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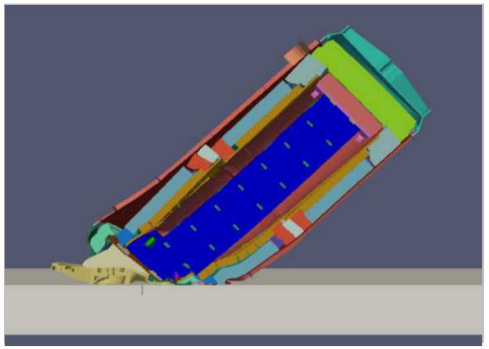


Launch Safety – Mars 2020 Mission

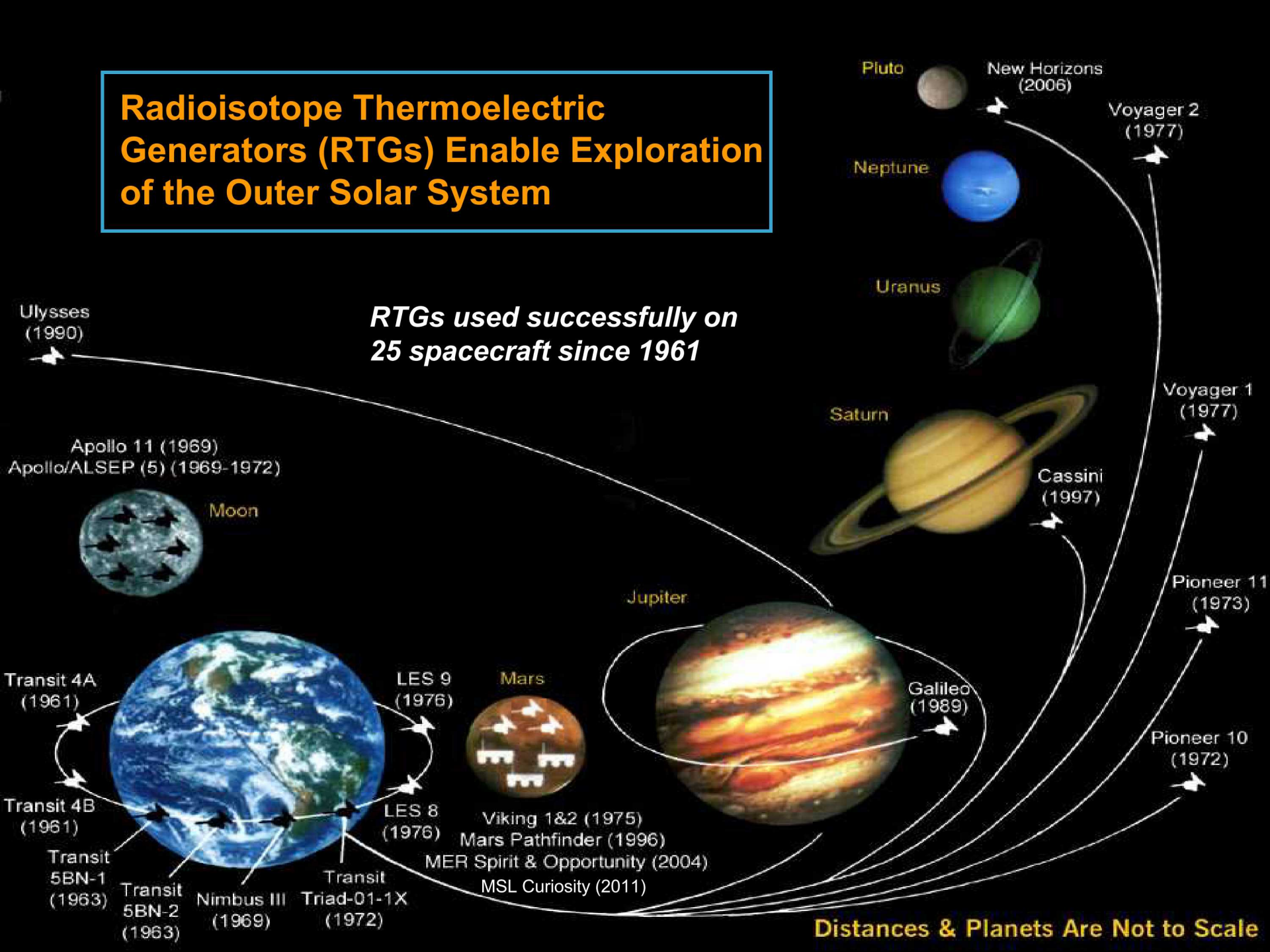
Dan Clayton

Radioisotope Power System Launch Safety (RPSLS) Project Manager

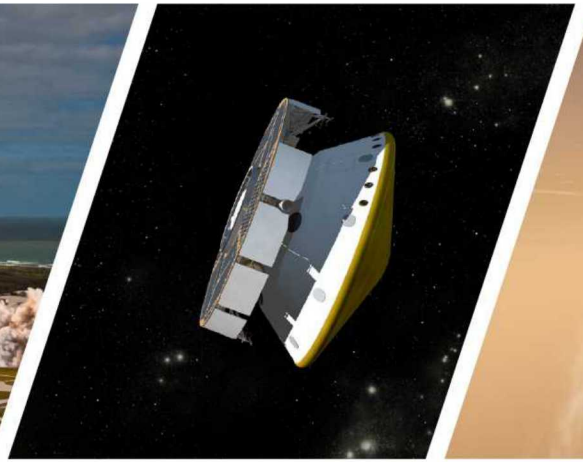
April 22, 2019

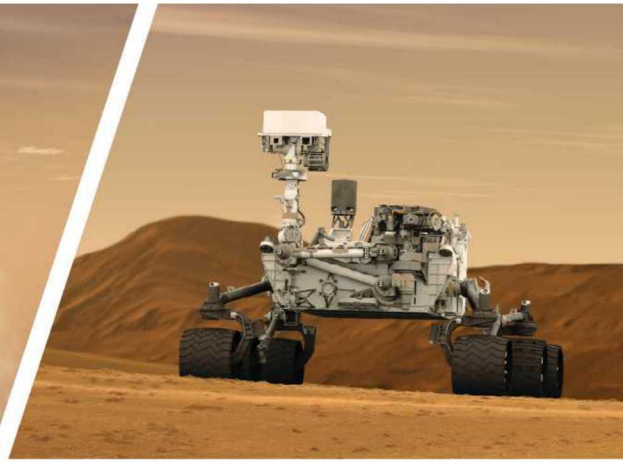
Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525. SAND2019-XXXX

Radioisotope Thermoelectric Generators (RTGs) Enable Exploration of the Outer Solar System



Mars 2020: Mission Concept



LAUNCH

- MSL Class/Capability LV
- Period: July/Aug 2020

CRUISE/APPROACH

- 7.5 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

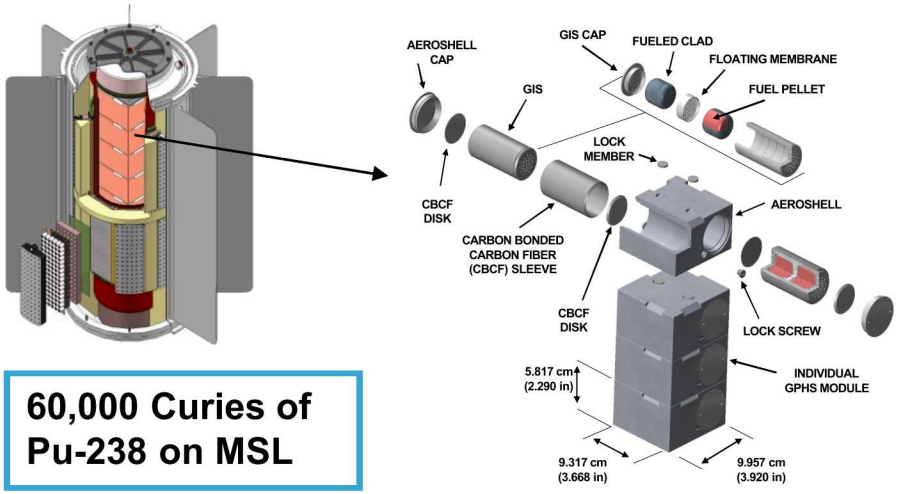
- MSL EDL system: guided entry and powered descent/Sky Crane
- 25x20km landing ellipse
- Access to landing sites ±30° latitude, ≤0.5 km elevation
- ~950 kg rover

SURFACE MISSION

- Prime mission of one Mars year
- 20 km traverse distance capability
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

http://mars.jpl.nasa.gov/mars2020/

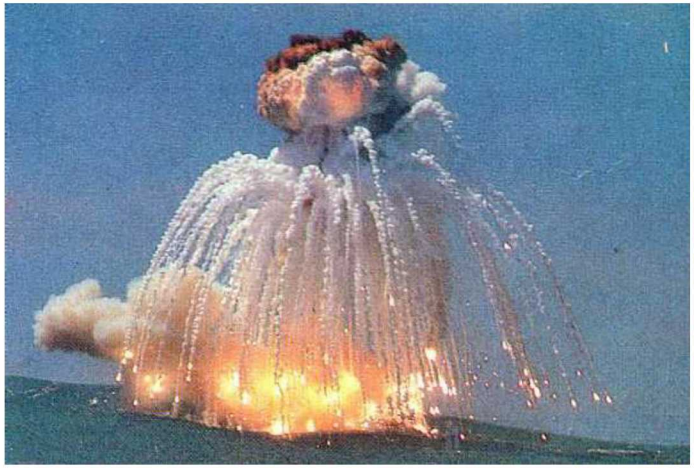
1% of all Launches Fail Near the Pad



60,000 Curies of Pu-238 on MSL

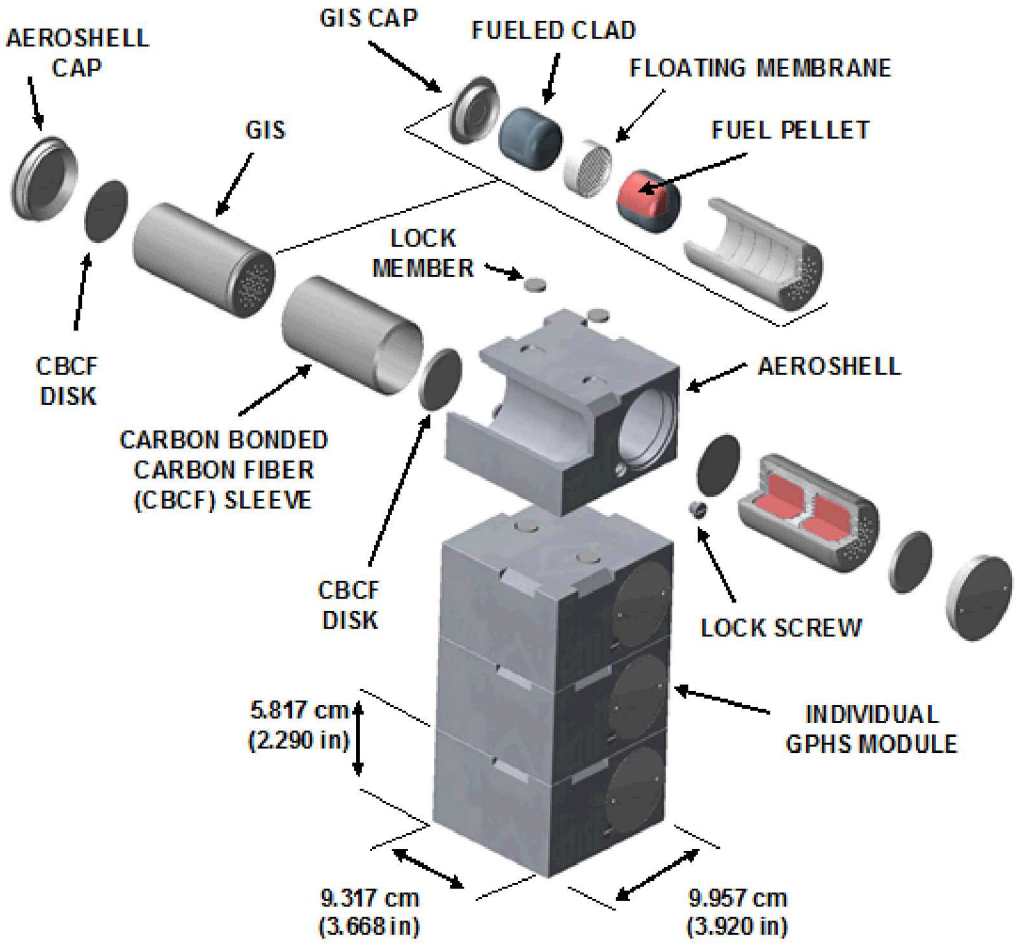
Delta 241 Jan 27, 1997

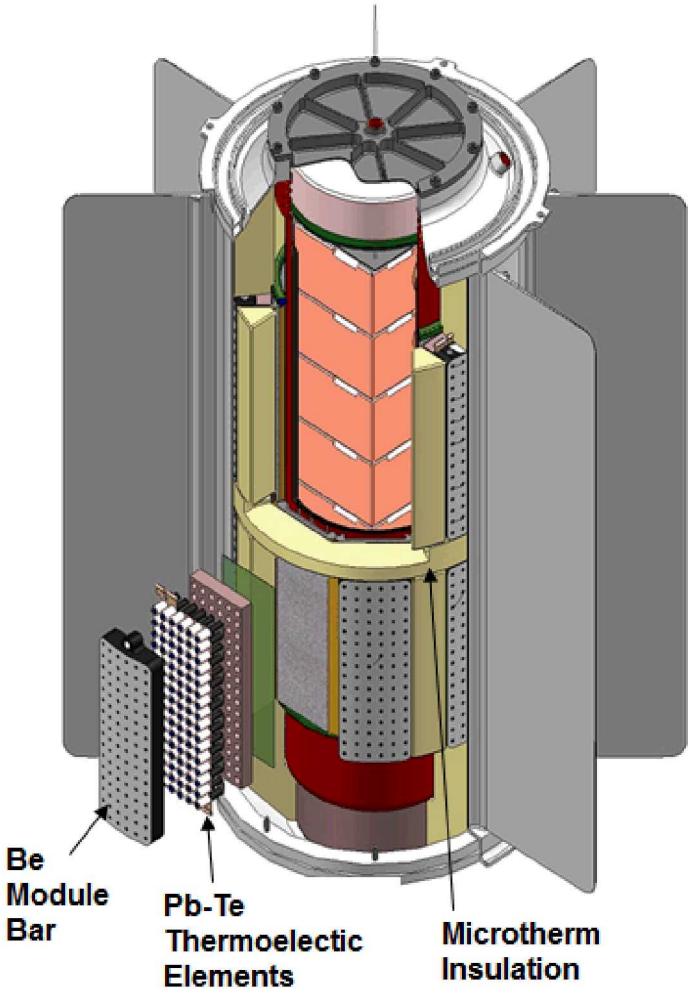
Atlas Fallback



Titan 34D

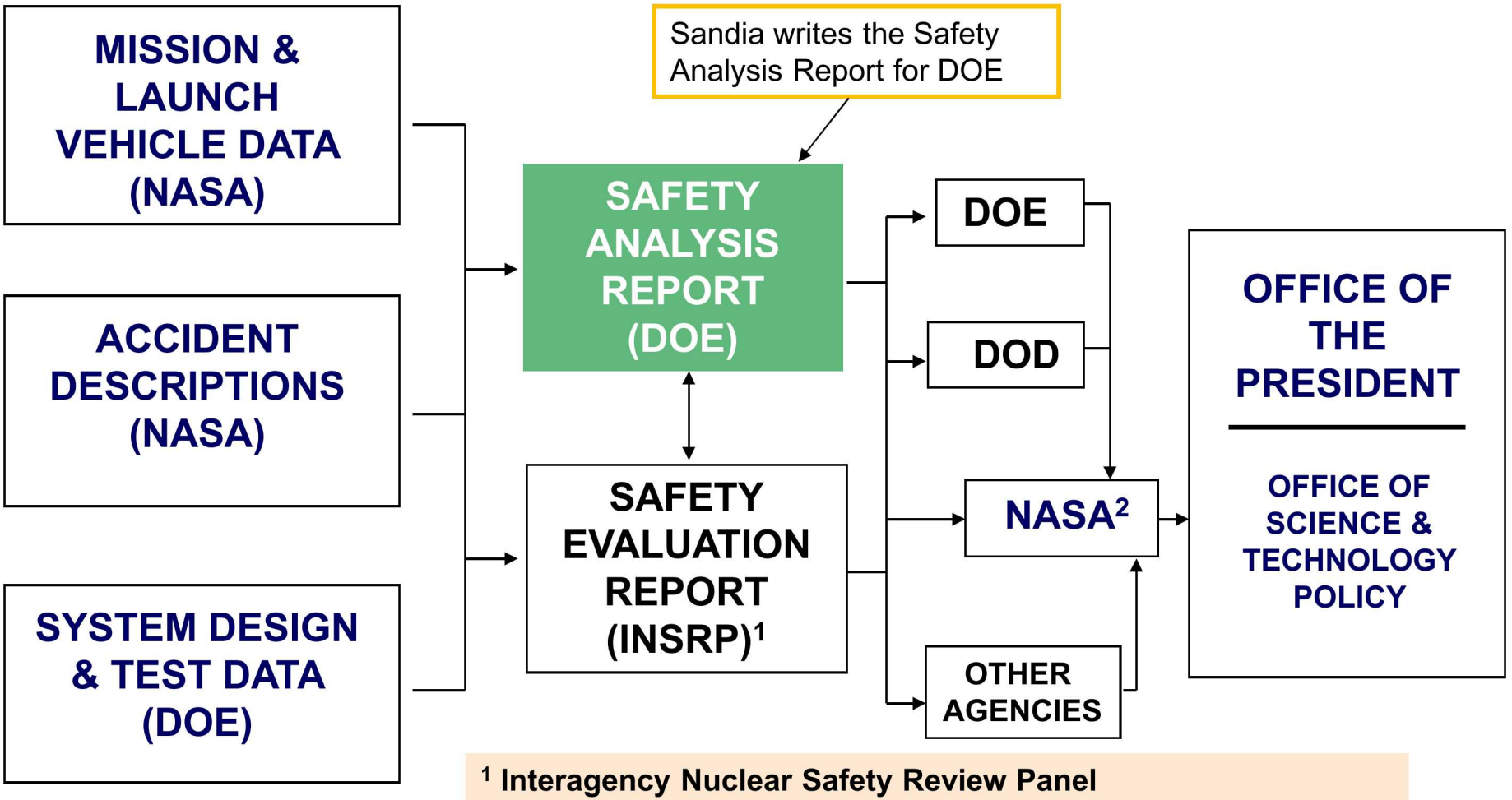
Step-2 GPHS Modules and MMRTG





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

Presidential Directive / NSC-25 Requires Presidential Approval (or Designee) for All Launches with Nuclear Payload



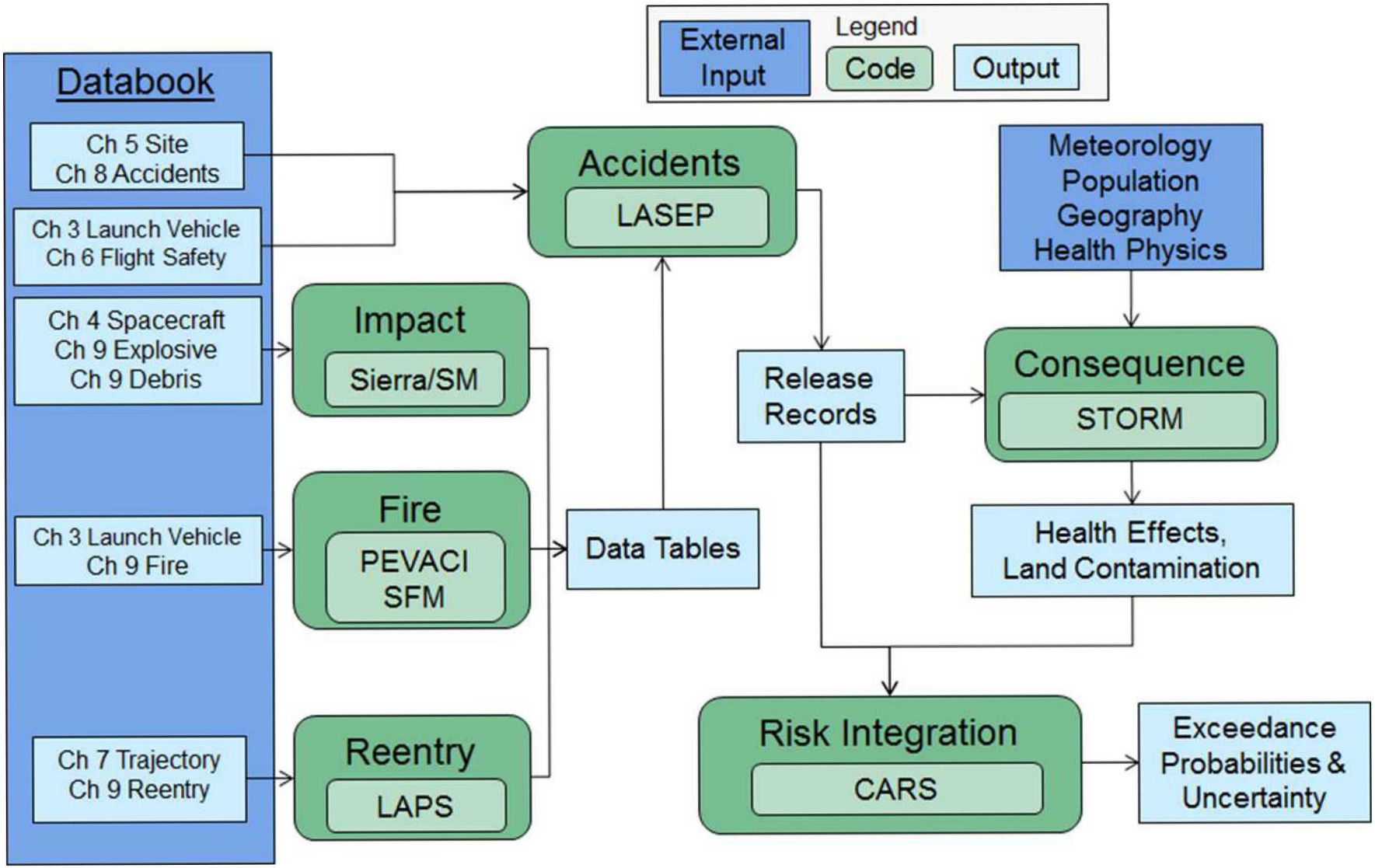
[1] Interagency Nuclear Safety Review Panel (DOE, NASA, DoD, EPA, NRC (advisory))
[2] Responsible mission agency makes launch recommendation

Risk Estimation Methodology

Sandia National Laboratories

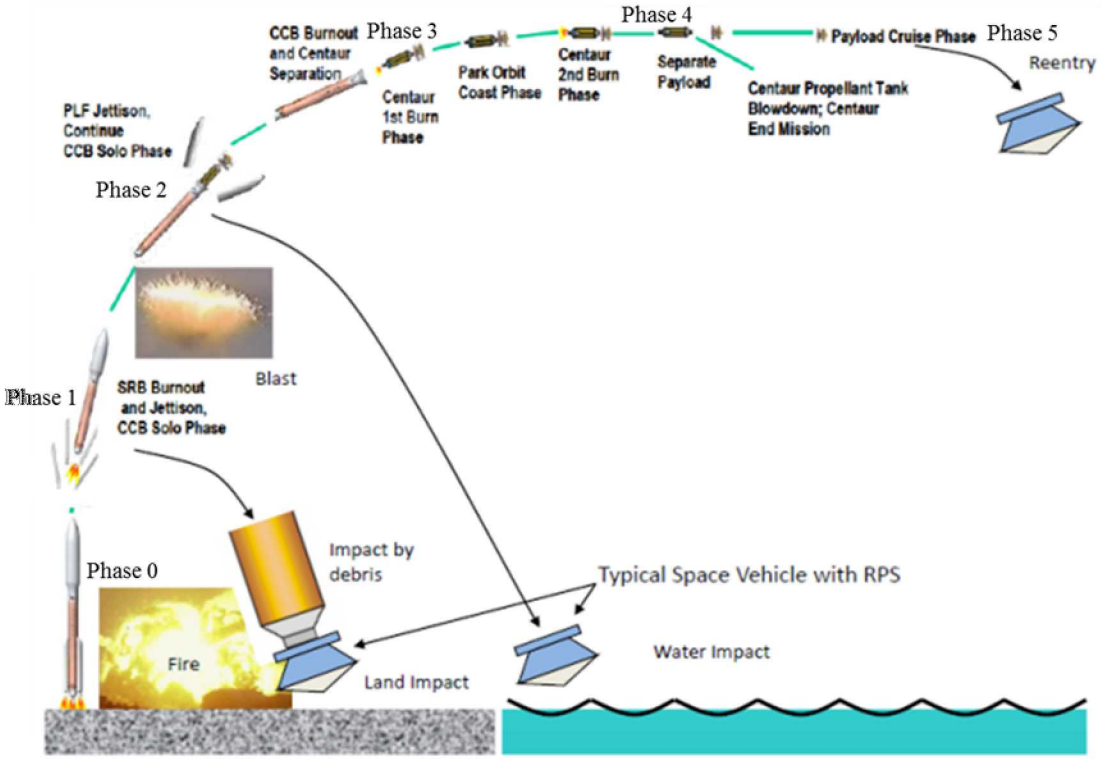
- Detailed simulations and Monte Carlo sequence codes used to develop the probabilistic risk analysis
  - Potential accidents associated with the launch
    - Probability
    - Environment
  - Detailed understanding of the response of power system to insults
    - Explosion Overpressure
    - Fragments
    - Ground Impact
    - Thermal Environment
    - Re-entry
  - Atmospheric transport and consequences
    - Thermal buoyancy effects from fires
    - Meteorological conditions
    - Population and land usage distribution

Launch Safety Code Suite



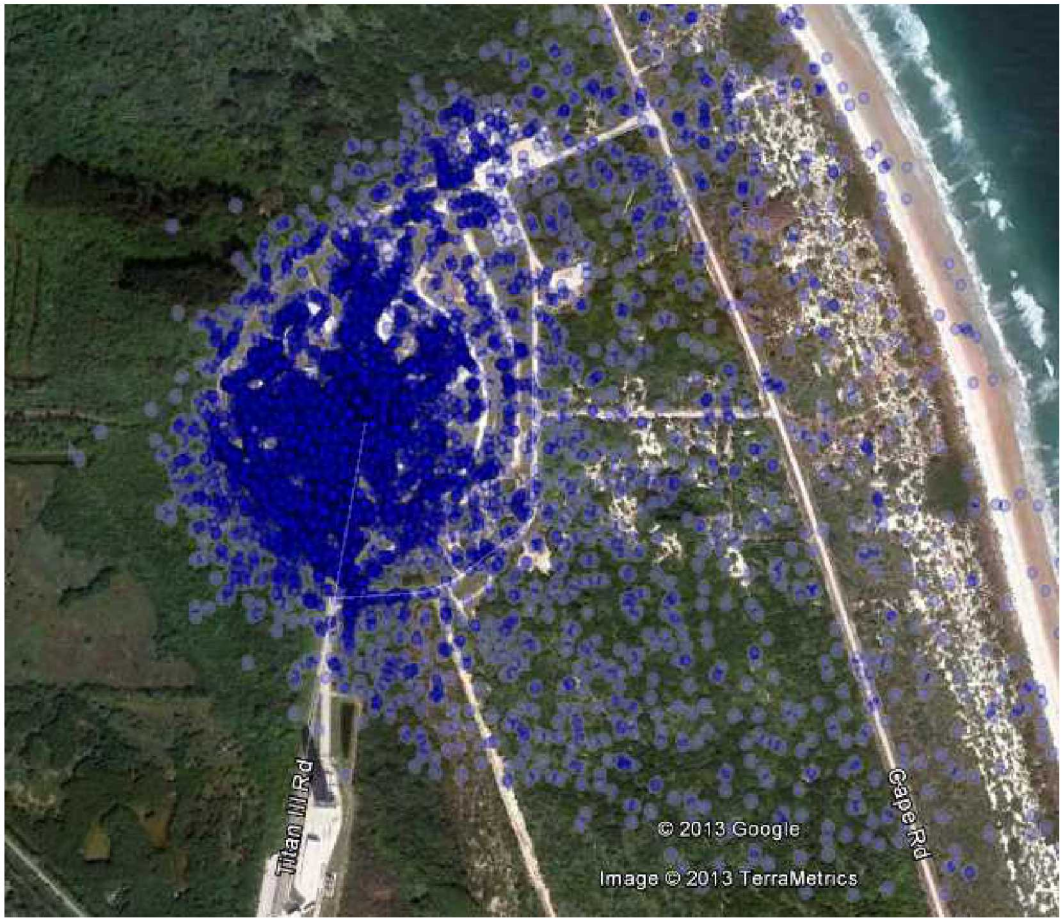
Representative Accident Scenarios (RASs)

- Divide mission into six phases
- Construct accident scenarios within each phase
- Groups accident environments into RASs
- Combine results from each RASs into phase and overall results, based on the relative probability



Release Locations and Amounts

- LASEP models numerous potential scenarios, randomly choosing time of failure, explosion characteristics, etc.
- Release location and amounts determined mechanistically
- Probability distributions for release are determined



Potential release locations from numerous LASEP launch simulations

Summary

- Safety analyses are required, and enabling, for the use of radioisotope power systems
- The response to potential accident scenarios is modeled in a stochastic manner with a Monte Carlo simulation
  - Results are summed and weighted by appropriate likelihood values
  - Estimated health risk calculated
- This information is used to guide power system or spacecraft designs, mission architecture or launch procedures
  - Potentially reduce risk
  - Inform decision makers