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Historical Insights for the Safe Launch of Radioactive Materials

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LOCKHEED MARTIN

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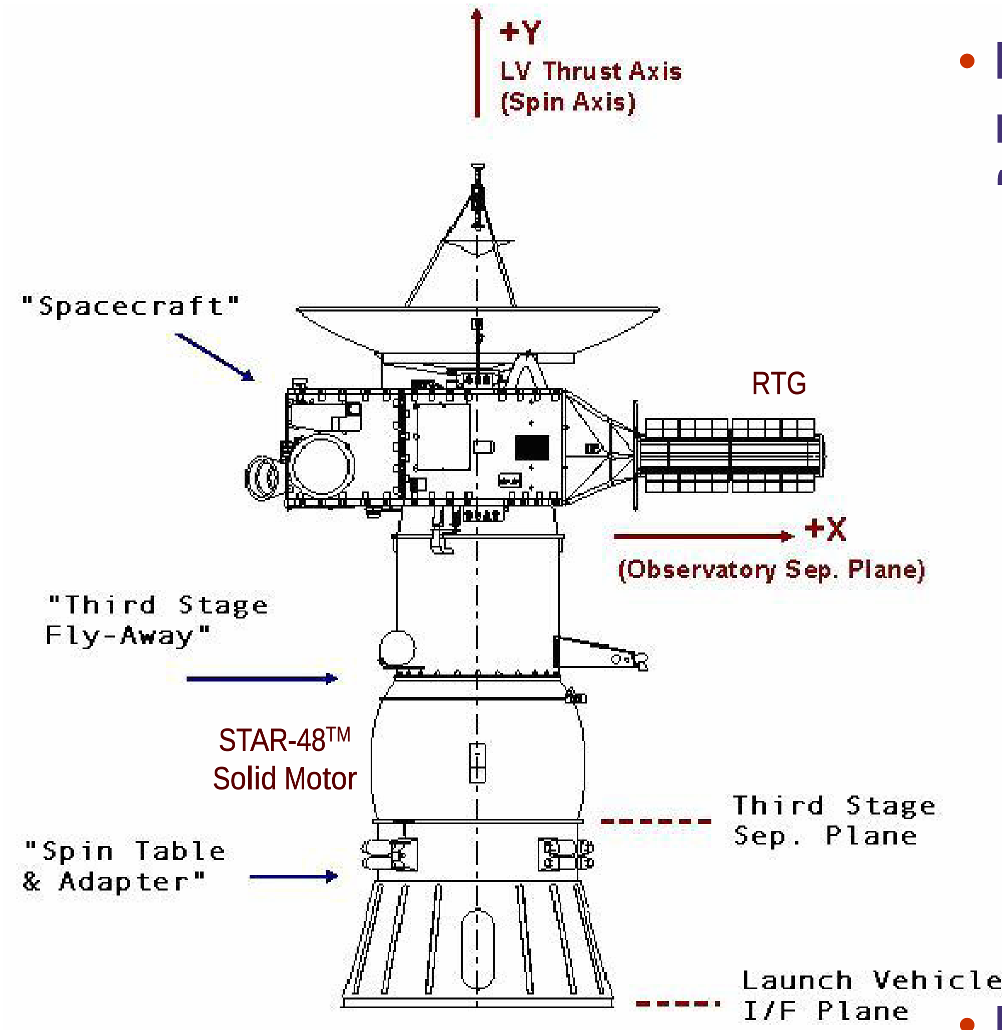
Outline

- Safety Threats to Radioactive Materials
- Evolution of Safety Philosophy
- Managing Risks for Radioactive Materials
- Summary

Typical Insult Environments



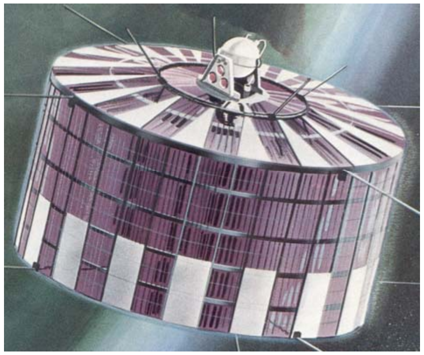
Pluto New Horizons Spacecraft
(Launch Vehicle is Below)

- **Energy that can threaten the radioactive material is called an "insult environment"**
  - **Overpressure**
    - **Burning liquid propellants**
  - **Thermal**
    - **Burning liquid propellants**
    - **Burning solid propellants on ground**
    - **Heat of atmospheric reentry**
  - **Impacts and Accelerations**
    - **Launch vehicle fragments in air or on ground**
    - **Impact of material with ground**
    - **Deceleration of atmospheric reentry**
- **Mission-specific characteristics can yield new insult environments**

Early Safety Philosophy:

Delay, Decay and Disperse

- **Delay materials' return to the biosphere**
  - **Allow adequate time in orbit for radioactive decay**
    - **Minimum altitudes ~1100 km (650 mi)**
- **Disperse materials broadly on reentry**
  - **Ensures individual doses are small**
    - **Residual radioactive material is highly diluted in the atmosphere**
- **Problems:**
  - **Spacecraft failure in orbit**
    - **SNAP-10A** *(failed, but in 4000-year orbit)*
  - **Failure to achieve orbit**
    - **Transit-5BN-3, Nimbus-B1**

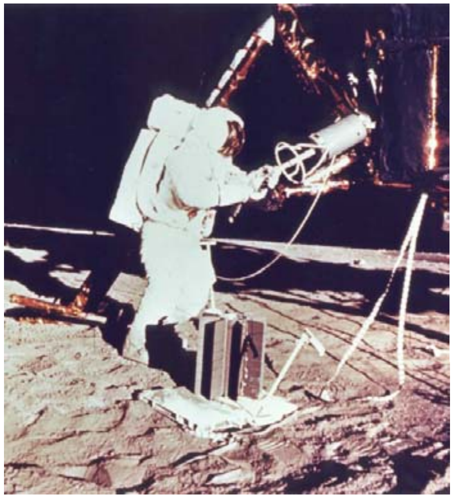


Above: *Artist's concept of Transit-4A satellite in orbit.*

Below: *SNAP-10A.*

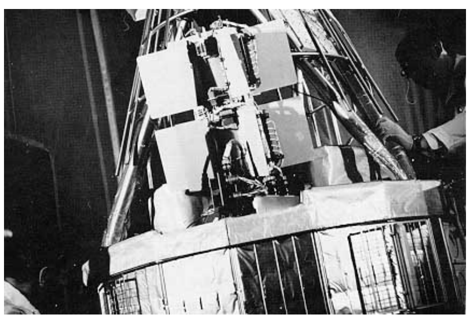
Evolved Safety Philosophy:

Strive to Survive the Accident



Above: *Alan Bean placing SNAP-27 during Apollo 12.*

Below: *Nimbus-B Satellite, which used RTGs*



- **Minimize both individual and *population doses***
  - **ICRP: any exposure to radiation, no matter how small, causes increased cancer likelihood**
  - *(Tiny dose) x (Many people) = (Some cancers)*

- **Materials & protective structures designed to withstand accident & reentry environments**
  - **Changes in radioactive materials**
    - **Metals replaced with highly stable ceramics**
  - **High-integrity protective structures**
    - **High-strength and high-temperature cladding materials**
    - **Protective structures or "casks" made from graphite or reentry heat shield materials**

- **Successes:**
  - **Apollo 13 RTG assessed to have survived reentry**
  - **Nimbus-B1 RTGs survived launch destruct & recovered**

Managing Radiological Risks

1. **Prevent the Accident**
2. **Prevent the Energetic Insult**
3. **Prevent the Release**
4. **Mitigate the Consequences**

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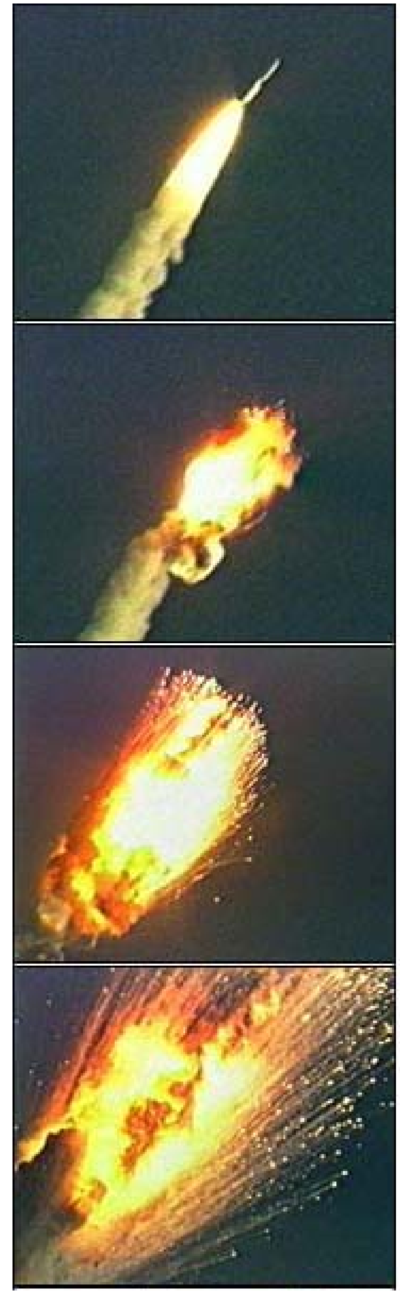
Managing Radiological Risks:

1. Prevent the Accident

- **Reliable launch vehicles**
  - **Current vehicles much more reliable than early vehicles**
    - **One part of a comprehensive risk management approach, as a “completely reliable” vehicle is likely unattainable.**
  - **Vehicle reliability requires a multifaceted effort**
    - **Design assurance, manufacturing methods, human reliability, quality assurance, …**



4. Mitigate the Consequences

- **Effective emergency response**
  - **Real-time prediction of weather, transport & deposition**
  - **Detect and manage contamination, e.g.:**
    - ***Land:*** **access controls, cleanup, crop interdiction…**
    - ***People:*** **information, sheltering and evacuation orders, decontamination, medical and psychological aid…**

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Managing Radiological Risks:

2. Prevent the Energetic Insult

Above: *ESA illustration of space debris*

Below: *Burning solid rocket propellant simulant*

- **Prevent the insult completely**
  - **Eliminate the source of the insult through design**
    - **Example: eliminate solid propellant upper stage**
    - **Must have a *complete* inventory of possible energy sources that may lead to insults**
- **Reduce insult likelihood**
  - **Ensure more benign outcomes are favored**
    - **Example: high-reliability vehicle destruct system**
    - **"High reliability" must encompass concept of operations & human actions, not just electromechanical system**
- **Reduce insult magnitude or duration**
  - **Manage insult characteristics to make sure design properties of protective structures not violated**
    - **Insult characteristics: fragment size, velocity, line-of-sight…**
    - **Example: small propellant fragments ➔ short fires**
    - **Engineered barriers may be necessary**

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Managing Radiological Risks:

3. Prevent the Release

- **Reduce release likelihood**
  - **Use materials & protective structures designed to withstand accident & reentry environments**
- **Reduce expected release magnitude**
  - **Robust structures also help contain materials to minimize release magnitude even if a release occurs**
- **Manage release characteristics**
  - **Particle size distribution**
    - **Favor larger particles – suppress fine particles and aerosols that can travel large distances**
    - **Reduce the likelihood of phenomena that can create fines and aerosols (e.g., propellant fires near released materials)**
  - **Potential for lofting of radioactive plume**
    - **Can the radioactive material be separated from the fire environment so releases are not entrained in its lofting plume?**

Scanning for radioactive contamination.

Summary

- Philosophy: *Survive the accident.*
    - Minimize individual *and* population doses
- Manage radiological risks
    - Prevent the Accident
        - Launch vehicle reliability is important
    - Prevent the Energetic Insult
        - Eliminate the source of the insult through design
        - Reduce insult likelihood, magnitude and duration
    - Prevent the Release
        - Use materials & protective structures designed to withstand accident & reentry environments
        - Manage release characteristics:
            - Minimize magnitude ➔ less potential exposure
            - Fewer fines & aerosols ➔ less transport in biosphere
    - Mitigate the Consequences
        - Effective emergency response

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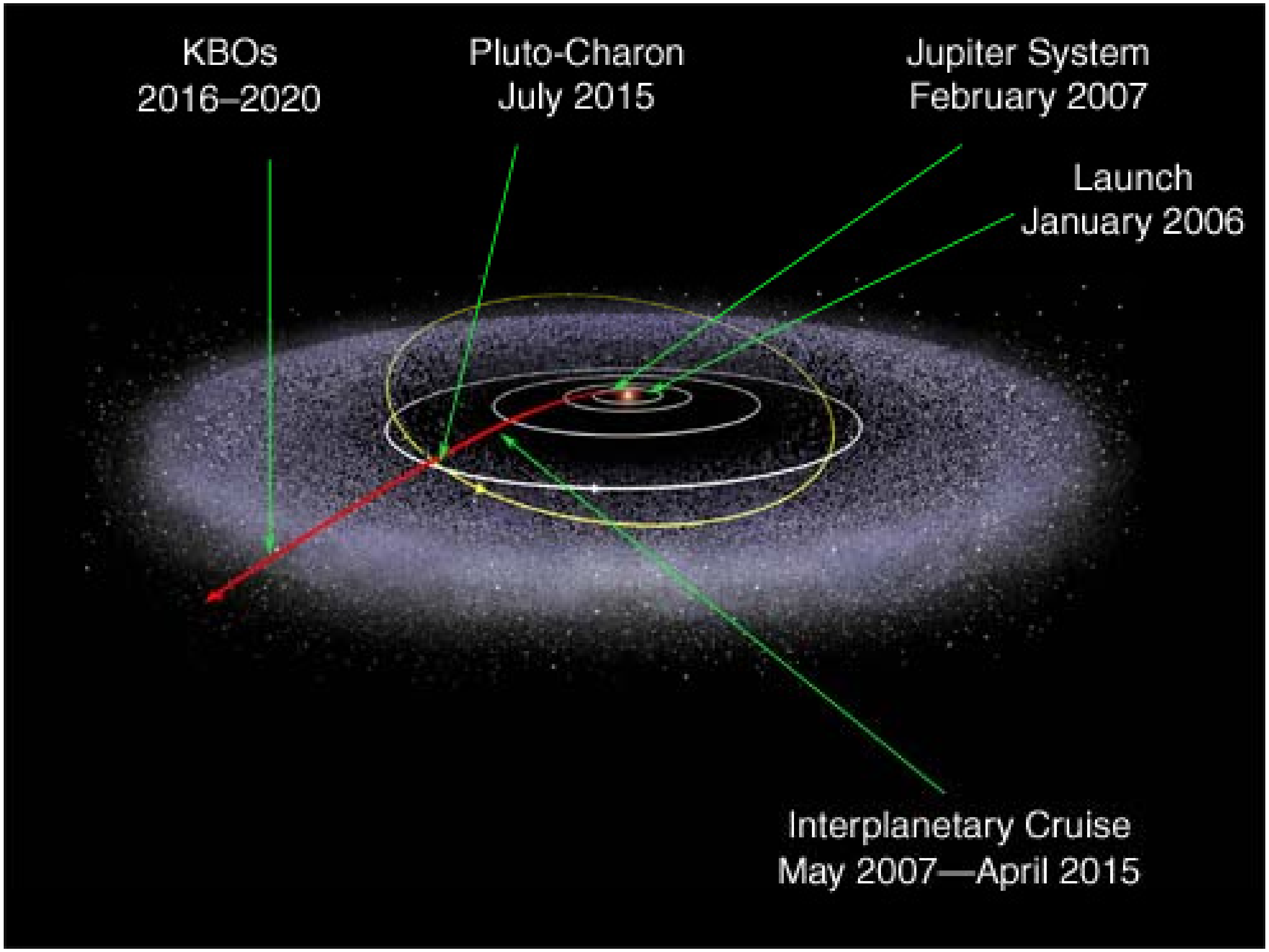
BACKUP MATERIAL

The Pluto – New Horizons Mission



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