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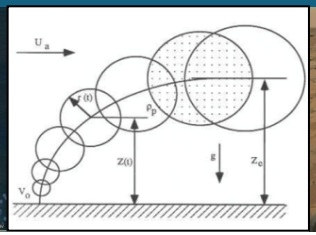
Sandia National Laboratories

Summary of the Nuclear Risk Assessment 2019 Update for the Mars 2020 Mission Environmental Impact Statement



PRESENTED BY

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Probabilistic Safety Assessment & Management PSAM 16

June 26-July 1, 2022

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Perseverance Rover on Mars

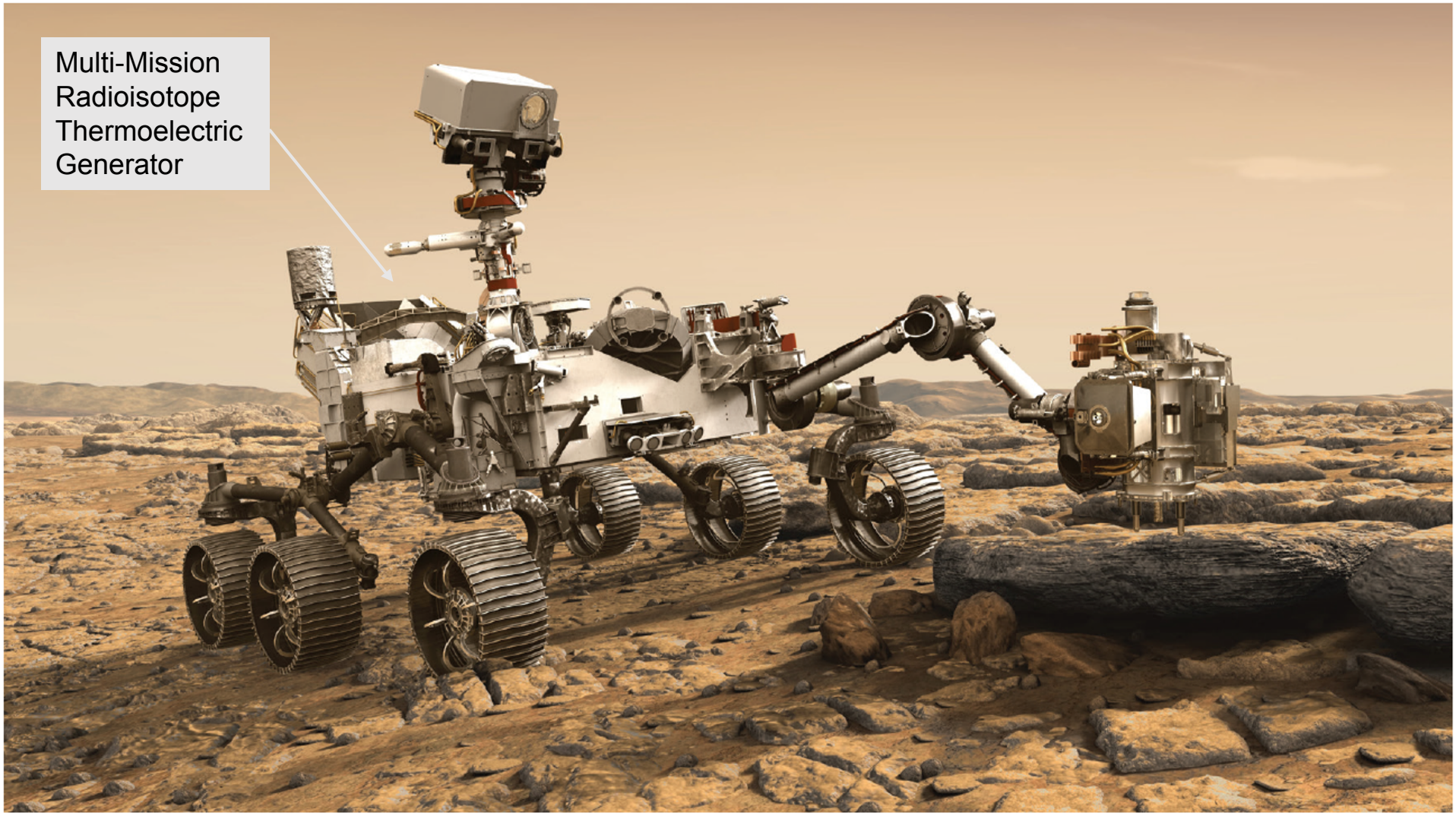
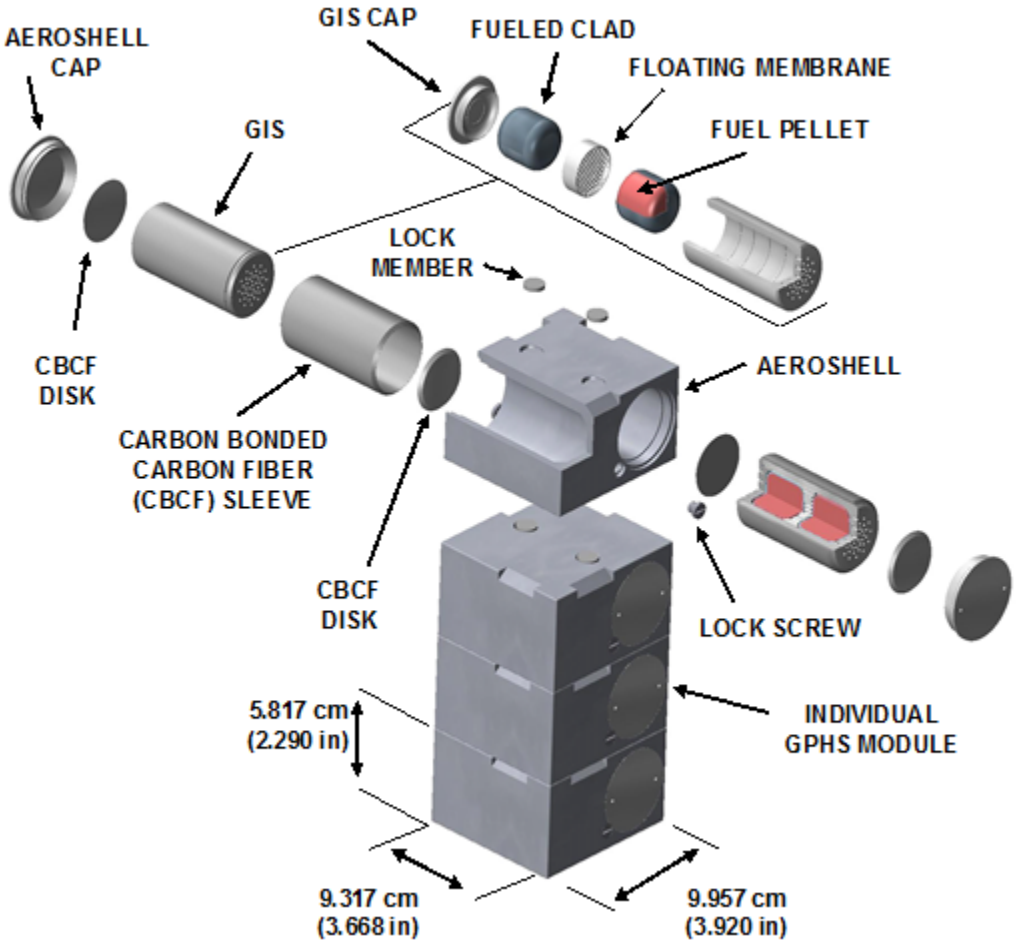
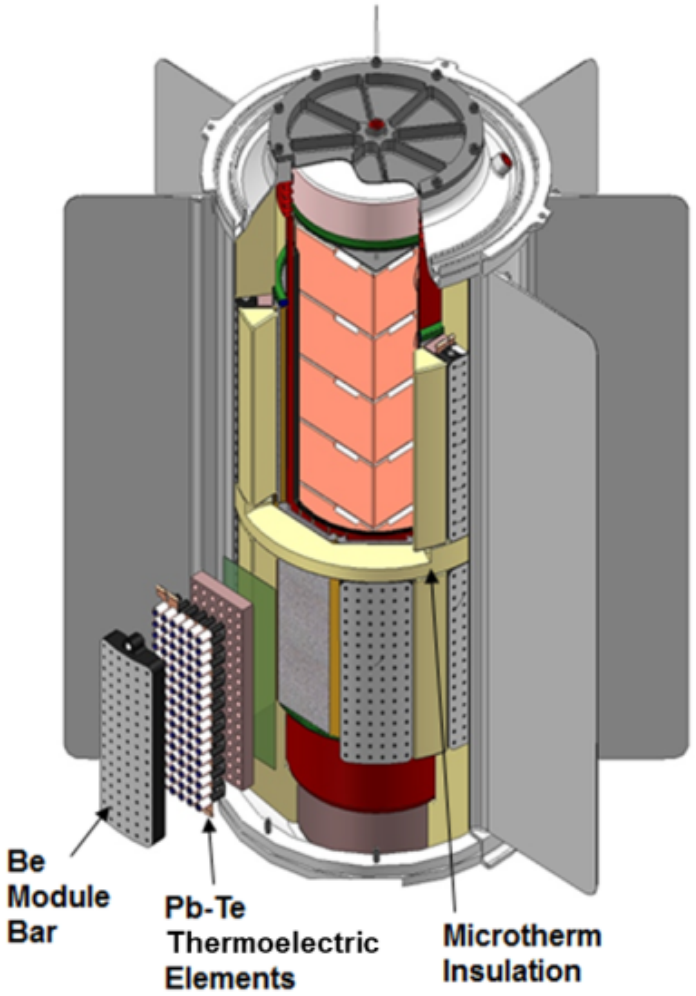


Image Courtesy NASA

Multi-Mission Radioisotope Thermoelectric Generator (MMRTG)





Safety is built from the inside out and from the outside in. Analysis must quantify this for decision makers.

Space Nuclear System Sits on Top of a Very Powerful Launch Vehicle

Images Courtesy NASA

Launches Can Fail

Atlas Fallback-1965

Titan 34D-Apr 18, 1986

Antares-Oct 28, 2014

Delta 241-Jan 27, 1997

Space Nuclear Systems Launch Safety Approach

Identify **main sources** of risk, to allow for potential **mitigating actions**, to **reduce** the overall mission **risk**

Goal: **Quantitative** estimate of the risk that is **defensible** and **credible**

- Mean probability of an accident
- Mean probability of release of radioactive material
- Mass of material released ("source term")
- Health effects (doses, latent cancer fatalities)
- Land, crop contamination
- All expressed as mean values, percentile values, and exceedance probability graphs
- Quantify uncertainty

Characterization of Risk

Probabilistic **methods** applied to generate specific **probabilities** of interest to define the **risk** picture for **decision makers**

$$P(C > c_i) = P(C > c_i|release)\ P(release|accident)\ P(accident)$$

Probability of an accident occurring

Probability of a release given an accident

Probability of a consequence greater than a certain threshold given a release

Mission Phases

Phase 0 – Prelaunch, $T < t_1$, from installation of the system to just prior to start of engines at t_1

Phase 1 – Early Launch, $t_1 \leq T < t_x$, start of engines to no potential for land impact in the launch area, t_x

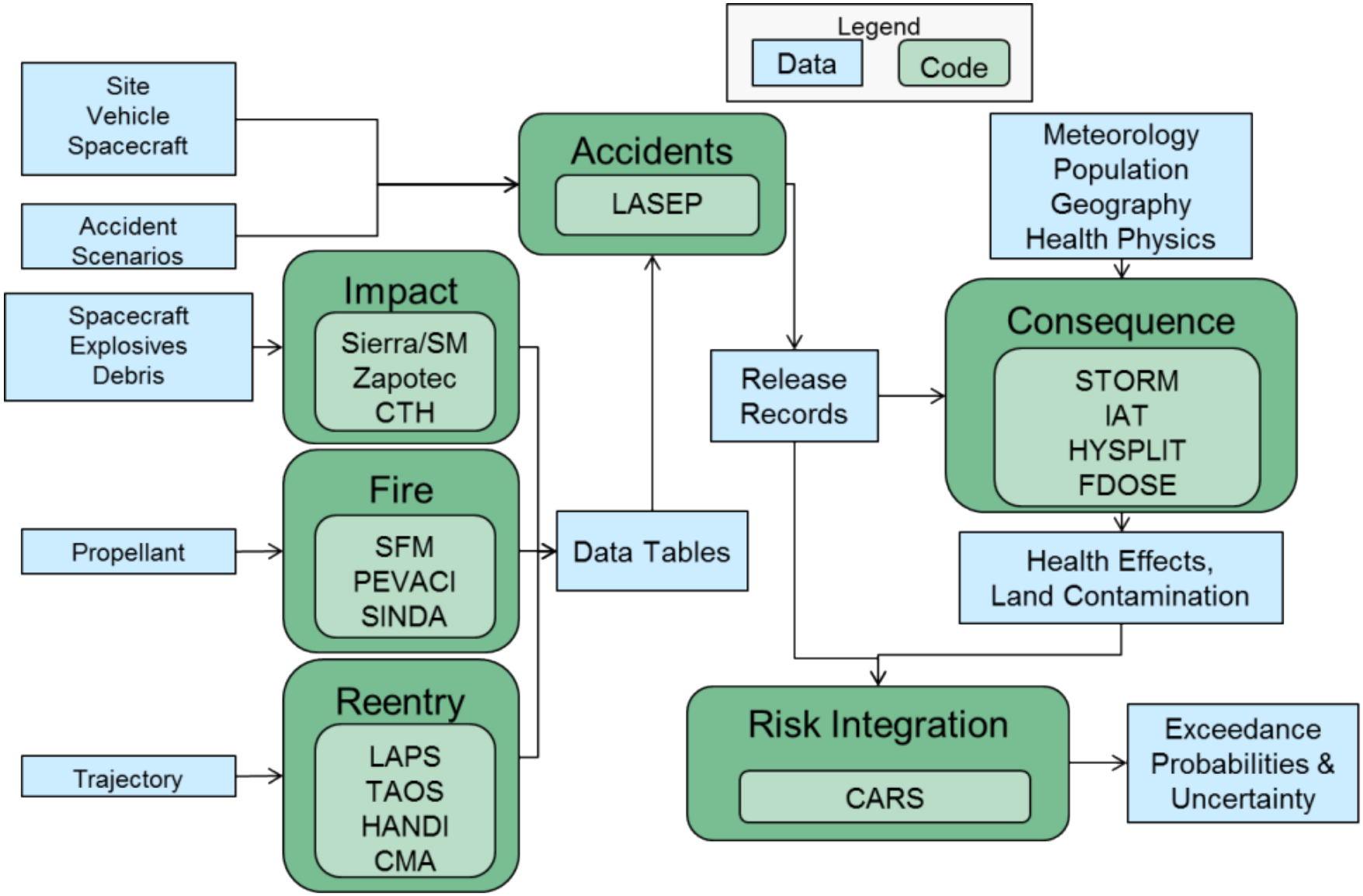
Phase 2 – Late Launch, $t_x \leq T$, end of Phase 1 to the launch vehicle reaching 30,480 m (100,000 ft), above which reentry heating could occur

Phase 3 – Suborbital Reentry, end of Phase 2 to just prior to orbit

Phase 4 – Orbital Reentry, end of Phase 3 to spacecraft separation

Phase 5 – Long-Term Reentry, end of Phase 4 to no chance of Earth reentry

Launch Safety Code Suite



National Environment Policy Act Activities

January 2014 – Nuclear Risk Assessment (NRA) for the Mars 2020 mission

November 2014 – Final Environmental Impact Statement (FEIS)

January 2015 – Record of Decision (RoD) to proceed with mission

Investments made towards mission

- Mars 2020 rover and scientific payload design
- Mars landing site selection
- Selection of launch vehicle and launch period
- Power system fueling
- NASA/DOE safety testing & modeling updates

July 2019 – Mars 2020 Mission Final Safety Analysis Report

August 2019 –National Security Presidential Memorandum-20 (NSPM-20)

September 2019 – Nuclear Risk Assessment 2019 Update

January 2020 – Supplemental Environmental Impact Statement (SEIS)

National Security Presidential Memorandum-20

This Memorandum establishes an updated and risk-informed **process** for **launching space nuclear systems** by

- Structuring launch authorization for space nuclear systems to follow a **tiered process** based on system characteristics, level of potential risk, and national security considerations
- Establishing **safety guidelines** to assist mission planners and launch authorization authorities in ensuring launch safety across the full range of space nuclear systems.
- Directing that safety analyses incorporate **past experience** to maximize effectiveness and efficiency.
- Replacing the mission-specific **ad hoc** Interagency Nuclear Review **Panel** (INSRP) with a **standing** Interagency Nuclear Safety Review **Board** (INSRB).

Comparison with NSPM-20 Safety Guidelines

Results from the **NRA 2019 Update** show **probabilities** and uncertainty intervals at the NSPM-20 **dose levels within safety guidelines**

Accident Probability Comparison

Reduction due to updated launch vehicle information

- Selection of launch vehicle
- Additional launches of similar launch vehicles
- Fault tree development

Total Probability of Release Comparison

Increase due to model and input parameter updates

- Solid propellant fragmentation and trajectory
- Liquid and solid propellant fire environments
- Plutonia release model
- Potential debris impact area
- Blast model information
- Module and iridium cladding response to impact forces

Consequence Measure Comparison

Increase due to model updates and increased source terms

- Weather data
- Propellant plume rise with particle tracking in plumes
- Age-specific and organ-specific dose coefficients
- Organ-specific and exposure pathway-specific risk coefficients
- Region-specific crop information

Consequence Risk Comparison

Increase in consequence risks

- Decrease in accident probability
- Increase in release probability, source term, and consequence measures

Uncertainty level of 25x specified in 2014 NRA

- Three consequence risks above factor of 25
- Three consequence risks below factor of 25

Summary

NRA addresses **response of system** to potential accident and abort conditions and provides the **technical basis** for radiological risks in **SEIS**

NRA updated based on specific investments and revised models and input parameters

Overall mission consequence **risks increased**

SEIS issued based on updated information

Well **within safety guidelines** in NSPM-20

Successful launch and landing on Mars (and still going strong)