Investigations of Radioactive Contamination of Near-Earth Space

N. Bakhtigaraev – Institute of Astronomy of RAS
M. Anikeeva - JSC «VNIIEM Corporation»
K. Boyarchuk - JSC «NIIEVM»
S. Kuzin - Lebedev Physical Institute of RAS
S. Ulin - Moscow Engineering Physics Institute
V. Chazov – Shternberg Astronomical Inst. MSU

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Radioactive and Fissile Materials in the Near-Earth Space

- On June 29, 1961 exploded 1961-015C ABLESTAR R/B with the formation of a 300 only large fragments. The same rocket have launched the first navigation satellite Transit-4A with the radioisotopic thermoelectric generator SNAP-3.
Radioactive and Fissile Materials in the Near-Earth Space

Nuclear reactor SNAP-10A (OPS 4682) was launched on the United States on April 3, 1965 to orbit with an inclination of 90.17 degrees and a height of 1283 x 1312 km.

The reactor successfully worked for 43 days - until May 16, 1965. Due to the numerous high-voltage breakdowns, were disrupted horizon sensors. On the false command from the voltage regulator were dropped details of the construction of the reflector of the reactor, which has ensured its irreversible jamming. Many fragments were formed.
Radioactive and Fissile Materials in the Near-Earth Space

On October 3, 1970, Cosmos-367 satellite with nuclear power unit of BES-5 «BUK» (fuel- 30 kg uranium) was launched from the Baikonur.

In total 32 satellites with nuclear power units were launched from 1970 to 1988.
Radioactive and Fissile Materials in the Near-Earth Space

The next Soviet space nuclear power system has become ТЭУ-5 «TOPOL» (TOPAZ-1), launched on February 2, 1987 (Cosmos-1818). The reactor had a fuel - uranium dioxide. Thermal capacity of 150 kW, the amount of 235U in the reactor 11.5 kg.
Satellites US-A functioned on orbits of a height of only 260 x 280 km. At the end of the work, the radiation-dangerous part of the satellite was placed to “grave” orbit with height of 900 x 950 km.

In two cases, the removal to “grave” orbit has not been implemented.
«Cosmos-954» fell on January 24, 1978 in Canada, causing radiation pollution of the area. The Improved «Cosmos-1402» have separated active zone of the reactor from the satellite on February 7, 1983, collapsed without harm over the Atlantic.

The third incident took place with the «Cosmos-1900», on which the disposal of the reactor was completed on September 30, 1988.

These events received wide publicity, and launches of satellites US-A had been terminated.
Instant picture of the location of 75 potentially radiation-dangerous objects of space debris (SPACECRAFT with nuclear power facilities and their fragments)
### The physical characteristics

<table>
<thead>
<tr>
<th>Object</th>
<th>Number of fragments</th>
<th>$H_{\text{min}}$ in km</th>
<th>$\text{AMR m}^2/\text{kg}$</th>
<th>Time of fall to the 600 km height [In Years]</th>
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<tbody>
<tr>
<td>Cosmos 1176 coolant</td>
<td>1</td>
<td>865</td>
<td>0.06</td>
<td>200</td>
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<tr>
<td>Cosmos 1932 coolant</td>
<td>1</td>
<td>988</td>
<td>0.06</td>
<td>400</td>
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<tr>
<td>Cosmos 1818</td>
<td>1</td>
<td>775</td>
<td>0.008</td>
<td>800</td>
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<tr>
<td>Cosmos 1818 deb</td>
<td></td>
<td>774</td>
<td>0.04</td>
<td>180</td>
</tr>
<tr>
<td>OPS 4682 (snapshot)</td>
<td>1</td>
<td>1283</td>
<td>0.001</td>
<td>$&gt;1000$</td>
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<tr>
<td>OPS 4682 deb</td>
<td>37</td>
<td>1260</td>
<td>0.23</td>
<td>1000</td>
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</table>
The method of complex monitoring of radioactive contamination of NEO

- Launch to LEO energy facilities containing radioactive and fissile materials, leads to an increase in the risk of global radioactive contamination of the atmosphere and the Earth's surface, which may occur as a result of the accident on the SPACECRAFT. The developed system of salvation of power installations on the SPACECRAFT are not always able to ensure the one hundred percent security.
The method of complex monitoring of radioactive contamination of NEO

To decrease the risks, connected with extraction of radioactive and fissile material in the near-earth outer space, it is necessary to create a system of space nuclear monitoring. The main objectives of this monitoring shall be as follows: - detection of radioactive and fissile materials in space objects; - identification of nuclear materials, and their quantitative estimation.
The method of complex monitoring of radioactive contamination of the NEO

The radiation of the space debris may consist of different components, which by its characteristics can be divided into three main groups:
1. Fragments of nuclear power reactors,
2. Shoot down reactors,
3. Operating satellites with nuclear reactors which have probability of collision with space debris or meteoroides.

Radioactive elements of these three groups have specific characteristics of gamma and neutron radiation.
The method of complex monitoring of radioactive contamination of the NEO

For the detection and identification of radioactive debris objects are used different methods. They can be divided into several groups.

1. Gamma-spectrometric methods. Gamma-spectrometers with good sensitivity and high energy resolution allow to measure the energy spectrum of the emitting object and to determine its isotopic composition and mass.
3. Methods of registration of electromagnetic radiation. The infra red imaging will allow to check the temperature of the satellite and its active zone.
4. Optical methods. The registration of objects that are associated with the radioactive debris allows to determine their trajectory.
Gamma - spectrometric instrument onboard the Spacecraft CORONAS-F.

- The experiment was conducted in the framework of the international program of the CORONAS (Complex Orbital near-Earth Observations of Active Sun) on the specialized automatic station CORONAS-F. CORONAS-F was launched on 31 July 2001, completed its work on 6 December 2005. The installed equipment AVS-F (Amplitude-Time spectroscopy of the Sun) is aimed to study the characteristics of the flux of hard x-ray and gamma-ray radiation of solar flares, as well as to search and to register gamma ray burst.
From July 2001 to December 2002. The SPACECRAFT CORONAS-F had a approachement with three of the 75 potentially radiation-dangerous objects. Average elements of their orbits

<table>
<thead>
<tr>
<th>Название</th>
<th>NORAD #</th>
<th>n</th>
<th>e</th>
<th>i</th>
</tr>
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<tr>
<td>CORONAS-F</td>
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<td>15.2</td>
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<td>Cosmos-1818</td>
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<td>14.3</td>
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<td>65.0</td>
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<tr>
<td>Cosmos-1867</td>
<td>18187</td>
<td>14.3</td>
<td>0.002</td>
<td>65.0</td>
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<tr>
<td>OPS 4682 DEB *</td>
<td>01399</td>
<td>14.5</td>
<td>0.005</td>
<td>90.4</td>
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</table>
Investigation of weak unidentified gamma events registered by the AVS-S from July 2001 to December 2002.

- For the period from August 2001 to December 2005 1100 gamma ray bursts were registered out a radiation belt and out of the South-Atlantic anomaly zones.
- Some of these events could be caused by the passage at sufficiently large distances (about 200 km) from the satellite objects with radioactive materials.
Experimental data of gamma ray detection during the passage of the OPS 4682 DEB at a distance 186 km from CORONAS-F in equatorial zone (a) and the same event after background reduction (b)
Experimental data of gamma ray detection during the passage of OPS 4682 DEB at a distance of 194 km from satellite CORONAS-F in the area of the polar zone.
Summary

• We developed the complex method of registration of the nuclear materials in space. The method is based on registration the gamma flux and optical observations.

• We found that space object OPS 4682 DEB (NORAD # 01399) could be radioactive one. Future investigations of this object are needed.
• The work performed in the framework of the Federal target program «Scientific and Scientific-Pedagogical personnel of innovative Russia» for 2009-2013.

• State contract # 02.740.11.0181, 25.06.2009.
Evolution of the orbital elements of OPS 4682 DEB *
H=690 km, AMR = 0.05
Evolution of the orbital elements of Cosmos 1818 deb. AMR = 0.04
Evolution of the orbital elements of Cosmos 1818 satellite. AMR = 0.5
Evolution of the orbital elements of the hypothetical fragment of Cosmos 1818 satellite. AMR = 0.008
Evolution of the orbital elements of the hypothetical fragment of Cosmos 1818 satellite. AMR = 0.2