center/Training Site. Retrieved March 15, 2020, from https://oakridgetoday.com/2019/01/19/director-named-at-radiation-emergency-assistance-centertraining-site/