ENSaF - Steps towards a European Space Nuclear Safety Framework

Leopold Summerer
DG-PI

Introduction and Background

Definitions

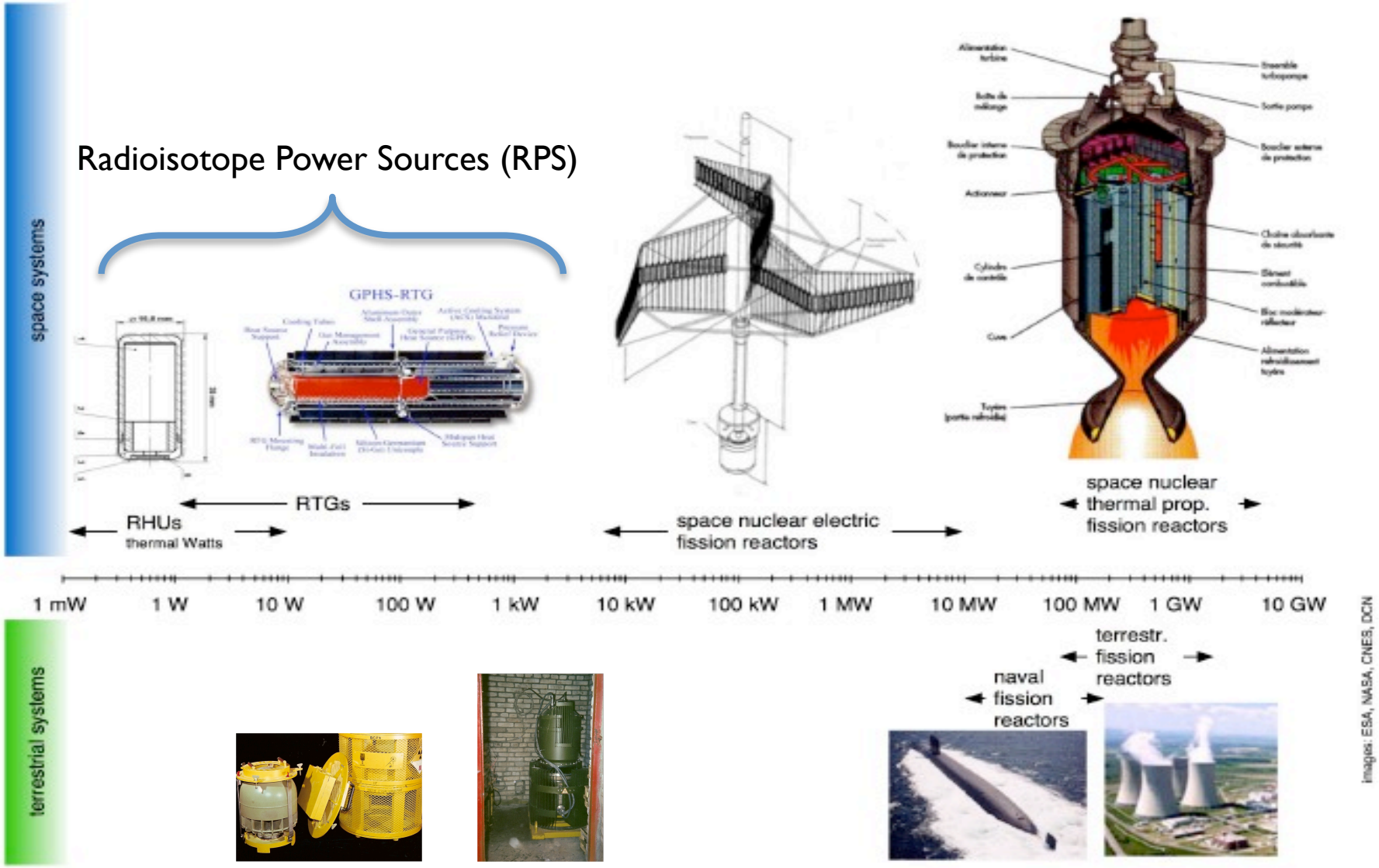
"Nuclear power sources for space":

- nuclear fission reactors
- radioisotope power sources (RHU, RTG)

"Nuclear Propulsion"

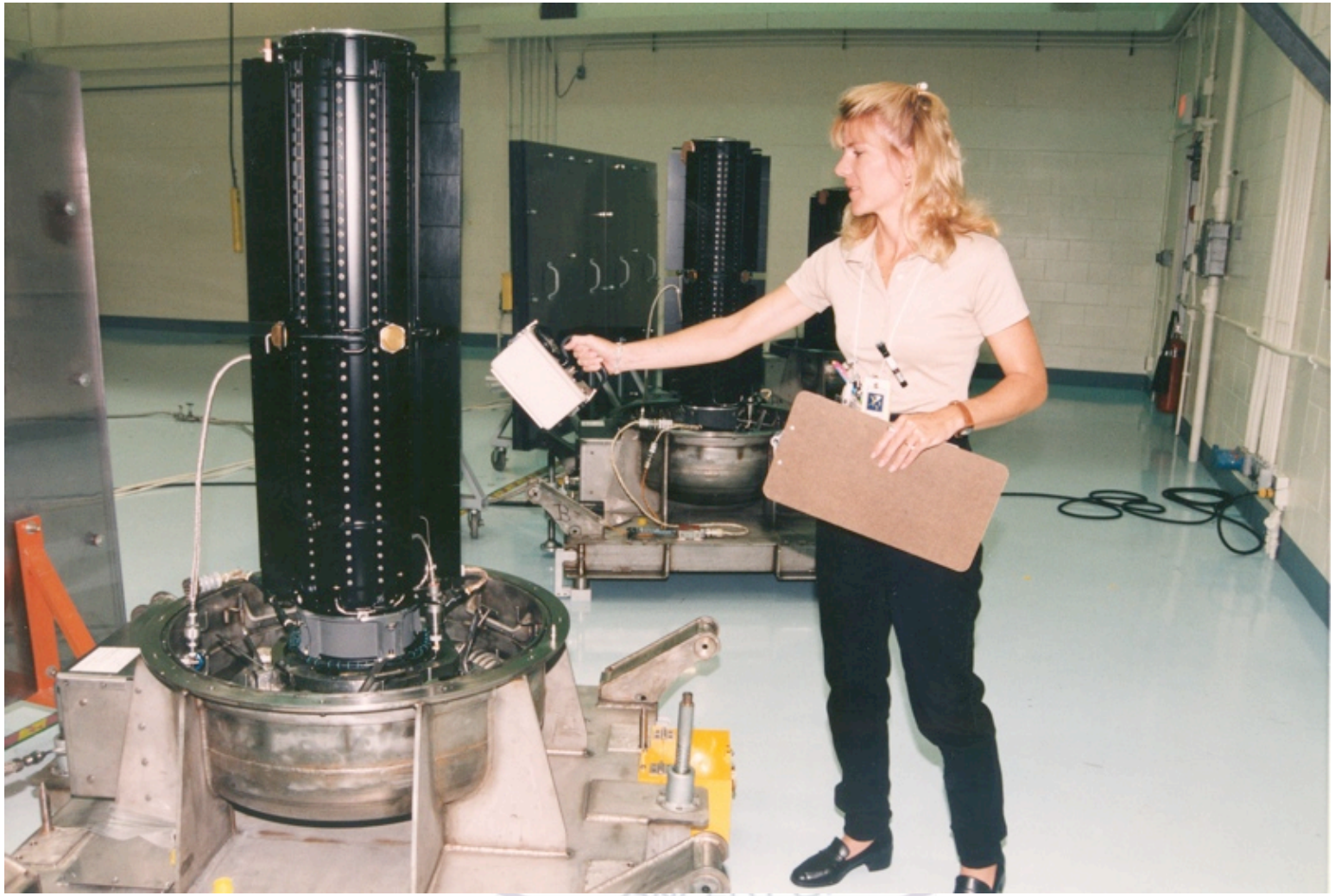
- Nuclear electric propulsion (NEP) systems
  (nuclear generated heat->electricity->electric thrusters)
- Nuclear thermal propulsion (NTP) systems
  (nuclear generated heat->direct propellant acceleration)

Background Information



Russian RHU "Angel"

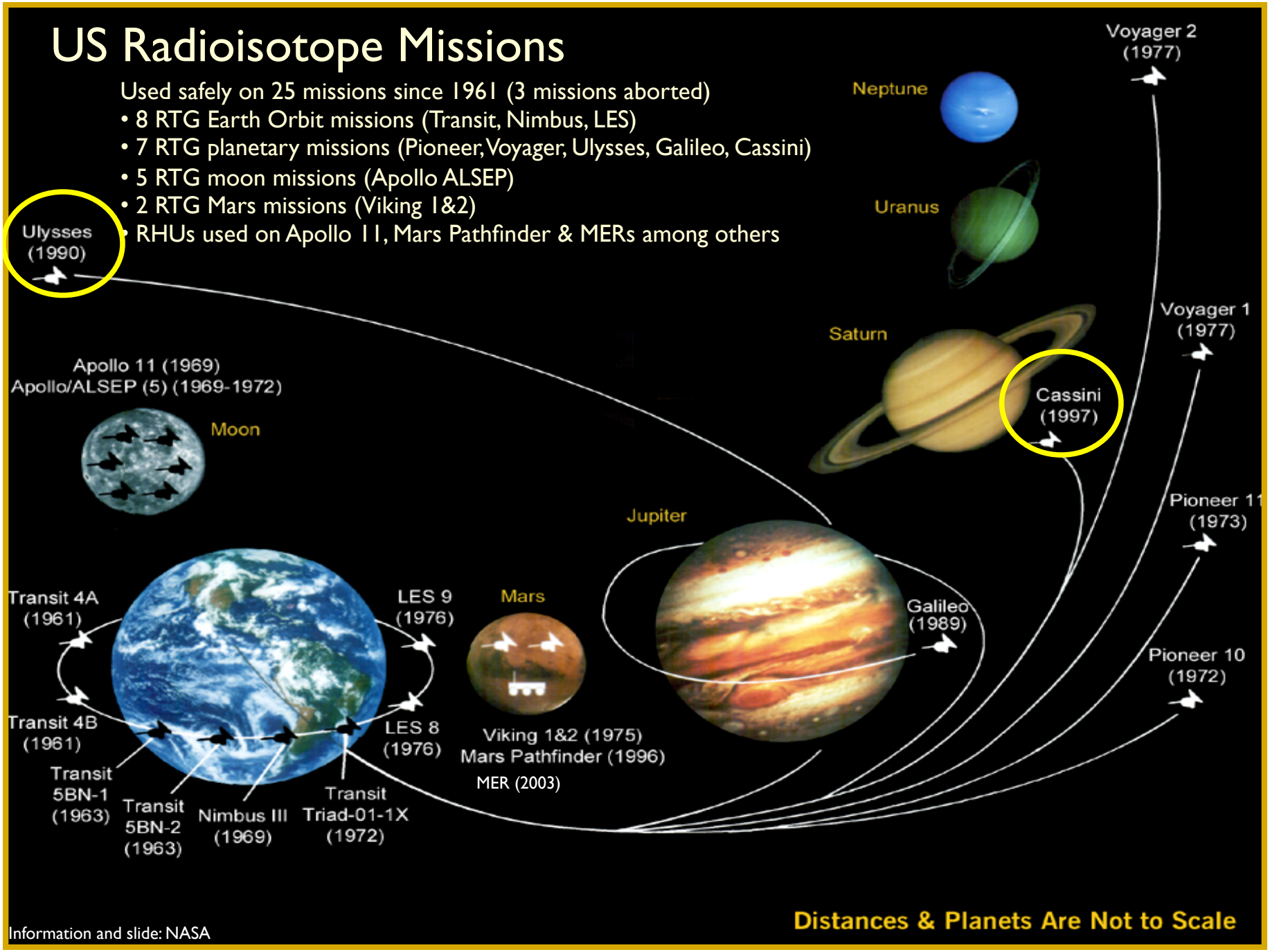
US Cassini-type GPHS-RTG



US Radioisotope Missions

Used safely on 25 missions since 1961 (3 missions aborted)

- 8 RTG Earth Orbit missions (Transit, Nimbus, LES)
- 7 RTG planetary missions (Pioneer, Voyager, Ulysses, Galileo, Cassini)
- 5 RTG moon missions (Apollo ALSEP)
- 2 RTG Mars missions (Viking 1&2)
- RHUs used on Apollo 11, Mars Pathfinder & MERs among others



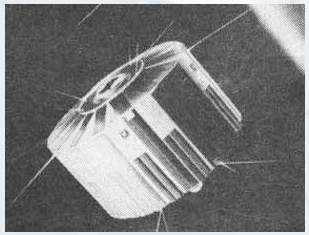
Information and slide: NASA

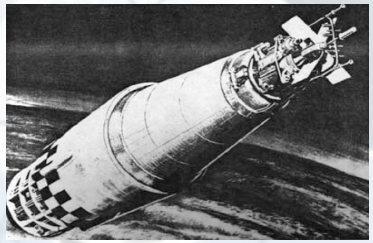
Use of Nuclear Power Sources

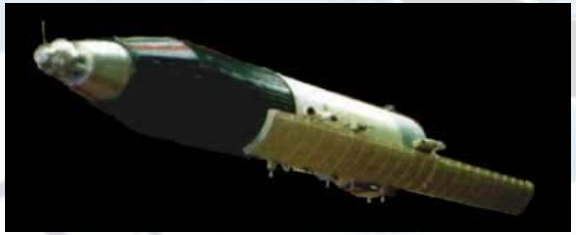
on almost all successful lunar and Martian landers
(e.g. Apollo, Viking, Pathfinder, MER Spirit & Opportunity)

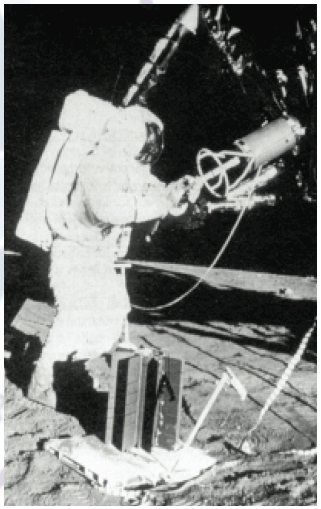
on all deep space missions to Jupiter and beyond

defence satellites (power, vulnerability, drag)









images: NASA, ESA, DoE

Particularities of Nuclear Safety for Space Missions

Specificities of Space NPS Safety

used infrequently - safety relevant phases very short

system safety requirements can vary substantially with mission

Launch and operational requirements impose restrictions on size and mass

launch and re-entry environments expose space NPS to unusually harsh environments

radioisotope exposure risks potentially regional or global

Remote autonomous very long-term use with no human intervention

UN COPUOS

International Space Nuclear Safety Framework

International Legal Frame

Principles Relevant to the Use of Nuclear Power Sources In Outer Space, 1992

Principle 4. Safety assessment

"A launching State [...] shall, prior to the launch, through cooperative arrangements, where relevant, with those which have designed, constructed or manufactured the nuclear power sources, or will operate the space object, or from whose territory or facility such an object will be launched, ensure that a thorough and comprehensive safety assessment is conducted. This assessment shall cover as well all relevant phases of the mission and shall deal with all systems involved, including the means of launching, the space platform, the nuclear power source and its equipment and the means of control and communication between ground and space."

COPUOS Activities

1992

- UN GA Resolution (GA Res. 47/68) "Principles Relevant to the Use of Nuclear Power Sources In Outer Space"

2003

- adoption of a work plan within STSC to "develop an international technically based framework of goals and recommendations for the safety of nuclear power source applications in outer space"

2006

- IAEA-STSC Workshop on Space NPS

2007-

- Creation of Joint STSC-IAEA NPS Expert Group for the development of the framework
  - drafting of first version during 2007 - discussed in Jun 07, Oct. 07, Feb 08
  - relatively high level (similar to IAEA SF-1)
- earliest adoption: 2009/2010

Current Outline of Draft Framework

1. Introduction
   1.1. Background
   1.2. Purpose
   1.3. Scope
2. Safety Objective
3. Guidance for Governments
   3.1. Safety Policy, Requirements, and Process
   3.2. Justification for Space Nuclear Power Source Applications
   3.3. Mission Launch Authorisation
   3.4. Emergency Preparedness and Response
4. Guidance for Management Elements
   4.1. Responsibility for Safety
   4.2. Leadership and Management for Safety
5. Technical Guidance
   5.1. Technical Competence in Nuclear Safety
   5.2. Safety in Design and Development
   5.3. Assessment of Risk
   5.4. Accident Consequence Mitigation
6. Glossary of Terms

1. Introduction - Purpose

1.2. Purpose

The purpose of this publication is to provide high-level guidance in the form of a model safety framework. The framework provides a foundation for the development of national and international intergovernmental safety frameworks while allowing for flexibility in adapting such frameworks to specific space NPS applications and organisational structures. Such national and international intergovernmental frameworks should include both technical and programmatic elements to mitigate risks arising from the use of space NPS.

Implementation of such frameworks would provide assurance to the global public that space NPS applications would be launched and used in a safe manner, and could facilitate bilateral and multilateral cooperation on space missions using NPS. This guidance reflects an international consensus on measures needed to achieve safety and is intended for both radioisotope power systems and nuclear reactor systems.

2. Safety Objective

The fundamental safety objective is to protect people and the environment in Earth's biosphere from potential hazards associated with relevant launch, operation, and end-of-service phases of space nuclear power source applications.

Government(s) and organisations responsible for authorising, approving or conducting space NPS applications should take measures to ensure that people (individually and collectively) and the environment in Earth's biosphere are protected without unduly limiting the beneficial uses of space NPS applications.

Guidance, for satisfying the fundamental safety objective, is grouped into three categories: Governmental, Managerial, and Technical. Guidance for Governments (Section 3) applies to governments and relevant international intergovernmental organisations responsible for authorising, approving, or conducting space NPS missions. Guidance for Management (Section 4) provides guidance to the management of the organisation that conducts space NPS missions. Technical Guidance (Section 5) provides guidance that is pertinent to design, development, and mission phases of space NPS applications.

3. Guidance for Governments

3.1. Safety Policy, Requirements, and Processes

Governments responsible for authorising, approving or conducting space nuclear power source missions should establish safety policies, requirements, and processes.

[…]

3.2. Justification for Space Nuclear Power Source Applications

The government's mission approval process should verify that the rationale for using the space nuclear power source application has been appropriately justified.

[…]

3.3. Mission Launch Authorisation

A mission launch authorization process for space nuclear power source applications should be established and sustained.

[…]

3.4. Emergency Preparedness and Response

Preparations should be made to respond to potential emergencies involving a space nuclear power source.

[…]

4. Guidance for Management

This section provides guidance for management of the organisations that use space NPS. In the context of this framework, management should comply with governmental and relevant intergovernmental safety policies, requirements, and processes to achieve the fundamental safety objective. Management responsibilities include accepting prime responsibility for safety and creating a robust "safety culture" within the organisation.

4. Guidance for Management

4.1. Responsibility for Safety

The prime responsibility for safety should rest with the organisation that conducts the space nuclear power source mission.

[…]

4.2. Leadership and Management for Safety

Effective leadership and management for safety should be established and sustained in the organisation that conducts the space nuclear power source mission.

[…]

5. Technical Guidance

This section provides the framework's technical guidance pertinent to the design, development, and mission phases of space NPS applications relevant to achieving the safety objective. To ensure a satisfactory technical basis for the government's authorization and approval processes and for emergency preparedness and response, guidance is provided in four key areas for organisation(s) involved in conducting space NPS applications:

- Establishing and maintaining a nuclear safety design, test, and analysis capability;
- Applying this capability in the design, qualification, and mission launch authorization processes of the space NPS application (i.e., space NPS, spacecraft, launch system, mission design, and flight rules);
- Assessing the radiation risks to people and the environment arising from potential accidents and ensuring that the risk is acceptable and as low as reasonably achievable; and
- Taking actions to manage the consequences of potential accidents.

5. Technical Guidance

5.1. Technical Competence in Nuclear Safety

Technical competence in nuclear safety should be established and maintained for space nuclear power source applications.

[…]

5.2. Safety in Design and Development

Design and development processes should provide the highest level of safety that can reasonably be achieved.

[…]

5.3. Assessment of Risk

Risk assessments should be conducted to characterise the radiation risks to people and the environment.

[…]

5.4. Accident Consequence Mitigation

All practical efforts should be made to mitigate the consequences of potential accidents.

[…]

ENSaF

Drafting of a European Space Nuclear Safety Framework

European Space Nuclear Safety Framework

US and Russian setup demonstrate the need to involve organisations not present in the regular launch approval process

space and nuclear safety experts from big ESA MS draft a technically sound European framework that

- provides a predictable, efficient, "workable" process for ESA missions
- addresses the main concerns of participating MS
- takes advantage of the existing European nuclear safety expertise and experience gained on the subject in US and Russia
- provides a technically sound basis for an early decision on processes, roles and responsibilities

Study initiated under General Studies Programme in 2005

Letter exchange ESA - NASA during Spring 2006 for cooperation on sharing experience within ENSaF

ENSaF in close alignment with IAEA-STSC process of drafting an international safety framework for NPS

ENSaF Involved Entities

Areva TA: study lead and nuclear engineering expertise

IRSN, GRS, Serco Assurance, RxTec: Technical Nuclear Safety Organisations of France, Germany, UK and Italy

TAS, DLR, EADS ST: space engineering and system expertise

CNES and CEA accompanying study alongside ESA (non contractual)

US advice via NASA HO, JPL, DoE: advice, review of documents, comments, suggestions, visibility,

WP description and results

WP11 - Analysis of Spacecraft AIV process for NPS

WP12 - Applicable Regulations (intern., European, F, G, UK, I)

- synthesis and recommendation by French IRSN

WP13 - US and Russian space nuclear safety processes

WP20 - Nuclear Safety Goals, Options, Methodology

- comparison of terrestrial safety goals and classifications with space NPS cases (normal operations, abnormal occurrences, DBA, accidents beyond the design basis)
- analysis of types of terrestrial nuclear safety goals
  - radiological criteria (e.g. deterministic and probabilistic dose limits for exposure, release criteria)
  - technical safety criteria (requirements for transport packages)
  - criteria for beyond design base accidents
- specification of General SNSG

WP description and results

WP30 - Space Nuclear Safety Process

- Distribution of Actors and Approval Process (GRS and IRSN)
  - No European competent authority for launch nuclear safety approval (i.e. no Office of Science and Technology Policy (OSTP) or Rostechnadzor)
  - Currently no European provider of NPS (i.e. no counterpart to DOE or ROSATOM)
  - No European environmental protection authority (U.S. EPA)
- Based on terrestrial French nuclear safety approval process with ASN and CNES
- Definition of Mission Classifications (Serco)
  - following US classification in essence but keeping only highest mission class

WP40 - Recommendations for Implementation of ENSaF

- Synthesis Report

ENSaF Summary

- identification and assessment of relevant international and national legislation and regulations - analysis wrt to space processes
- integration of standard terrestrial nuclear safety assessment process into launch safety assessment process
- early technical involvement and "sensibilisation" of technical nuclear safety organisations (TSO) in F, D, I, UK
- principal technical consensus among TSOs of F, D, UK around a proposed modified standard French nuclear safety process
- central role for CNES
- implementation options discussions ongoing

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ENSaF Synthesis Report Outline (draft)

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