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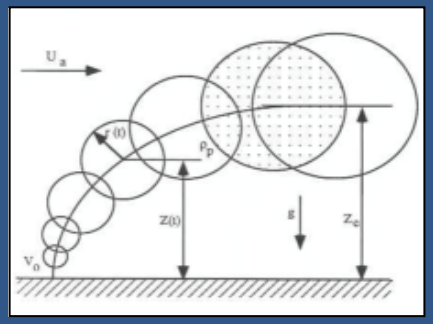


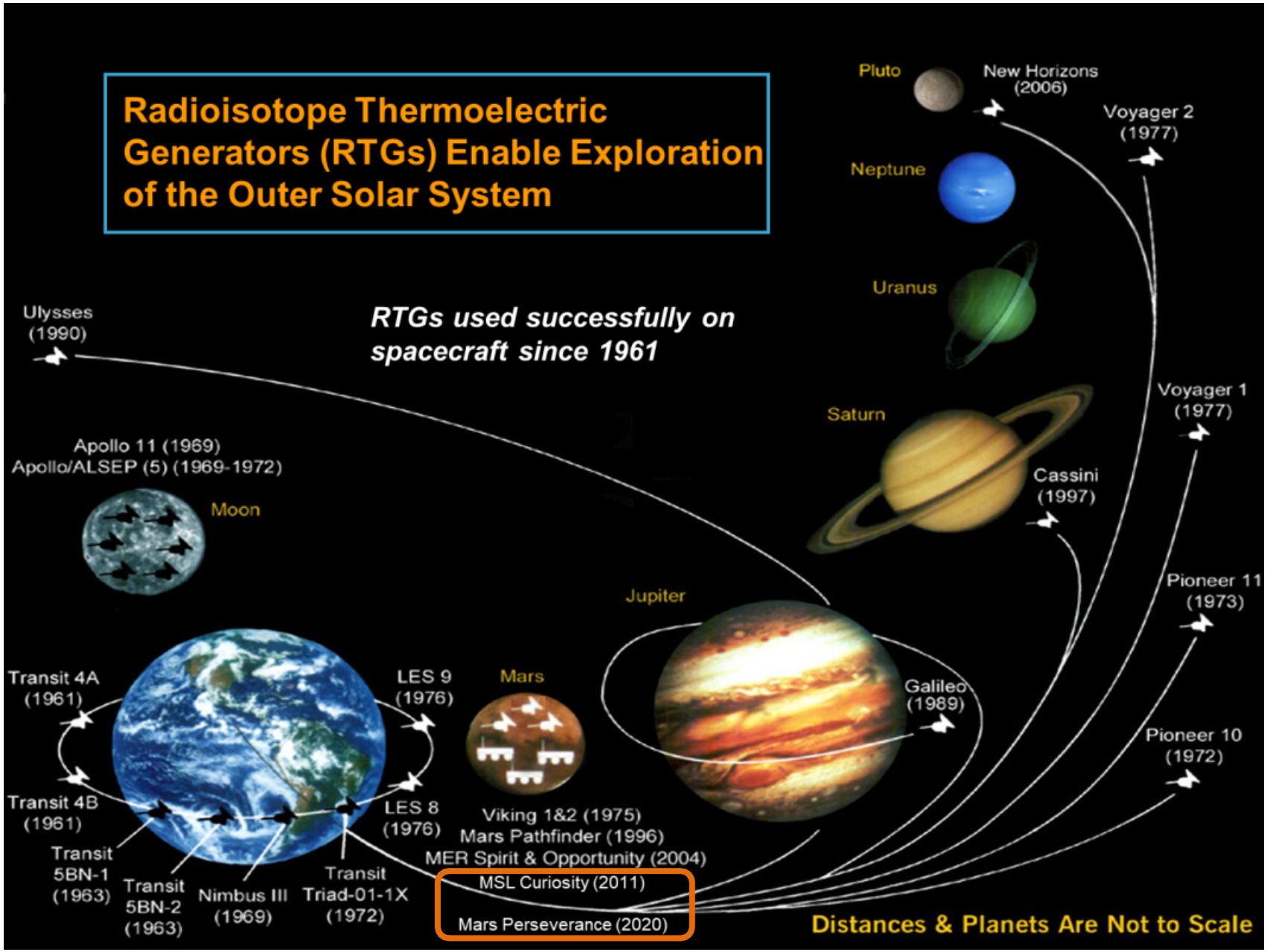
Space Launch Safety at Sandia National Laboratories

Geoff Freeze

Canadian Science Policy Conference (CSPC 2020)
Powering the Next Phase in Space Exploration
November 19, 2020

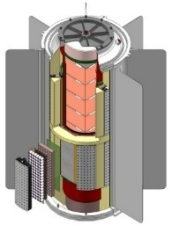
SAND2020-xxxxC

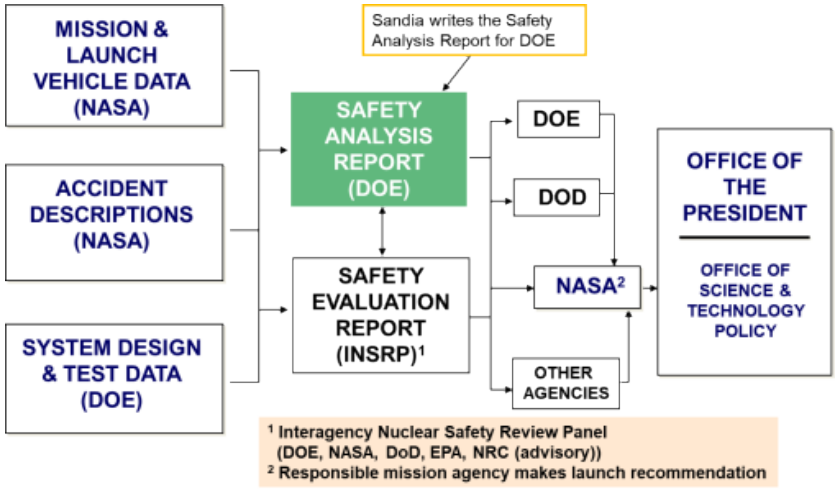
Sandia National Laboratories is a multi-mission laboratory managed and operated by National- Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

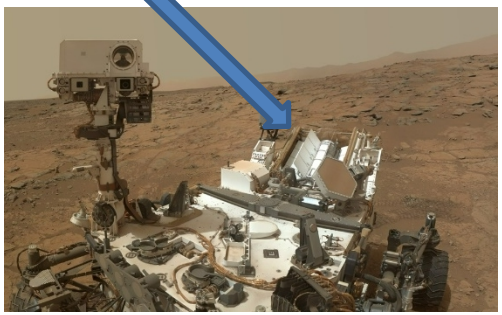

Radioisotope Thermoelectric Generators (RTGs) Enable Exploration of the Outer Solar System
RTGs used successfully on spacecraft since 1961
Pluto
New Horizons (2006)
Voyager 2 (1977)
Neptune
Uranus
Ulysses (1990)
Voyager 1 (1977)
Saturn
Cassini (1997)
Apollo 11 (1969)
Apollo/ALSEP (5) (1969-1972)
Moon
Jupiter
Pioneer 11 (1973)
Transit 4A (1961)
LES 9 (1976)
Mars
Galileo (1989)
Transit 4B (1961)
LES 8 (1976)
Pioneer 10 (1972)
Viking 1&2 (1975)
Mars Pathfinder (1996)
MER Spirit & Opportunity (2004)
MSL Curiosity (2011)
Transit 5BN-1 (1963)
Transit 5BN-2 (1963)
Nimbus III (1969)
Transit Triad-01-1X (1972)
Mars Perseverance (2020)
Distances & Planets Are Not to Scale

Sandia History of Space Mission Support

- **Space Launch Safety for Missions with Nuclear Payloads**
  - Sandia has supported space launch safety for DOE and NASA since 2006
    - Power and/or thermal heating provided by Radioisotope Power Sources (RPSs)
      - Radioisotope Thermoelectric Generators (RTGs)
      - Radioisotope Heater Units (RHUs)







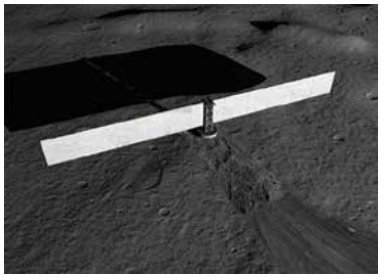
MSL Curiosity Rover on Mars

  - Sandia produced the Final Safety Analysis Report (FSAR) an essential document for Presidential Launch Approval (under Presidential Directive NSC-25)
    - Mars Science Laboratory (MSL) mission launch in 2011
    - Mars 2020 mission launch in 2020

Sandia History of Space Mission Support

- **Nuclear Propulsion**
  - Can leverage R&D on small modular reactors (SMRs) and micro-reactors

- **Space Power Systems**
  - Supported the development of a nuclear powered moon base
    - Fission Surface Power Reactor with a closed Brayton cycle power system
    - Stirling engine power systems
  - Solar Electric Propulsion (SEP) system for near earth operations
  - Can leverage R&D in electrical microgrids
  - Can leverage R&D in photovoltaics and concentrating solar-thermal power

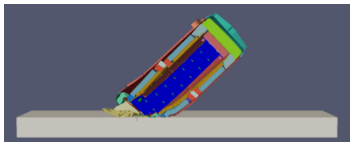


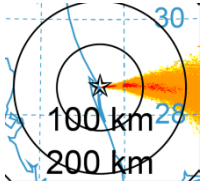
Space Launch Safety

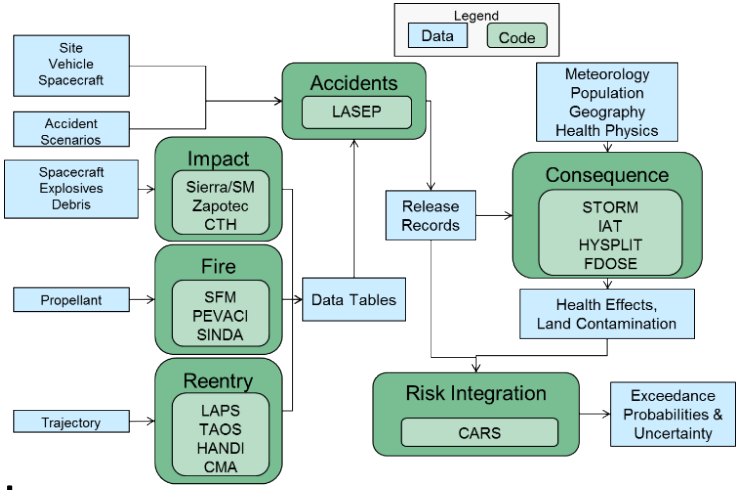
- Launches can fail
  - ~1% of all launches fail near the pad
- A safety analysis is required to assess the potential hazards from accident scenarios during prelaunch, launch, and reentry
  - The FSAR provides
    - a quantitative estimate of radiological risk that is defensible and credible
    - information to mission designers on areas where nuclear safety could be improved by making modifications to the launch vehicle, space vehicle or mission architecture
  - During preparation of the Mars 2020 FSAR, Sandia interfaced with
    - DOE
    - NASA Jet Propulsion Laboratory (JPL)
    - Interagency Nuclear Safety Review Panel (INSRP)
    - Idaho National Laboratory (INL)
    - Los Alamos National Laboratory (LANL)

Space Launch Safety Analyses

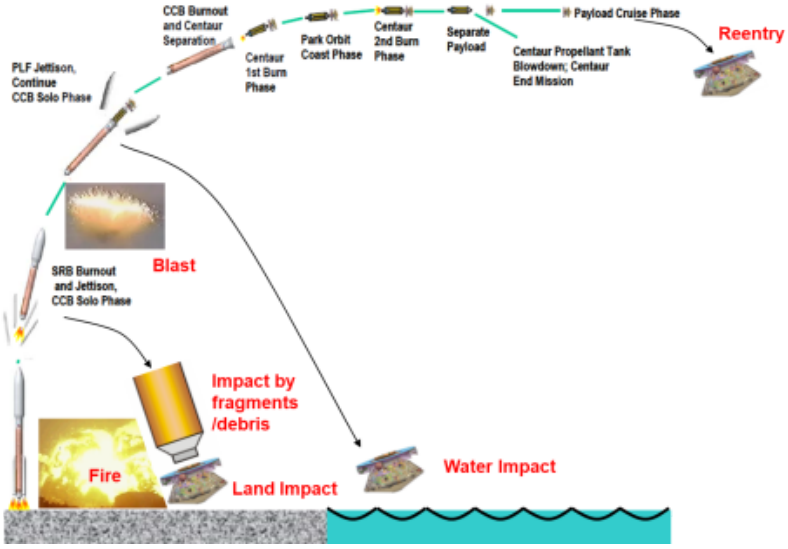
- Integrated phenomenological modeling of the accident scenarios
  - Blast
  - Impacts
  - Fire
  - Reentry
  - Atmospheric transport
  - Consequences







- Probabilistic estimate of radiological risk
  - Health effects (dose, latent cancer fatalities over 50 years)
  - Land, crop contamination
  - Quantify uncertainty
- Document the analyses in a FSAR



Summary

- Sandia has capabilities to support space missions
  - Space Launch Safety
  - Nuclear Propulsion
  - Space Power Systems
- Safety analyses are required, and enabling, for nuclear missions
  - FSAR is an essential document for Presidential or Agency Launch Approval
    - Presidential Directive NSC-25 (1977)
    - National Security Presidential Memo 20 (2019)