IMPLEMENTATION OF THE SAFETY FRAMEWORK FOR NUCLEAR POWER SOURCE APPLICATIONS IN OUTER SPACE

Presentation by the Russian Federation

Workshop: "Implementation of the Safety Framework for Nuclear Power Source Applications in Outer Space: Modern and Planned Applications and Challenges"

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SPACE REACTOR NUCLEAR POWER IN XXI CENTURY

Use of reactor nuclear power in outer space on the basis of the latest technologies, together with the creation of nuclear power propulsion system (NPPS), are essential in order to meet current and future challenges in near and deep space and to develop space exploration in the twenty-first century

MAIN ADVANTAGES OF SPACE REACTOR NUCLEAR POWER USING

- ✓ The production of electrical energy with help of reactor NPS does not depend on solar radiation intensity, spacecraft orientation or distance from the sun, thus making feasible deep space missions
- ✓ The possibility of high-capacity nuclear power systems development and application
- ✓The possibility of high-efficiency electric propulsion thrusters using
- ✓ The possibility to make a qualitative leap to the new power- and cost-efficient space vehicles development

EXPERIENCE OF DEVELOPMENT AND SAFE OPERATION OF RADIOISOTOPE NPS IN SPACE

September 3, 1965 – launch of AS «Kosmos-84» with radioisotope thermoelectric generator (RTG) «Orion-1», polonium-210 fueled.

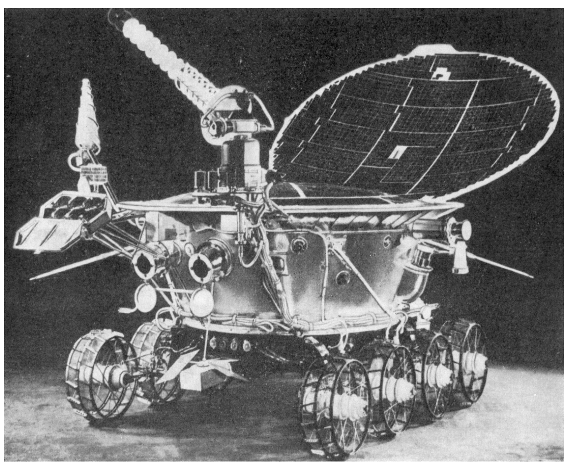
September 18, 1965 – launch of AS «Kosmos-90» with RTG «Orion-1».

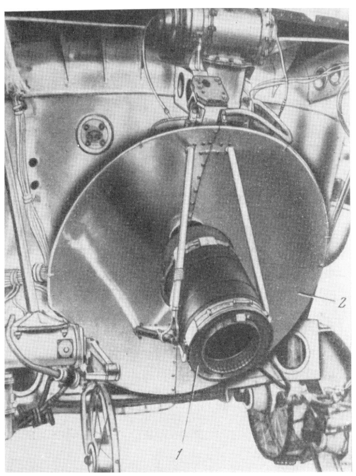
February 19, 1969 – launch of «Lunokhod» with radioisotope heating assembly (RHA), polonium-210 fueled. Emergency during orbital injection, RHA was not destructed.

November 10, 1970 – launch of «Lunokhod-1» with RHA. Successful work on the Moon surface.

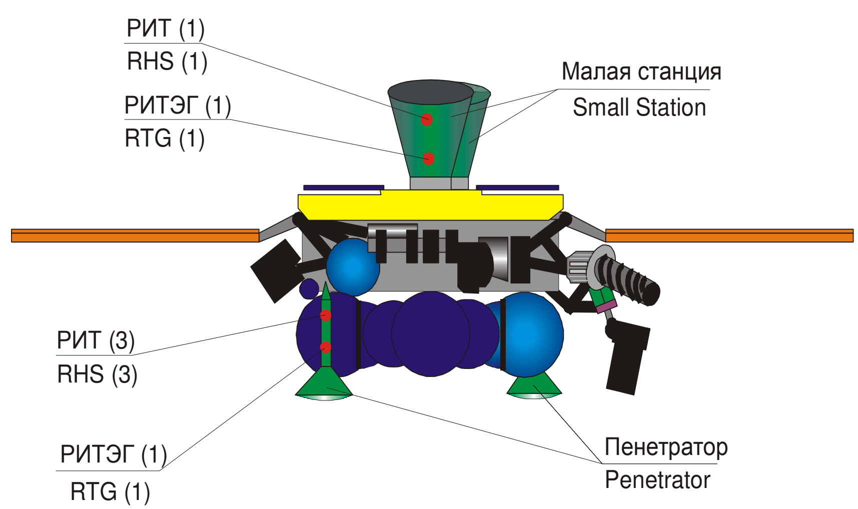
January 8, 1973 – launch of «Lunokhod-2» with RHA. Successful operating on the Moon surface.

November 16, 1996 – launch of automatic interplanetary station (AIS) «Mars-96» with thermal, electrical and combined power radioisotope generators (RG), plutonium-238 fueled. Emergency at orbital injection, RG were not destructed.





Lunokhod with RHA

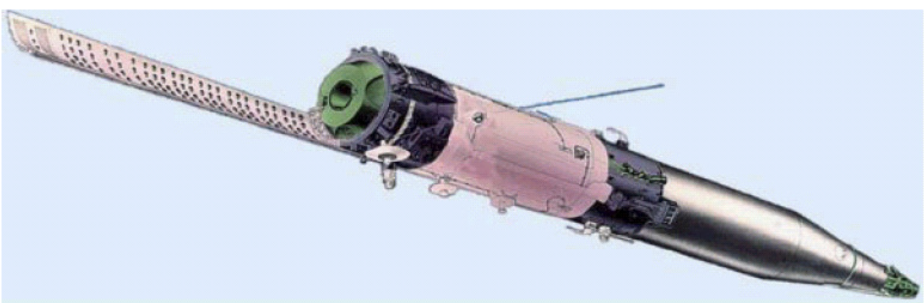


Arrangement of RG on AIS «Mars-96»

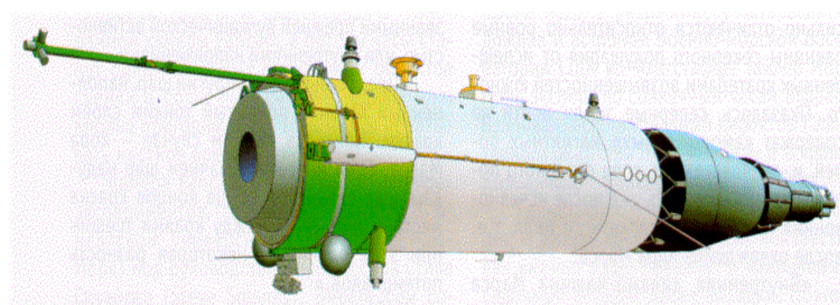
EXPERIENCE OF DEVELOPMENT AND EXPLOITATION OF SPACE NUCLEAR POWER IN RUSSIA

In 1960 – 1980 the essential experience of development and exploitation of NPS as a part of purpose-oriented space complexes was gathered in Russia:

- ✓ 1970-1988 – 31 "Kosmos" SC with NPS “Buk” of 3 kW electrical power were injected at low-Earth orbit
- ✓ 1987 – two “Plasma-A” SC (Kosmos-1818, Kosmos-1876) with NPS “Topaz” of 5 kW electrical power and 1 year lifetime were injected at low-Earth orbit
- ✓ Efficiency of providing radiation safety system (graveyard orbit injection at the end of life, aerodynamic dispersion of NPS elements) was confirmed



" Kosmos" SC with 3 kW NPS "Buk"



" Plasma-A" SC with 5 kW NPS "Topaz"

DEVELOPMENT OF TRANSPORT-POWER MODULE BASED ON MEGAWATT CLASS NUCLEAR POWER PROPULSION SYSTEM

(TPM with NPPS)

PROJECT OBJECTIVES

- **Technical and technological space nuclear power groundwork development**
- **Providing of the basis for realization of advanced programs aimed at deep space exploration and exploitation**
- **Creation of the new generation space vehicles with high power available**
- **New technologies implementation and innovative products creation**

THE MAIN PROJECT STAGES

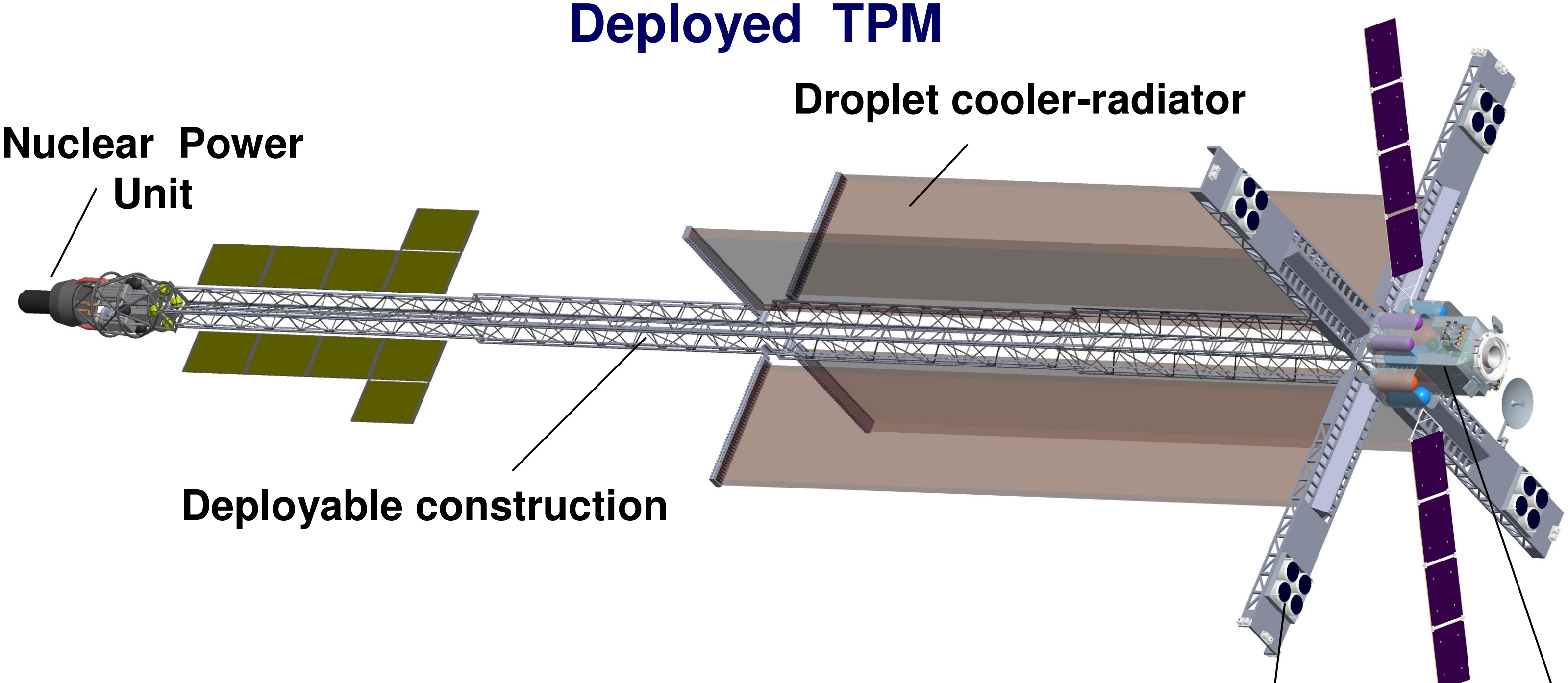
✓ **2010 год – beginning of the Project activity**

✓ **2012 год – TPM and NPPS draft design development**

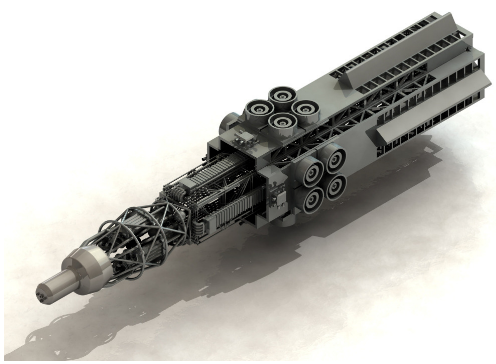
✓ **2018 год – ground testing and TPM flight test preparation**

TPM WITH NPPS IS THE BASIC PROJECT FOR NEW GENERATION SPACE VEHICLES DEVELOPMENT

Deployed TPM



TPM in transport position at assembly orbit (before deployment)



TPM WITH MEGAWATT CLASS NPPS POSSIBLE APPLICATION

SCIENCE AND OUTER SPACE EXPLORATION

✓Testing of technologies needed for Mars manned mission realization
✓Moon exploration program support
✓Development of means for outer space (including different space objects such as Solar System planets, asteroids, comets etc) research and exploration
✓…

GLOBAL SECURITY PROVIDING

✓Earth protection from asteroid and cometary hazards

✓Removal of out-of-operation satellites and space debris from near-Earth orbits

✓…

SOCIOECONOMIC PROGRESS

✓ Heavy all-purpose space platforms:
-Telecommunication satellites with wide frequency band
-Personal communication
-Radar and optical-electronic systems for the Earth, near-Earth space and other space objects remote sensing
✓…

NUCLEAR POWER SOURCE EXPLOITATION IN SPACE SAFETY PROVIDING

As early as the 1960s, during the initial phase of the creation of space vehicles with first-generation reactor NPS, the USSR developed solutions for ensuring nuclear and radiation safety during their operation. Those solutions were subsequently endorsed by the United Nations Committee on the Peaceful Uses of Outer Space.

Russian experts are developing the TPM with megawatt-class NPPS in full compliance with the international agreements relating to NPS exploitation.

They are also conducting their activities in relation to TPM development in accordance with national federal laws.

NATIONAL DOCUMENTS, CONCERNING NUCLEAR POWER USING IN SPACE

FEDERAL LAWS

Law of RF from August 20, 1993 № 5663-1 “Space Activities Act”

Federal law of RF from November 21, 1995 № 170-ФЗ “Act on the Use of Atomic Energy”

Chapter IX. Article 43. Special conditions of operation of space and flying vehicles with nuclear systems and radiating sources.

Rules of the notification about the failure of space and flying vehicles with nuclear systems and radiating sources

Federal law from January 9, 1996 N 3-ФЗ «Act on Protection of the Public from Radiation»

Federal law from January 10, 2002 N 73-ФЗ (edition from 19.07.2011) «Environmental Protection Act»

Federal law of RF from November 23, 1995 № 174-ФЗ “Environmental Assessment Act”

REGULATIONS

Radiation Safety Standards (НРБ-99/2009)

Basic Public Health Regulations for Radiation Safety (ОСПОРБ-99/2010)

DOCUMENTS OF UN COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE, ENSURING THE SAFETY OF NUCLEAR POWER APPLICATION IN SPACE

Principles Relevant to the Use of Nuclear Power Sources in Outer Space

Approved by the General Assembly of UN in resolution 47/68 from December 14, 1992

Safety Framework for Nuclear Power Source Applications in Outer Space

Approved by the General Assembly of UN in resolution 64/86 from December 10, 2009

The Safety Framework states that "foreseeable space NPS applications include […] nuclear reactor systems for power and propulsion".

SAFETY PROVIDING OF SPACE REACTOR NPS EXPLOITATION IN SPACE

INTERNATIONAL RECOMMENDATIONS OF NUCLEAR SAFETY PROVIDING ARE ENSHRINED IN THE "PRINCIPLES RELEVANT TO THE USE OF NUCLEAR POWER SOURCES IN OUTER SPACE"

- ✓Maintaining of NPS reactor in subcritical state (preventing chain reaction) until spacecraft with NPS is injecting into nuclear safe orbit, including all emergency situations;
- ✓ Actuation of NPS reactor only at the nuclear safe orbit;
- ✓Obligatory reactor shutdown after the realization of vehicle flight program and also at emergency situation;
- ✓ Isolation of NPS from the Earth population during the period of time which is needed for the inactive reactor radioactivity decreases down to a safe level.

SAFETY PROVIDING OF SPACE REACTOR NPS EXPLOITATION IN SPACE

METHODS OF NPS ISOLATION

✓**Injection on radiation safe orbit.**
Realized by SC with NPS “Topaz”. SC was injected into nuclear safe orbit with 800 km altitude, operated on this orbit and stayed there after completion of operation.

✓**Injection into nuclear safe orbit (high orbit) with the help of special unit assembly after the low-earth orbit operation.**
Realized by SC with NPS “Buk”. After the operation at the low-Earth orbit with 265 km altitude NPS with the help of special breakout unit was separated from SC and injected into the orbit with 900 km altitude.

✓**Controlled descent of NPS in designated area without destruction.**
Can be realized by new generation SC with NPS.

METHODS OF NPS DISPERSION

Methods of NPS reactor active zone destruction to particles of size no more than several hundreds micron and dispersion of these fragments on the area not less than several hundreds square kilometers.

✓Aerodynamic destruction at the descent in atmosphere of the Earth. Realized by SC with NPS “Buk”.

Russia has an experience of application of appropriate methods for providing safety reactor NPS exploitation in space

SAFETY FRAMEWORK FOR NUCLEAR POWER SOURCE APPLICATIONS IN OUTER SPACE

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.

The guidance set out in the Safety Framework for fulfilling that fundamental safety objective is divided into three categories:

- ✓ **Guidance for governments intended to governments which resolve and approve space missions with NPS;**
- ✓ **Guidance for the management intended to management of the organization which realize space missions with NPS;**
- ✓ **Technical guidance concerns engineering, development and stages of space missions with use of NPS.**

SAFETY FRAMEWORK FOR NUCLEAR POWER SOURCE APPLICATIONS IN OUTER SPACE

GUIDANCE FOR GOVERNMENTS

Governmental responsibilities include:

✓ establishing safety policies, requirements and processes;
✓ ensuring compliance with those policies, requirements and processes;
✓ ensuring that there is acceptable justification for using a space NPS when weighed against other alternatives;
✓ establishing a mission launch authorization process;
✓ ensuring emergency preparedness and response.

National regulations in the Russian Federation are currently being updated in connection with the development of the TPM with NPPS:

✓ «General safety provisions for space nuclear power systems»;
✓ «Nuclear safety regulations for space nuclear power systems»;
✓ «Public health regulations for ensuring the radiation safety of space nuclear power sources»;
✓ «Requirements relating to the content of safety assessment reports for space nuclear power systems».

SAFETY FRAMEWORK FOR NUCLEAR POWER SOURCE APPLICATIONS IN OUTER SPACE

GUIDANCE FOR MANAGEMENT

Management responsibilities include:

✓ accepting prime responsibility for safety;
✓ complying with governmental safety policies, requirements and processes in order to achieve the fundamental safety;
✓ ensuring the availability of adequate resources for safety;
✓ promoting and sustaining a robust safety culture at all organizational levels;
✓ providing relevant, accurate and timely information to the public.

For the realization of guidance to the management during the creation of TPM:

✓ establishment of a council comprising the heads of the enterprises participating in the TPM project;
✓establishment of working group for coordinating activities relating to the adoption of technical solutions for ensuring nuclear and radiation safety during the construction and operation of the TPM;
✓ information concerning the progress of works on creation of TPM is provided to the public in a timely manner through the mass media.

SAFETY FRAMEWORK FOR NUCLEAR POWER SOURCE APPLICATIONS IN OUTER SPACE

TECHNICAL GUIDANCE

Main regulations of technical guidance
for organizations using space NPS:

- ✓ it's necessary to provide and support technical competence in questions of nuclear safety at development, testing and exploitation stages

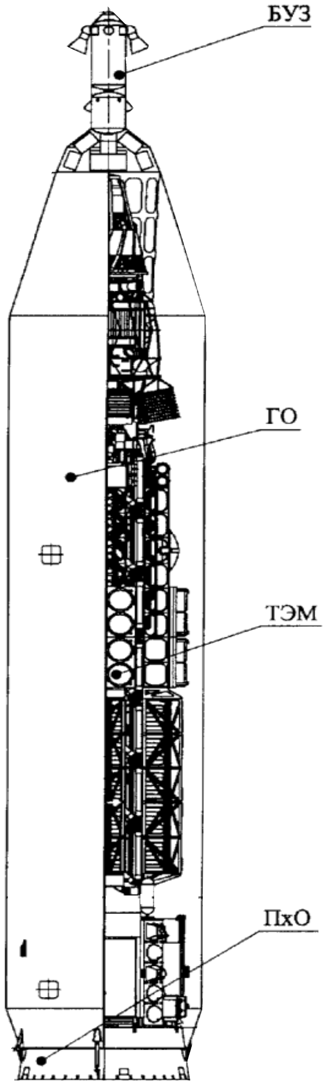
- ✓ the NPS design and development should therefore ensure the highest possible level of safety;

- ✓ it is necessary to make radiation risk estimation from the population and environments safety point of view;

- ✓ it is necessary to make all realizable efforts for easing of possible emergencies consequences.

To ensure nuclear and radiation safety experience obtained at development and application of previous generation space nuclear power systems will be implemented in the TPM and its component parts designing and testing.

TPM WITH NPPS SAFETY PROVIDING BEFORE IT REACHES NUCLEAR SAFE ORBIT



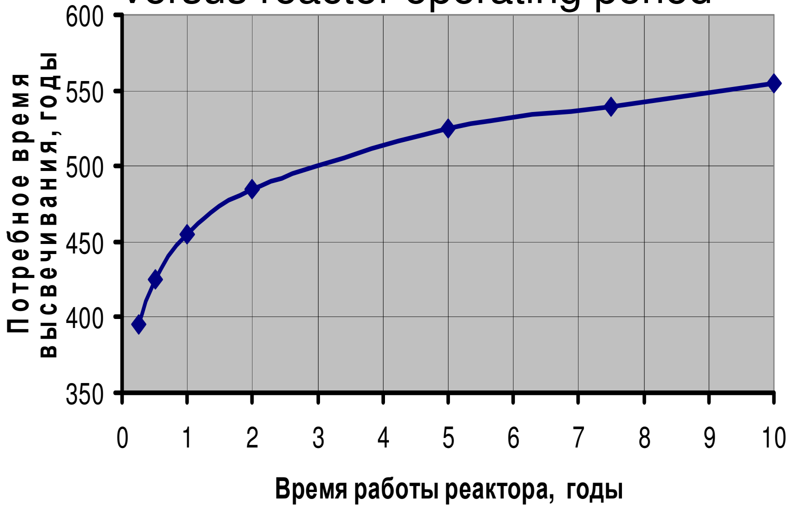
The NPPS reactor will not be put into critical state until the TPM has reached a sufficiently high operating orbit (nuclear safe orbit) or it has been directed into an interplanetary trajectory

In the event of any potential incident the nuclear reactor is constructed in such a way as to ensure that it is maintained in subcritical condition before entering operating orbit or an interplanetary trajectory

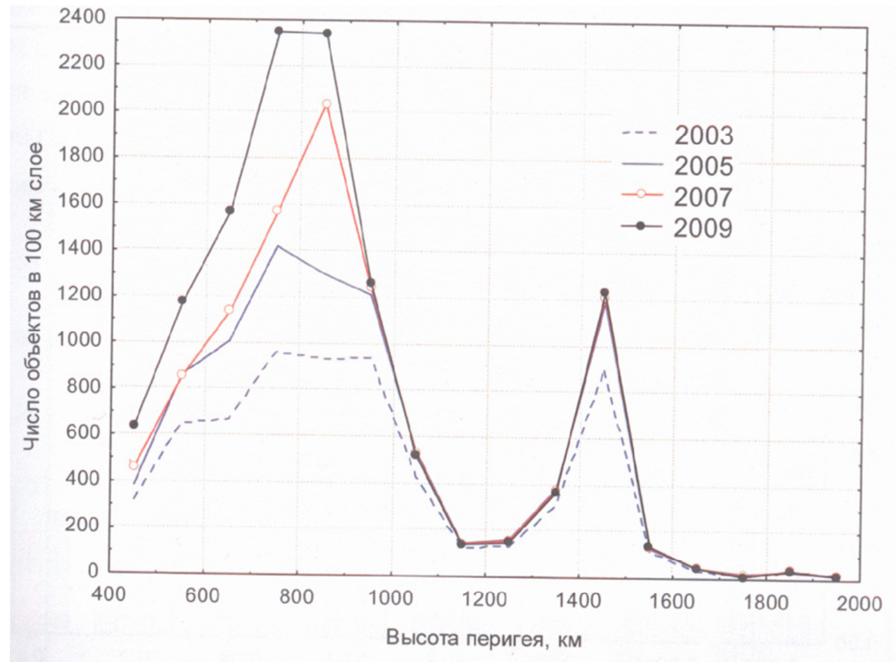
In case of failure of TPM injection into a nuclear safe orbit, TPM deorbiting with help of special unit is being considered

SAFETY OPERATION PROVIDING OF TPM WITH NPPS ON NUCLEAR SAFE ORBIT

Luminescence time versus reactor operating period



Space objects distribution on orbits with altitude range 500-2000 km (2003-2009 years data)



Nuclear safe orbit minimal altitude estimation

To minimize collision probability with near-Earth space debris, orbits with altitude range 1200 - 2000 km are being considered as a minimum possible ones for TPM operation

INTERORBITAL TRANSFER VEHICLE BASED ON TPM OPERATION ALGORITHM, EXCLUDING DANGER FOR EARTH POPULATION

(example of payload module injection into geostationary orbit)

1. Minimum altitude of the transfer vehicle's operating orbit should be 1200-2000 km. Here TPM docks with the payload module and tugs it into geostationary orbit then returns back for the next payload module

2. Collisions between the TPM and registered objects constituting space debris at any point along the route can be prevented by the choice of appropriate launch date and interorbital trajectory for transfer mission and also by execution of an evasive maneuver with help of the TPM propulsion system

3. After the final payload module delivery into geostationary orbit, the TPM is sent into a graveyard orbit located 300 - 500 km above the geostationary orbit, thus virtually eliminating the risk of the TPM falling to Earth

CHALLENGES IN ENSURING THE SAFETY OF NEW-GENERATION SPACE NPS

PROTECTION OF THE NEAR-EARTH ENVIRONMENT

Requirements relating to pollution level in outer space caused by radiation from the reactor or its radioactive products and components have not yet been established

Reactor or its components radiation level in operational or off mode should be of such a value which provides minimal risk for current and future space missions realization

With regard to reactor radiation types that pose a potential risk of outer space pollution, positron radiation should be taken into account

Requirements relating to near-Earth space radiation pollution acceptable level should be determined

PROTECTION OF HUMANS IN OUTER SPACE FROM THE NPS EFFECT

Manned space vehicles crew protection

PROTECTION OF OTHER SPACE OBJECTS ENVIRONMENT

Other space objects radiation pollution prevention

CONCLUSION

1. The Russian Federation has established a system for the safe use of space vehicles with NPS that meets the requirements of international instruments

2. In accordance with United Nations recommendations, a body of State and space-sector regulations to ensure the safe use of transport power modules (TPM) with megawatt-class nuclear power propulsion system (NPPS) is being drawn up

3. The project of TPM with a megawatt-class NPPS creation is being implemented in accordance with all technical safety measures recommended by the United Nations and prescribed by national regulations

4. While the TPM is being developed, new issues relating to the safe use of NPS in space are being examined and identified for further investigation