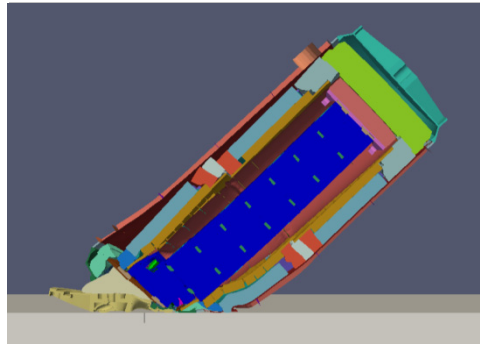


Exceptional service in the national interest



Risk Estimation Methodology for Launch Accidents

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¹Sandia National Laboratories, Albuquerque, NM 87185

²U. S. Department of Energy, Germantown, MD 20874

PSAM12 Conference, Honolulu, HI

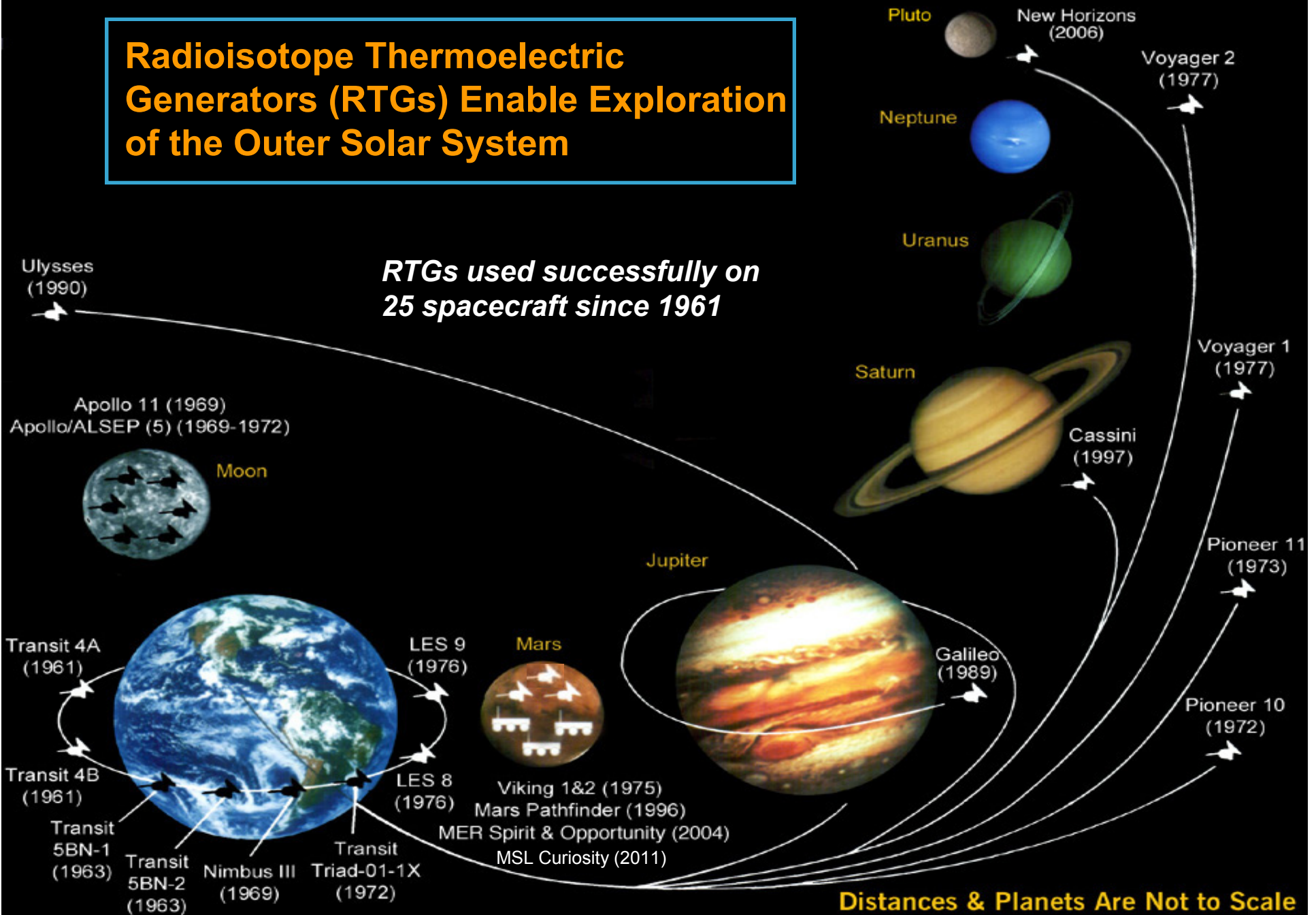
June 22-27, 2014



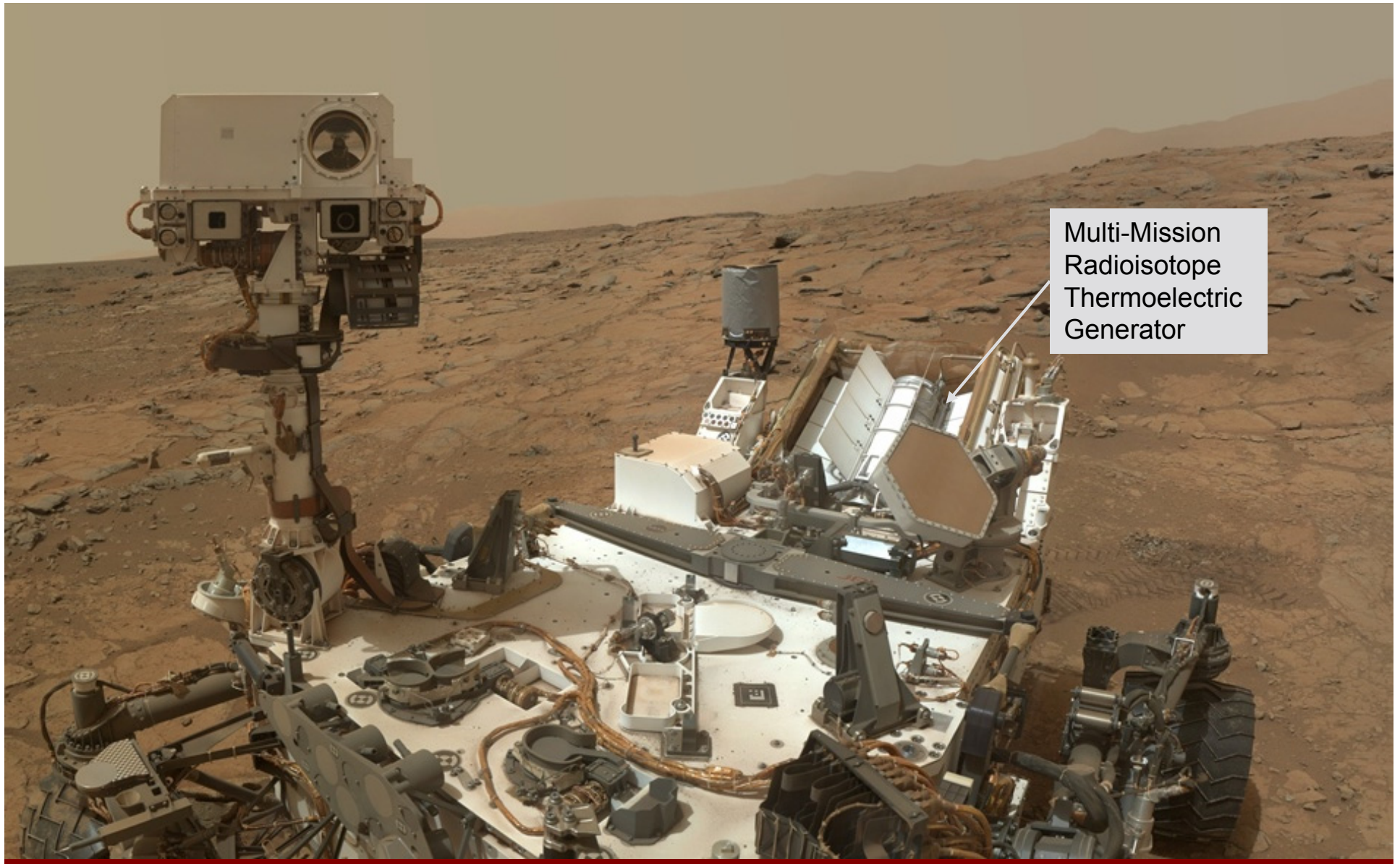
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2014-15002PE

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

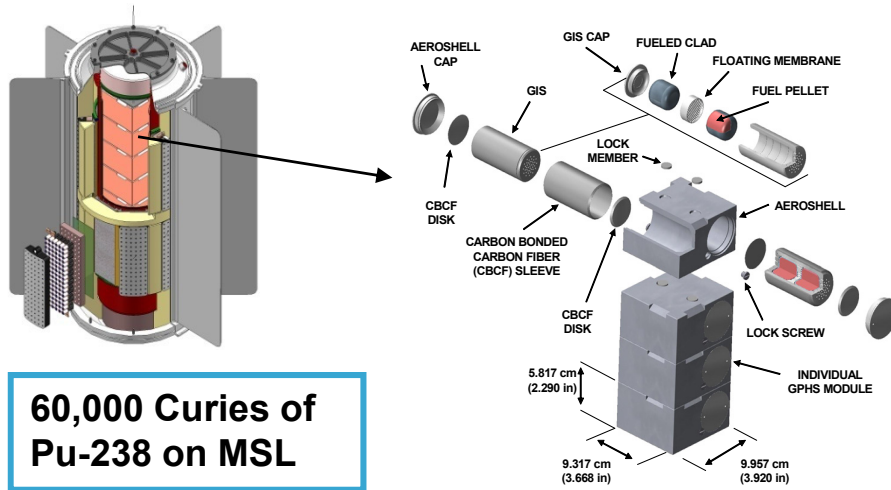
RTGs used successfully on 25 spacecraft since 1961



Curiosity on Mars



1% of all Launches Fail Near the Pad



60,000 Curies of Pu-238 on MSL



Delta 241 Jan 27, 1997

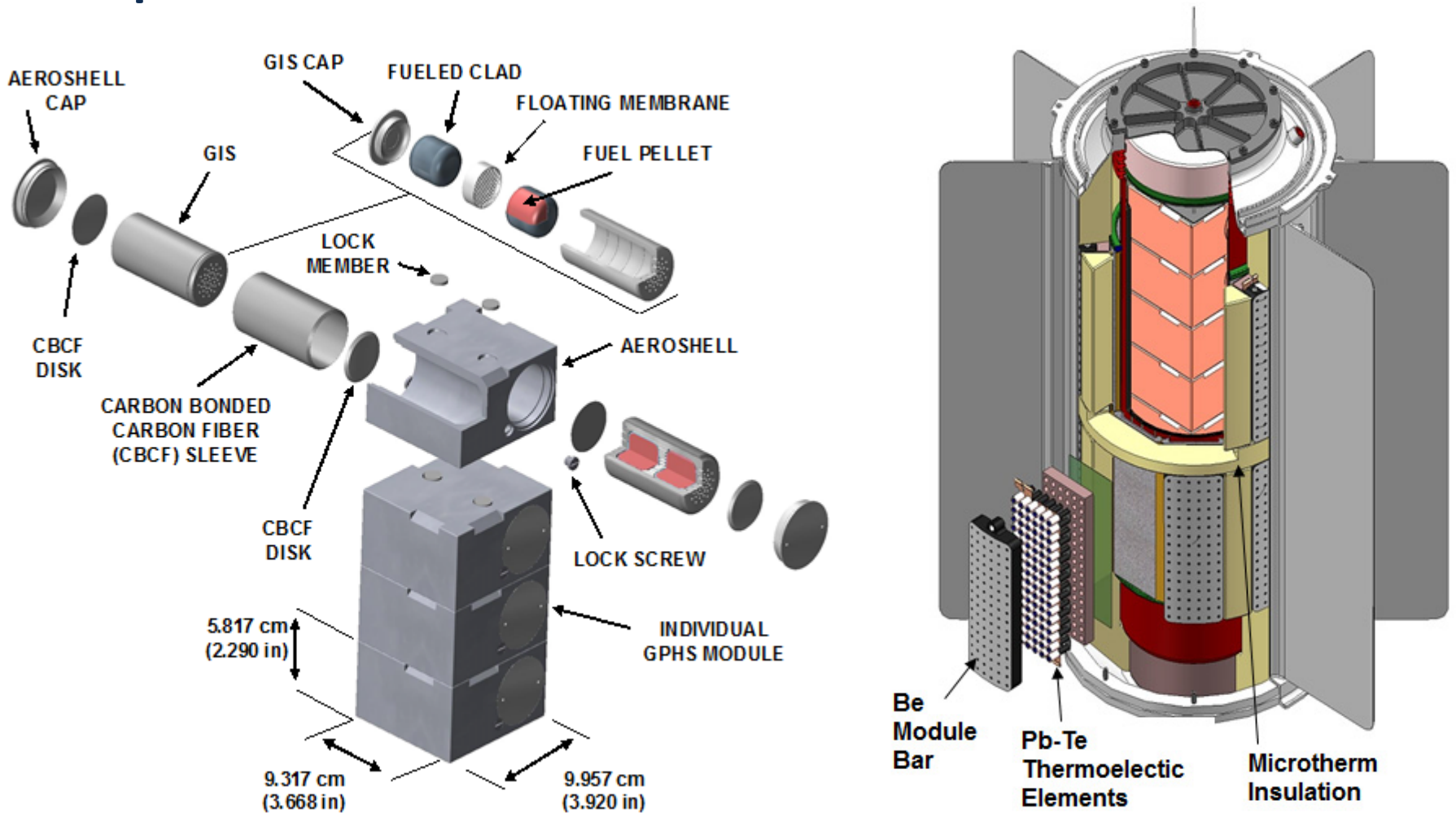


Atlas Fallback



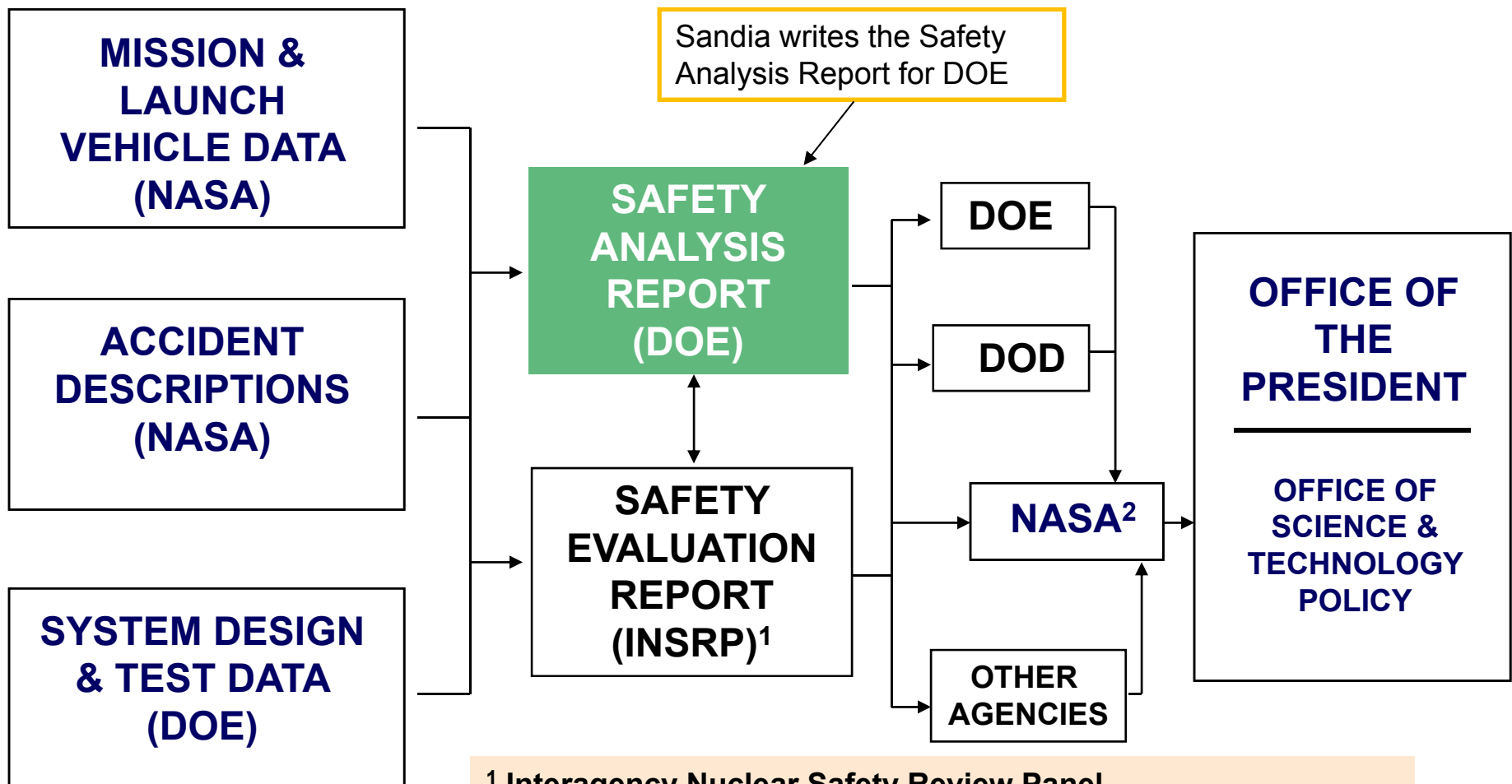
Titan 34D

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

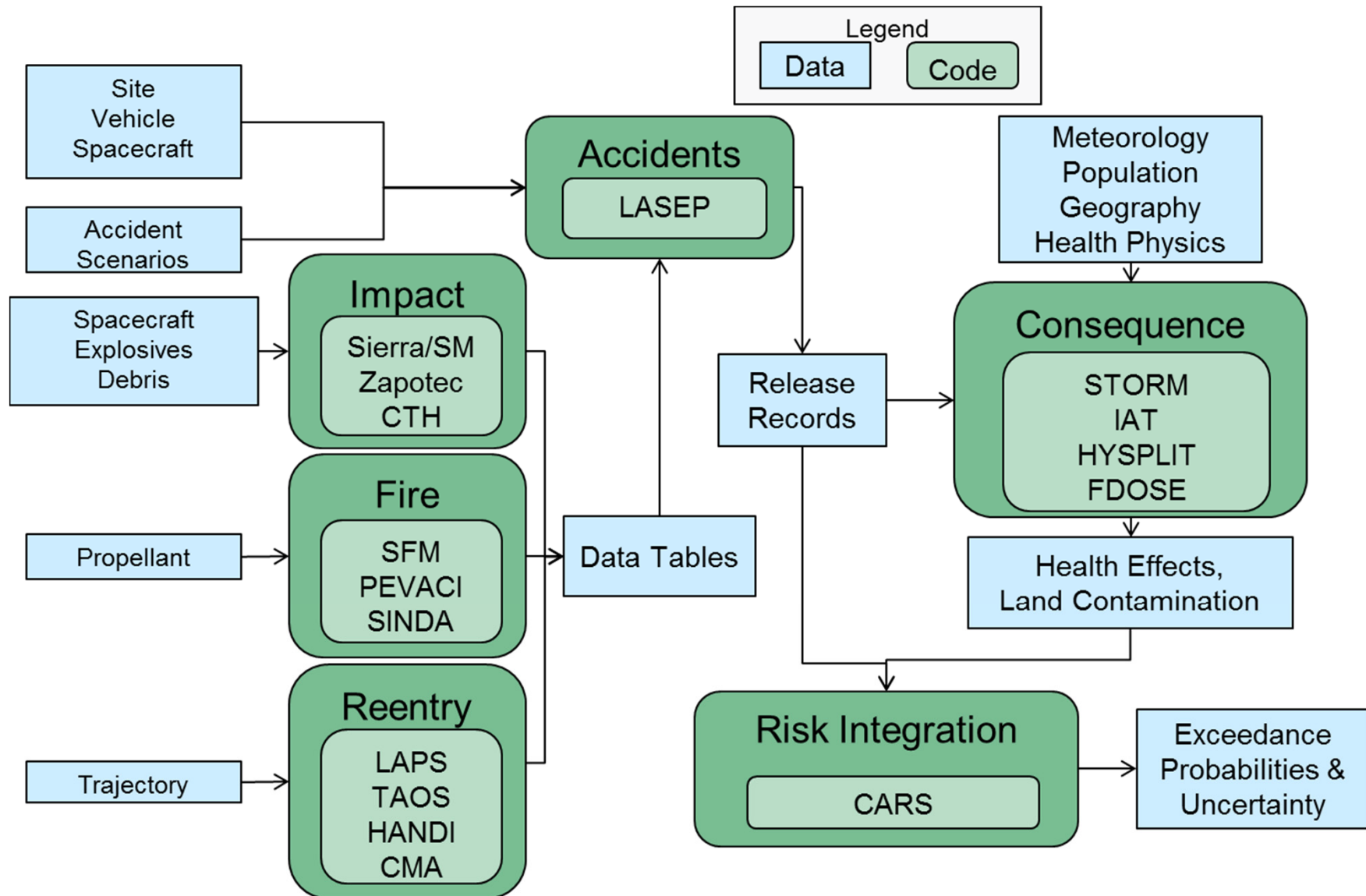


¹ Interagency Nuclear Safety Review Panel (DOE, NASA, DoD, EPA, NRC (advisory))
² Responsible mission agency makes launch recommendation

Risk Estimation Methodology

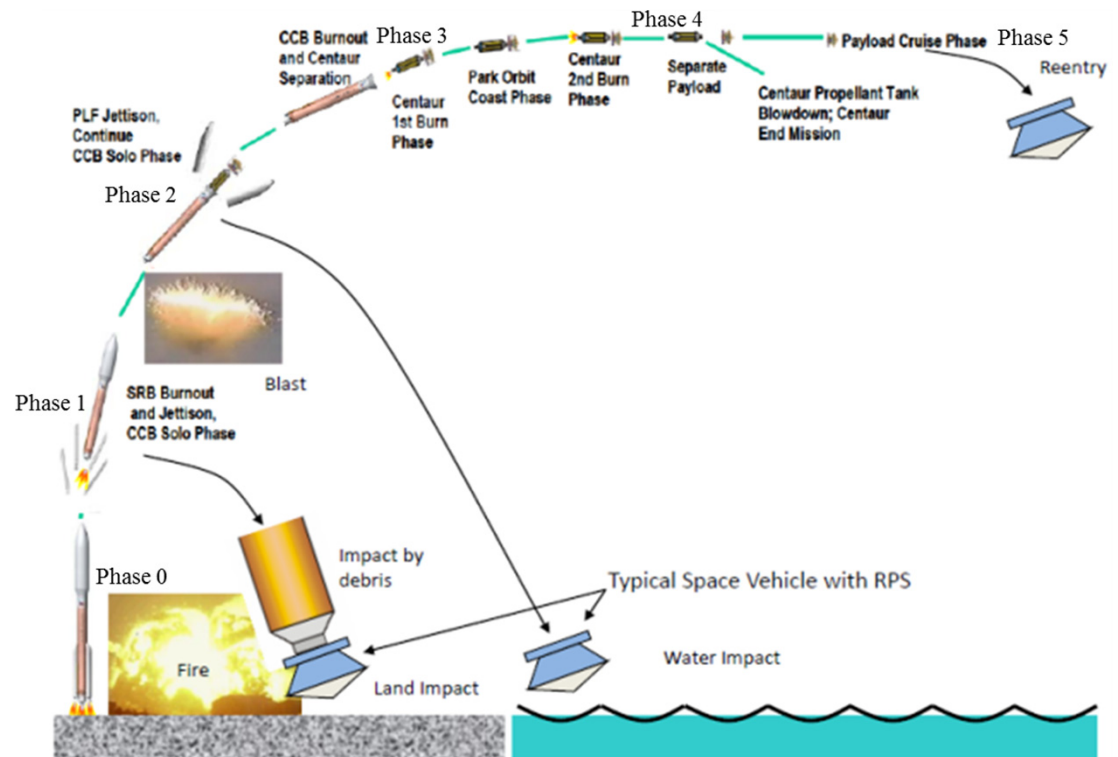
- Detailed simulations and Monte Carlo sequence codes used to develop the probabilistic risk analysis
 - Potential accidents associated with the launch
 - Probability
 - Environment
 - Detailed understanding of the response of power system to insults
 - Explosion Overpressure
 - Fragments
 - Ground Impact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

Launch Safety Code Suite



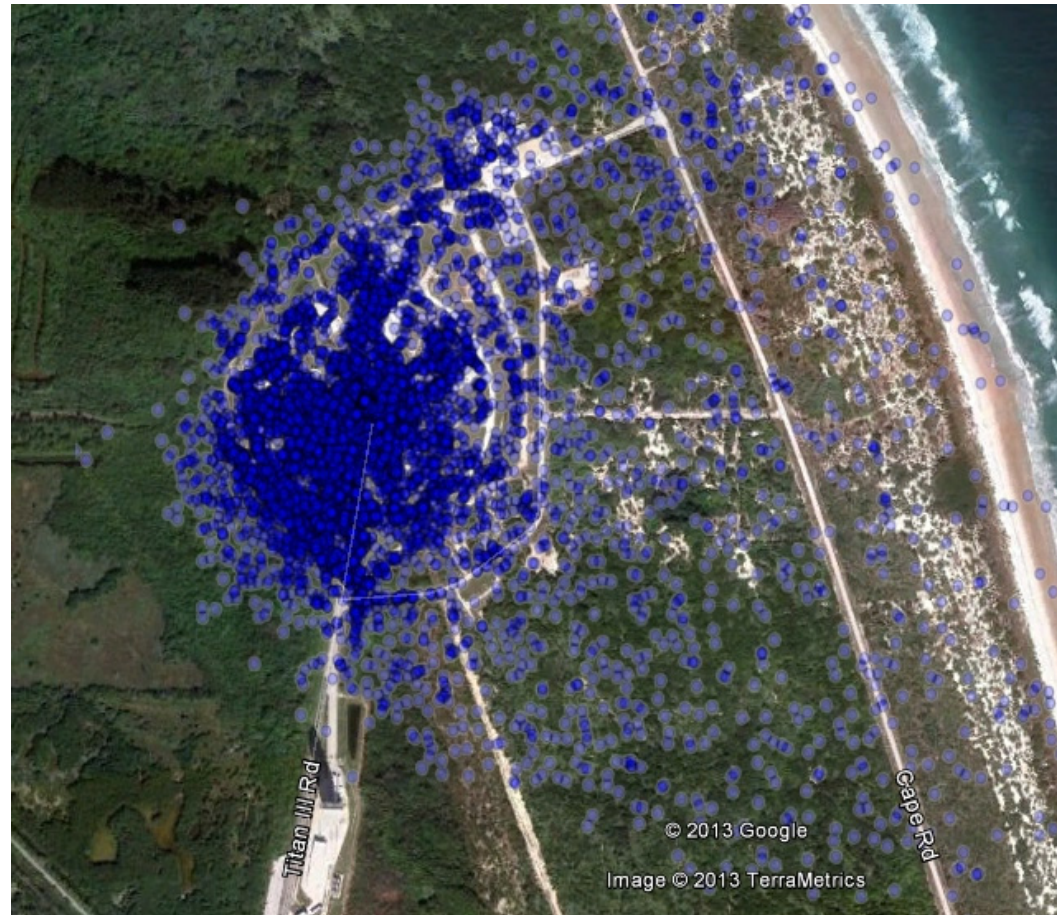
Representative Accident Scenarios (RASs)

- 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

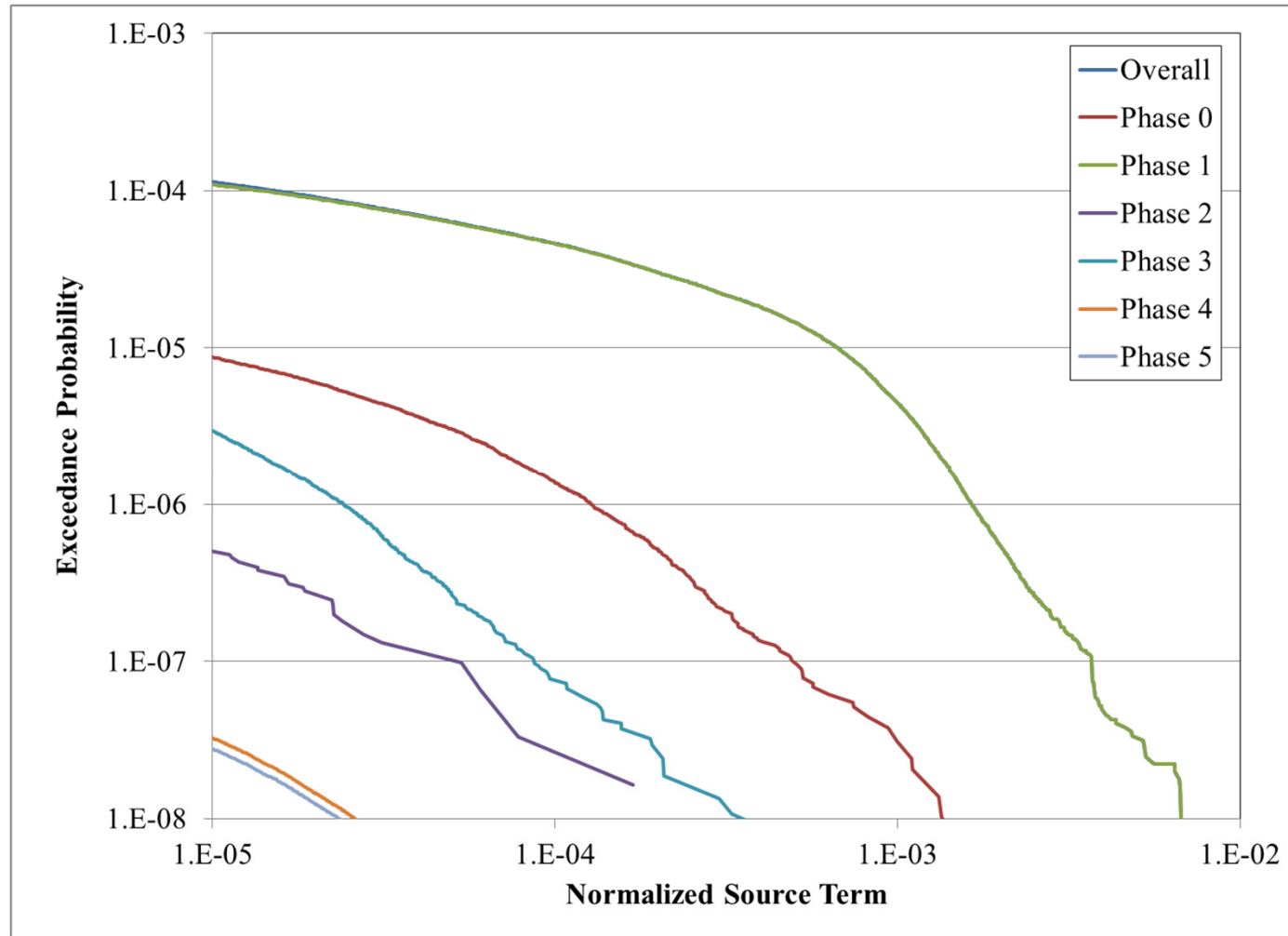
- LASEP models numerous potential scenarios, randomly choosing time of failure, explosion characteristics, etc.
- Release location and amounts determined mechanistically
- Probability distributions for release are determined



Potential release locations from numerous LASEP launch simulations

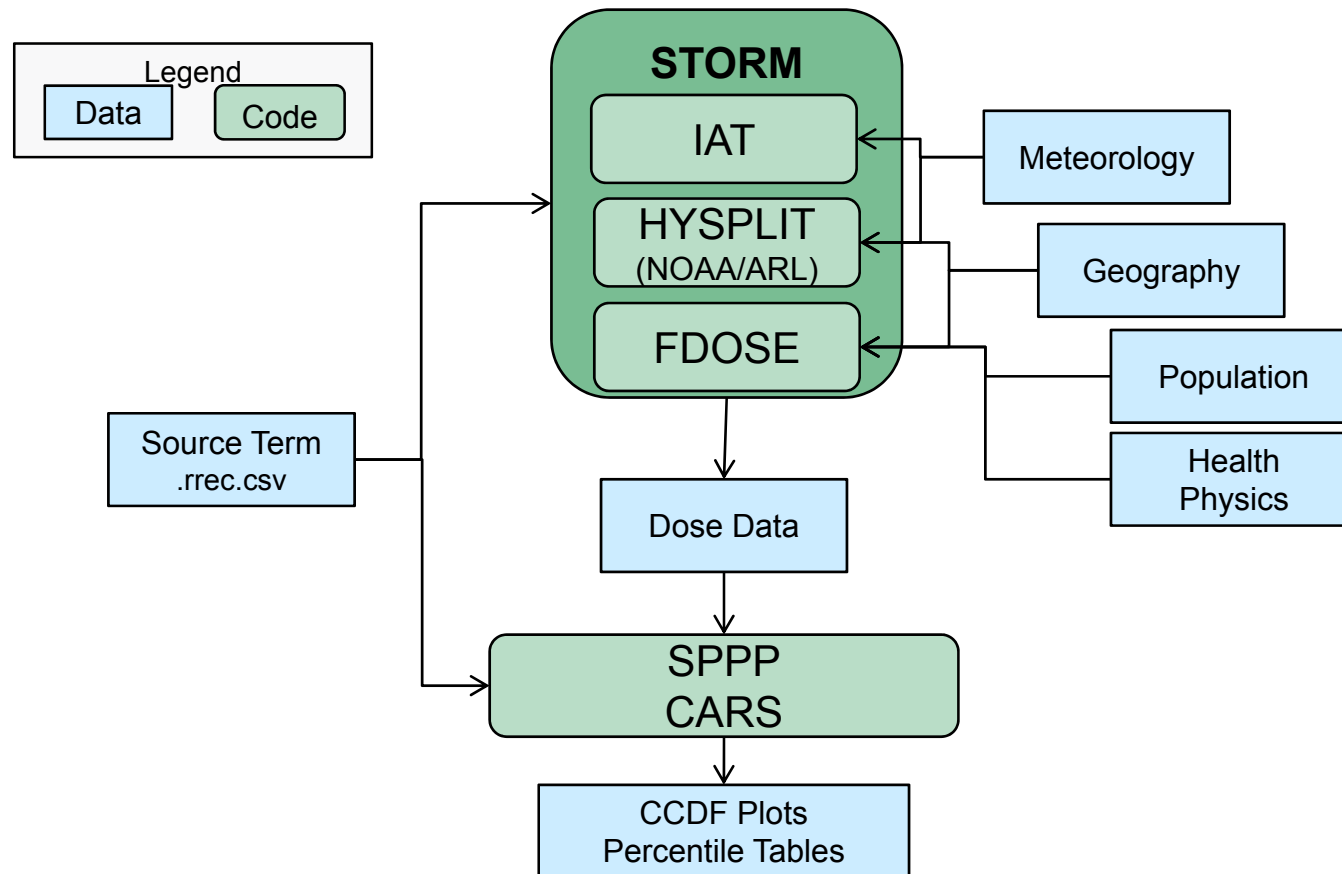
Example Source Term Results

Source Term
Exceedance
Graph

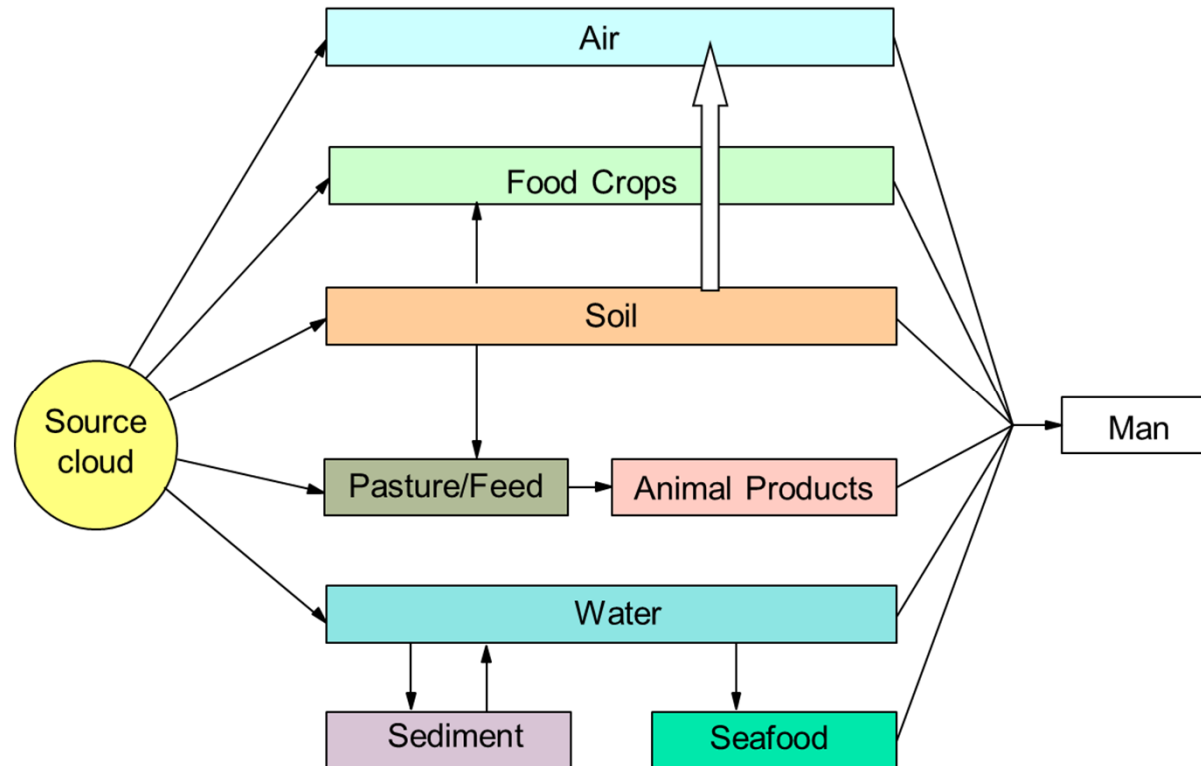


Consequence Modeling

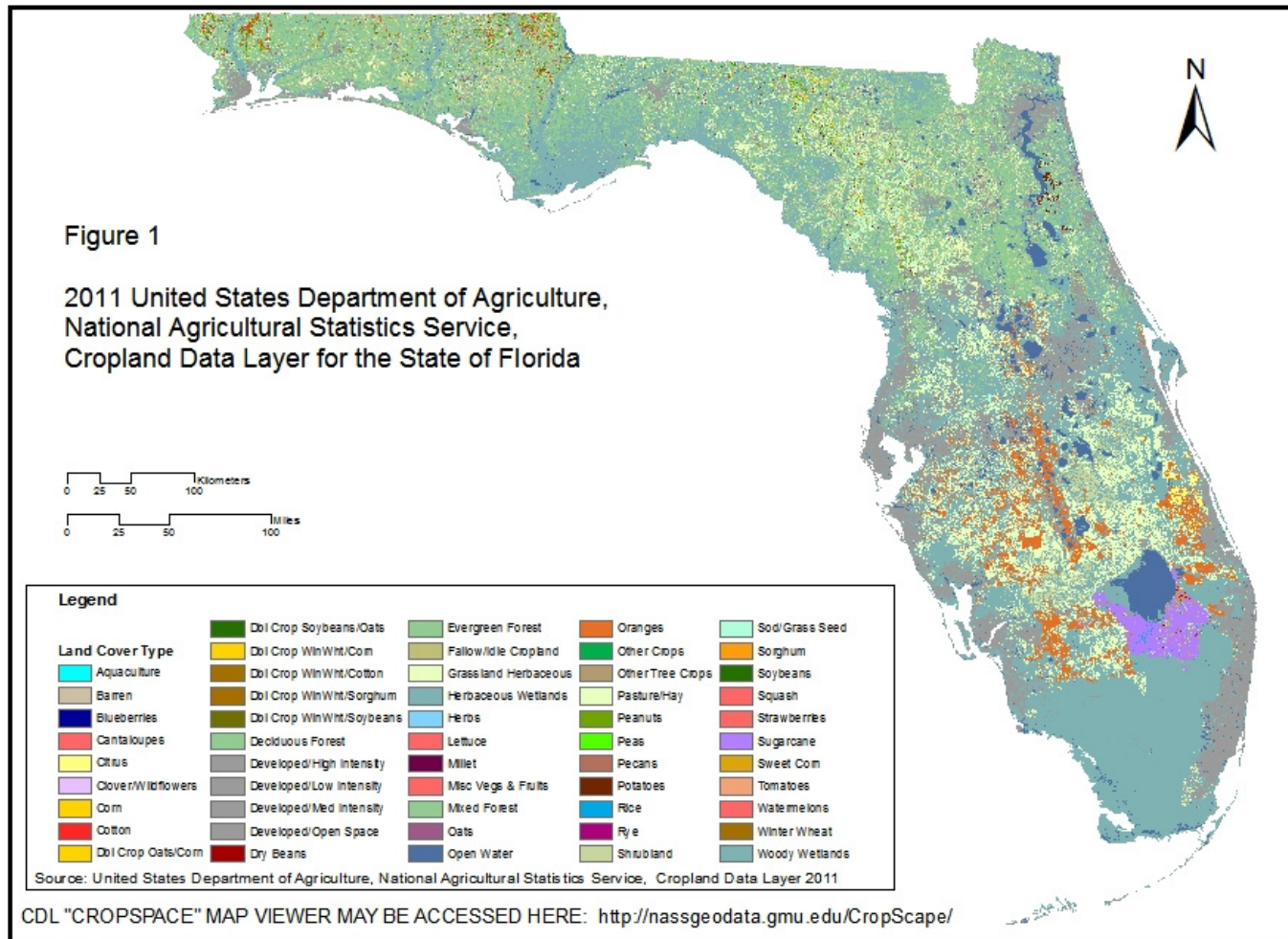
Sandia-developed Transport Of Radionuclides Model (STORM) uses NOAA's HYSPLIT code, leveraging NOAA's extensive investment and readily accessible weather database



Potential Exposure Pathways



Florida Crop Use Data



Map Document: (K:\GProject\SPACE_2011\Maps\FL_Landuse.mxd)

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