

Safe, Sound, & Space-Bound

The role of nuclear safety in the new space race



Vic Hall | U.S. Nuclear Regulatory Commission

Maryland Space Business Roundtable | May 20, 2026





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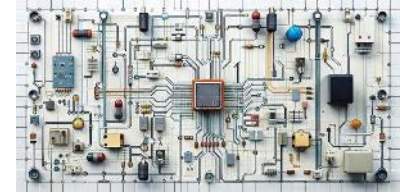


VICTOR HALL

- Terp



- Electrical Engineer



- Two Summer Internships



- Nuclear Safety Regulator (*since 2003*)



- Responsible AI Official

- Expert in Calculated Risk

(Adrenaline Junkie, Attempted Pilot, Racecar Driver...)





The NRC Commission



The Nuclear Regulatory Commission

Independent Federal Regulator

Established 1975

Regulates Civilian Nuclear Use

Power reactors, advanced reactors, fuel cycle, nuclear materials & medical uses

Not DOE. Not an Operator.

Independent safety oversight





“Sound decision making on safety under uncertainty is essential to enable reliable and progressively more ambitious space nuclear missions.”



POWER DENSITY: A MASSIVE DIFFERENCE

Same usable energy (1 million watt-hours)

NUCLEAR FUEL PELLETT

(Uranium dioxide)



Mass: **~7 grams**

1 pellet
≈ **1 million watt-hours**
of energy

VS.

EQUIVALENT ENERGY FROM LITHIUM-ION BATTERIES



Mass: **~500 kg (1,100 lb)**

~7,000 lithium-ion cells
≈ **1 million watt-hours**
of energy



Nuclear fuel stores ~70,000× more energy per unit of mass

That's why nuclear power enables missions that batteries simply can't.

Values are approximate and for illustrative comparison.

SAME POWER. DRAMATICALLY DIFFERENT SIZE.

RTG

(Radioisotope Thermoelectric Generator)



~45 kg
(100 lb)

~110 Watts
continuous for decades

EQUIVALENT POWER FROM BATTERIES

(to deliver ~110 Watts for ~14 years)



~5,000 kg
(11,000 lb)

~110 Watts
for ~14 years

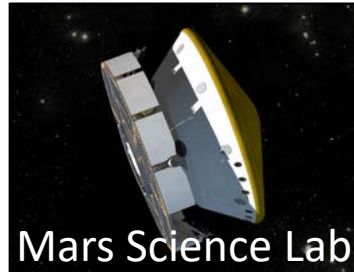


RTGs provide reliable, long-life power
for missions where recharging isn't possible.



Timeline of Space Nuclear Activities

NASA's Nuclear Flight Safety Program was established with ad hoc safety reviews (e.g., Interagency Nuclear Safety Review Panels)



National Security Council/Presidential Directive (NSC/PD)-25

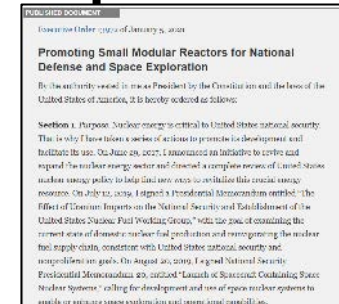
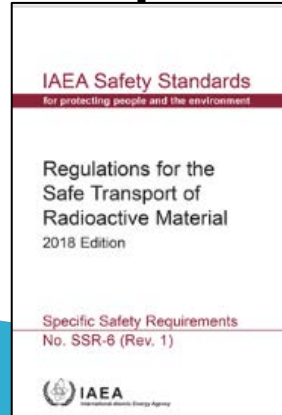
United Nations Principles for Using Nuclear Power in Outer Space

IAEA Safety Standards Series No. SSR-6 (Rev. 1)

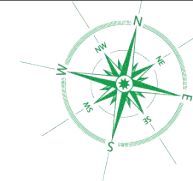
NSPM-20 establishes the Interagency Nuclear Safety Review Board (INSRB)

Space Policy Directive-6

Executive Order 13972



Timeline not to scale



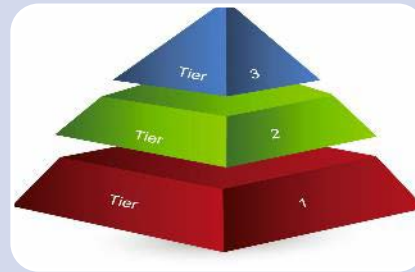
NAVIGATING the
NUCLEAR FUTURE



NSPM-20, “Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems”



Outlines objective safety guidelines that limit public exposure to risk (i.e., exceedance frequency vs. dose thresholds)



Established three-tiered approach to launch authorization:

- Radioisotopes fall within Tier I, II, or III depending on quantity and risk to public
- Reactors fall within Tier II or III, depending on enrichment and risk to public



Charges the sponsoring agency to produce a safety analysis report (SAR) that demonstrates how the NSPM-20 safety guidelines have been met or exceeded



Established the standing INSRB to review the SAR and produce a safety evaluation report (SER) to document findings for U.S. Government launches

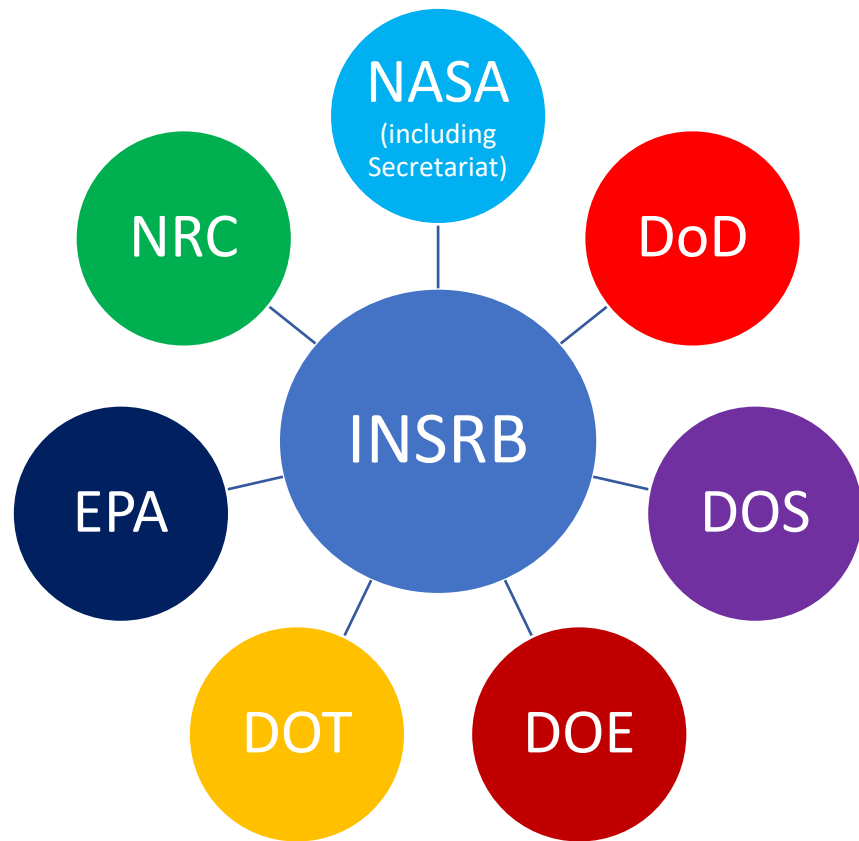


DOT/FAA continues to be safety authority for commercial nuclear launches





What Is the Interagency Nuclear Safety Review Board (INSRB)?



- Has an advisory role, reporting to the space launch sponsoring agency or department.
- Has published a [Charter](#) and a [Playbook](#) for trial use.
- Has basic intents:
 - To provide missions with insightful feedback.
 - To provide the community with continuity in safety evaluation that promotes stable practices and lessons learned from mission to mission.
 - To provide agency heads (and others) with insightful reviews that foster confidence.



2016
SpaceX Falcon 9 exploded during a simulated countdown at Cape Canaveral, destroying the booster and a \$200 million communications satellite.



<https://spaceflightnow.com/2016/09/01/spacex-rocket-and-israeli-satellite-destroyed-in-launch-pad-explosion/>

2025, SpaceX Starship exploded during fuel loading



<https://spaceflightnow.com/2025/06/19/next-starship-explodes-on-test-stand/>

SPACE NUCLEAR INCIDENT RECORD

The U.S. history is mostly old — and instructive

Table 2-3 U.S. Space Mission Incidents Involving Nuclear Systems

Mission name	NPS(s)	Incident date	Incident description
Transit 5-BN-3	SNAP-9A	Apr. 1964	Orbital failure, RTG disintegration into atmosphere
SNAPSHOT	SNAP-10A	Apr. 1965	Voltage regulator malfunction, precautionary reactor shutdown after 43 days of operation
Nimbus B-1	SNAP-19B (two units)	May 1968	Launch failure, both RTGs recovered and fuel reused
Apollo 13	SNAP-27	Apr. 1970	Spacecraft damage, RTG reentered and submerged into South Pacific intact

Source: "Safety Status of Space Radioisotope and Reactor Power Sources," Bennett, 1990.

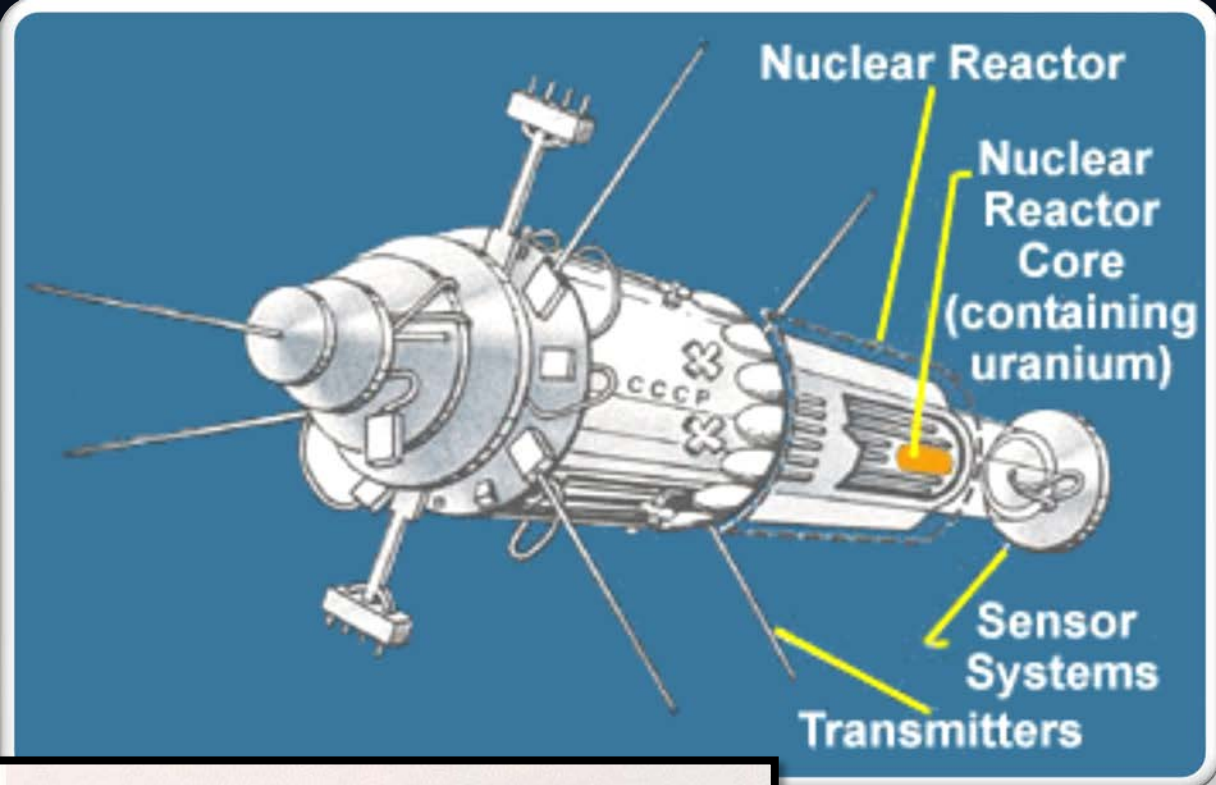
Some of the rest...

Table 2-4 Soviet Space Mission Incidents Involving Nuclear Systems

Mission name	NPS type	Incident date	Incident description
Unknown	Reactor	Jan. 1969	RORSAT launch failure ^a
Cosmos 300	RPS	Sep. 1969	Escape trajectory failure, polonium-210 source disintegration in atmosphere ^a
Cosmos 305	RPS	Oct. 1969	Escape trajectory failure, polonium-210 source disintegration in atmosphere ^a
Unknown	Reactor	Apr. 1973	RORSAT launch failure ^a
Cosmos 954	Reactor	Jan. 1978	Malfunction leading to uncontrolled reentry
Cosmos 1402	Reactor	Jan.-Feb. 1983	Orbital failure (spacecraft and core separated at reentry)
Cosmos 1900	Reactor	Sep. 1988	Unknown failure, automatic separation and orbital boost
Mars 96	RTG	Nov. 1996	Escape trajectory failure, Pu-238 RTG intact after reentry and impact

Sources: "Soviet Space Nuclear Reactor Incidents: Perception Versus Reality," Bennett, 1992; "Nuclear Power Assessment Study: Final Report," TSSD-23122, JHU/APL, 2015.

^a Marked causes are speculative due to lack of information.



Nuclear System

Description

Launch failure

Trajectory failure

Integration

Trajectory failure

Integration



Oct. 1973	RORSAT launch failure
Jan. 1978	Malfunction leading to
Jan.-Feb. 1983	Orbital failure (spacecraft and core at reentry)
Apr. 1988	Unknown failure, automatic separation of orbital boost
Nov. 1996	Escape trajectory failure, Pu-238 after reentry and impact



Incidents: Perception Versus Reality," Bennett, 1992; "Nuclear Waste Management, JHU/APL, 2015. Lack of information.

Radioactive debris being prepared for removal. In general, the materials were wrapped in plastic film to prevent dispersal of any dust or fine particles. The more radioactive objects were then manipulated into special shielded containers for safe transport.



NASA's Dragonfly mission to Saturn's moon Titan

Artist's concept of Dragonfly on the surface of Titan
NASA/Johns Hopkins APL

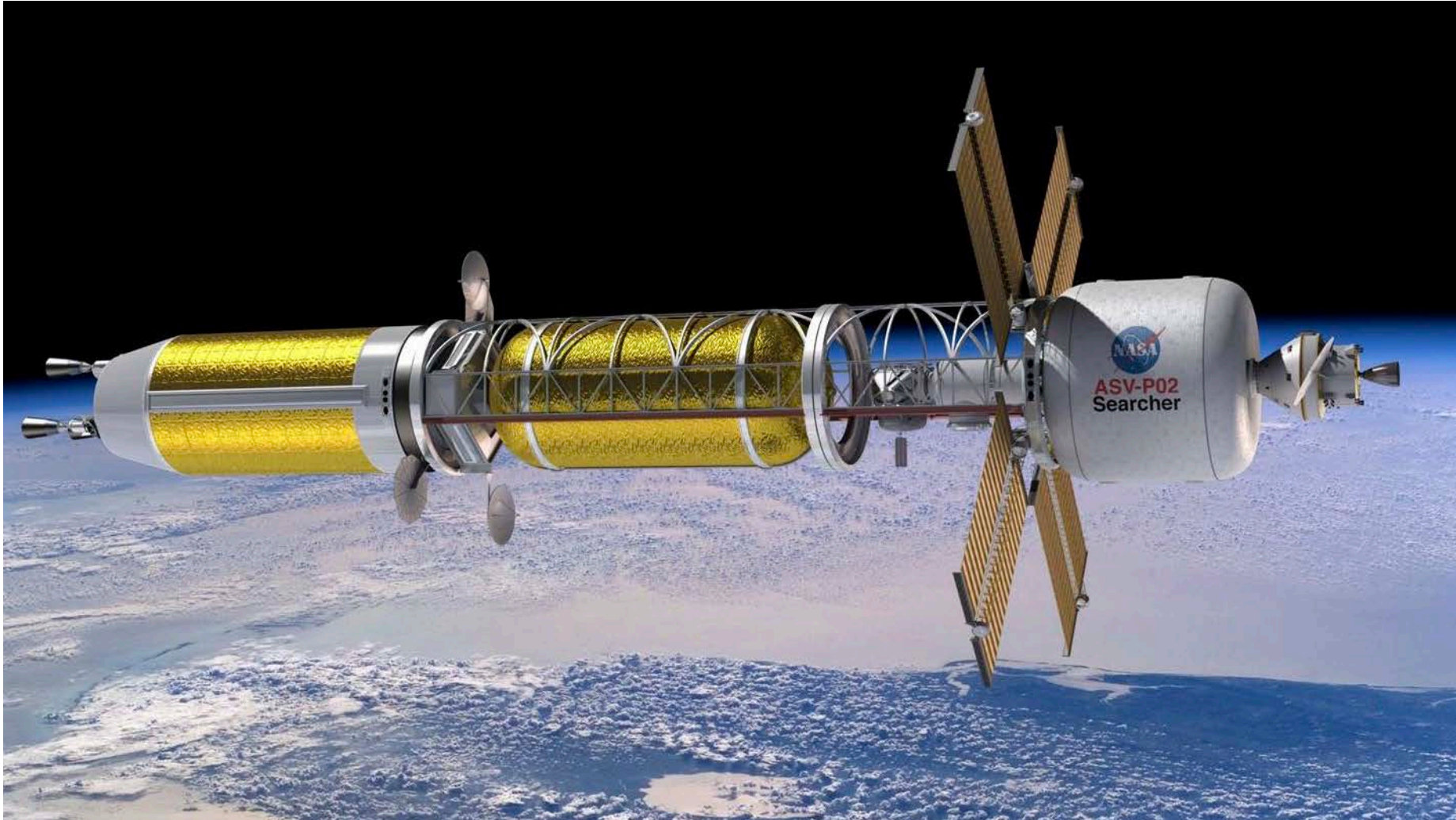
<https://science.nasa.gov/mission/dragonfly/>



ESA / NASA Rosalind Franklin mission to Mars

ESA's Rosalind Franklin rover will search for evidence of Martian life. Credit: ESA

<https://spacenews.com/nasa-selects-falcon-heavy-to-launch-esa-mars-rover-mission-despite-budget-threat/>



**NASA
Announces
Nuclear
Thermal
Propulsion
Reactor
Concept
Awards**

Illustration of a spacecraft enabled by nuclear thermal propulsion. **Credits: NASA**

<https://www.nasa.gov/news-release/nasa-announces-nuclear-thermal-propulsion-reactor-concept-awards/>



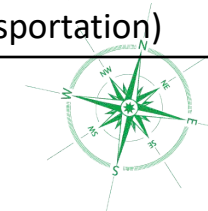
**SpaceX's Falcon Heavy
Chosen as launch vehicle for NASA's Dragonfly and ESA Rosalind Franklin missions**

<https://www.geekwire.com/2018/photos-first-launch-spacex-falcon-heavy-rocket/>



Anticipated Technical Peer Review Roles in the INSRB Process

	Nuclear Safety Analysis Report (SAR)	Technical Peer Review in NSPM-20	Federal Agency Review	Interagency Review	Nuclear Launch Authority
Case 1 (e.g., NASA plutonium-238 radioisotope power system mission)					
Nuclear system (i.e., system SAR)	DOE (including contractors)	Component of the DOE process	DOE SER	INSRB Technical Report (if requested)	-
Flight (i.e., mission SAR)	DOE/NASA (including contractors)	Component of the DOE process	DOE SER	INSRB SER	NASA Administrator or Exec. Office of the President
Case 2 (e.g., DoD space reactor mission)					
Nuclear system	DoD program office (including contractors)	Separate DoD program office contractor	DoD SER	INSRB Technical Report (if requested)	-
Flight	DoD program office contractor	Separate DoD program office contractor	DoD SER	INSRB SER	Secretary of Defense or Exec. Office of the President
Case 3 (e.g., fully commercial)					
Nuclear system	NRC applicant (terrestrial safety aspects)	-	NRC terrestrial license	INSRB Technical Report (if requested)	-
Flight	FAA applicant for launch or reentry (flight safety aspects)	FAA applicant	FAA launch or reentry license	INSRB SER (if requested by Sec. of Transportation)	Secretary of Transportation



← JULY 16, 1969

JULY 20, 1969

JULY 21, 1969 →



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ASK ME!

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