

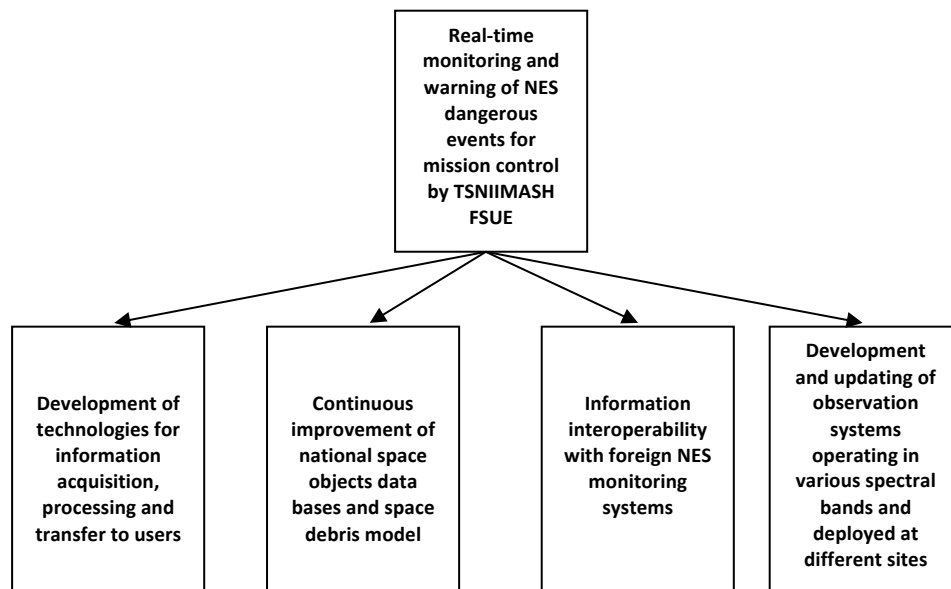
Implementation of Real-Time Monitoring and Warning of Near-Earth Space Dangerous Events by Roscosmos

I. Oleynikov, V. Ivanov, and M. Astrakhantsev

A lot of uncontrolled man-made objects, which regularly threaten the safety of the spacecraft's (SC) flight, were generated in the near earth space (NES) area in recent years. In order to solve this problem Russia developed a system for real-time monitoring and warning of near-earth space dangerous events (ASPOS). The main goal of this system is to send space operators warnings about the possible dangerous collisions with uncontrolled space objects.

The main design work on the given system include (pic.1):

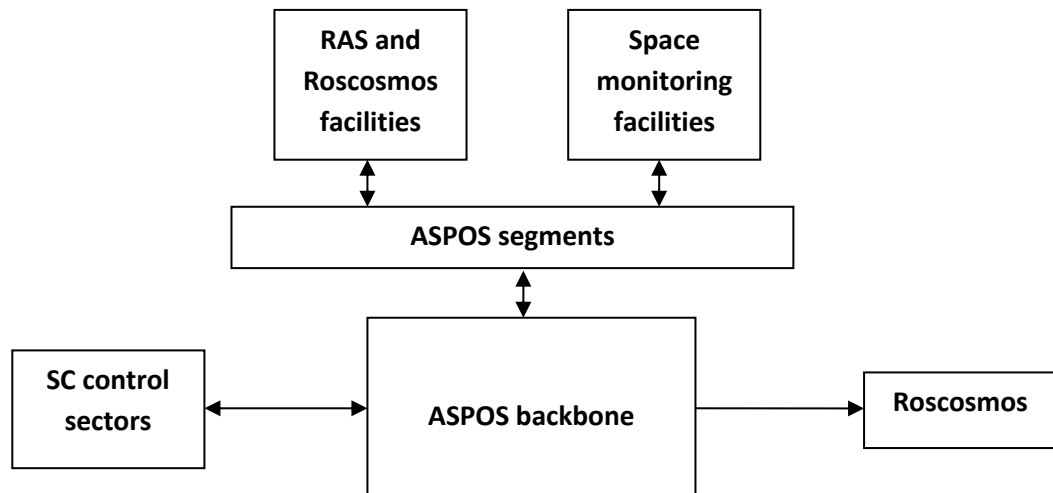
- 1) Development of technologies for acquisition, processing, and transfer to the user of the information obtained from the different sources.
- 2) Continuous improvement of the national databases and space debris model.
- 3) ASPOS integration with foreign NES monitoring systems.
- 4) Development of observation systems operating in the various spectral bands and deployed at different sites, namely integration of the following assets in the system:
 - a) ground and space-based optoelectronic equipment
 - b) ground radar equipment



pict.1

Each work is a separate complicated task, which needs a realization of careful science researches during its implementation. The space debris generation and distribution model is to be continuously updated, and the space debris fragments catalog is modified taking into account the formation of new information sources, new system subscribers, and growth of the NES space debris population. So the main work on the system design is to combine different observation systems, the acquisition, processing and transfer systems, and the computing facilities into one structure, which should guarantee the safety of any spacecraft, and has the possibility of the integration with foreign analogues.

Functional scheme of ASPOS is shown on pict.2



pict.2

The picture shows the cooperation between the main system's elements and the information consumers. Also, the picture presents some technologies in the structural connections and element's decomposition which were applied during the process of system design.

1) Emphasis is on the central core, which is responsible for the coordination of all actions between system's main elements and where the main computations are conducted. Also, the central core sends space operators warnings about the dangerous proximity with an uncontrolled space object, and sends Roscosmos the report about system's work.

2) Information from the observation facilities is received by the central core through separate segments, where a reduction and filtration of this information is implemented. This structure allows to avoid big changes in the central core's internal organization with the new information sources connection, and also allows to decrease the account of computations in the central core, which makes its more operative.

The ASPOS system's structure enables to solve the following problems:

1) Regular tracking of man-made space debris object motion, which presents a certain danger for manned and unmanned spacecraft, with processing and analysis of information received from various sources;

2) Detection and prediction of NES dangerous event dynamics (proximity and deorbit events, etc.);

3) Monitoring of spent SLV, booster and SC removal to disposal zones;

4) Providing Roscosmos with the information insupport of Russia's participation in international "reentry" space object test campaigns.

The regular space objects monitoring is fulfilled by the space monitoring facilities of the Russian Ministry of Defense, the Russian Academy of Sciences, and the Russian Space Agency. The uninterrupted information exchange between the ASPOS backbone and other observation facilities enables responds to any NES dangerous event (proximity and deorbit events), and to instantly notify the spacecraft operators.

The ASPOS Data Base contains information on 16,000 space objects with complete practicable data enabling the system's backbone to solve such problems as safety control support of the ISS and Roscosmos constellation missions in the test mode (Resurs-DK, Coronal-Foton, Sterkh, GLONASS, Eelectro-L and Luch satellites).

In 2011 around 3,000 space debris object proximity events with Russian spacecraft were monitored due to the ASPOS system operation results.

The International Space Station fulfilled 4 avoidance maneuvers within the framework of the joint NASA - Russia ISS mission safety control program.

The problems of ballistic and information support of deorbiting space objects, with identification of their impact time and areas, are solved at the high level. For 2011-2012 over 100 derobits were tracked, including three space object deorbits during international test campaigns.

It is intended to complement the system with the Roscosmos facilities (6 telescopes) by mid 2013.

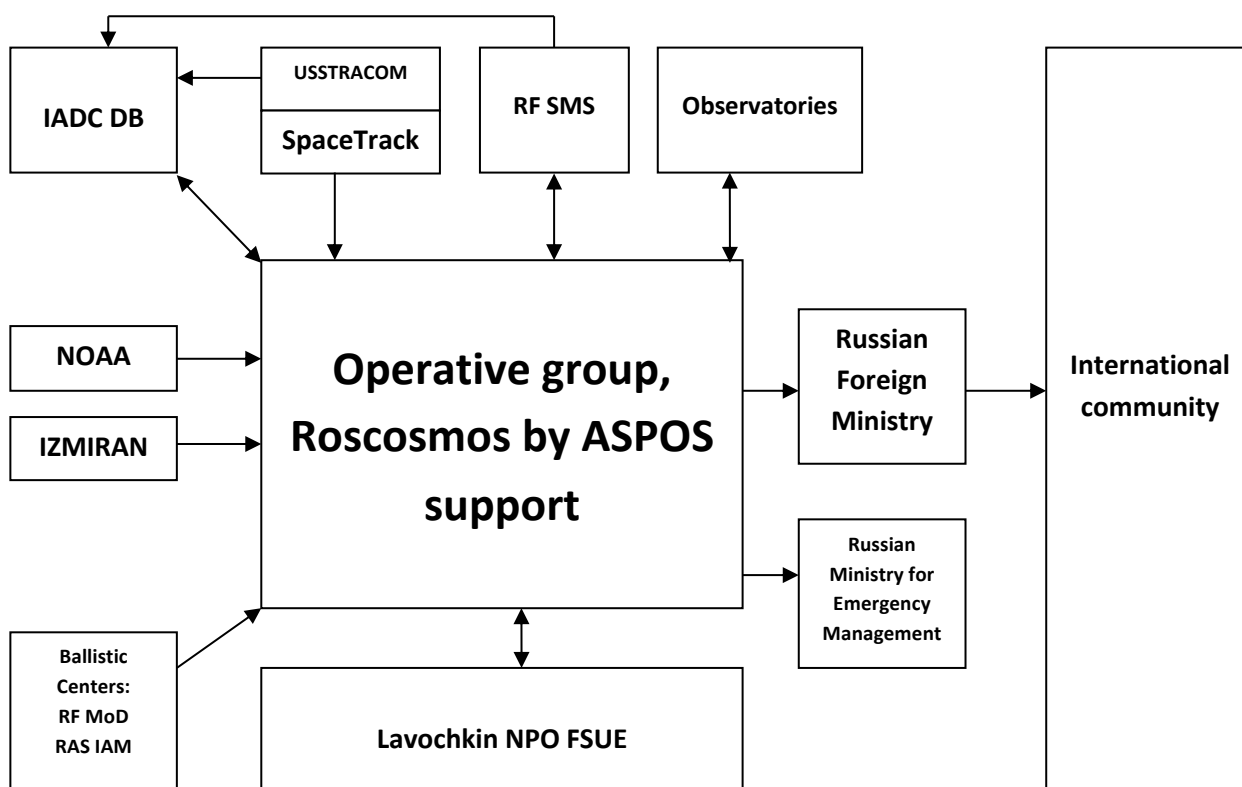
According to the native and foreign experience in our days, there are some approved technologies of receiving information:

- low-orbit area, in the most cases, is controlled by radar stations;
- high-altitude area is controlled by optoelectronic stations;

The utilization of the space-based and naval facilities can make the observation facilities more effective. The mobility of the sea based facilities will increase the accuracy of the object's orbit determination. The equator parallel motion of the sea-based facility helps to reduce the amount of the invisible space areas. The motion transversely to equator allows to observe objects with inclinations which are invisible for fixed stations. Space based facilities increase the amount and the accuracy of the measurements thanks to the lack of influence of the atmosphere and weather conditions. The utilization of the different based observation facilities becomes the popular tendency in the process of its modernization. Now the USA and Canada use extensively the utilization of different based observation facilities in the process of space area monitoring.

From the end of 2011 to the beginning of the 2012 years ASPOS was engaged in some international deorbit and reentry campaigns, where it demonstrated the ability of the international cooperation for solving the serious problems related with the space area pollution.

Phobos-Grunt reentry operations tracking (pict.3)



pict.3

Due to the engine failure, the Phobos-Grunt spacecraft remained in LEO and couldn't be further used as designated. Taking into consideration its limited orbital active service life, the Roscosmos management decided to organize real-time tracking of the Phobos-Grunt flight and deorbit with the prediction of impact time and area of its unburnt fragments. The main calculations were made by the TSNIMASH Mission Control Center (MCC) using the Automated System for NES Dangerous Event Warning. The scheme of interaction between the participants is shown above. The MCC used the following information as input data :

- Trajectory data from the RF Space Monitoring System (RFSMS) and space observatories and SC TLE format orbital data from Internet accessible sources;
- National Oceanic and Atmospheric Administration (NOAA) information;
- Impact time and area prediction data from the Russian Academy of Sciences Institute of Applied Mathematics (RAS IAM) and Russian Federation Ministry of Defence (RF MoD).;

Using this input information the TSNIMASH MCC regularly specified the SC orbital parameters predicting the SC impact time and area. The SC primary contractor – the Lavochkin NPO - calculated SC fragmentation at its reentry, and its unburnt fragments scatter on the basis of the TSNIMASH impact prediction data. Regularly updated data on SC motion and its descent were operatively transmitted to Roscosmos and the Ministry for Emergency Management, then the Roscosmos transmitted the information to the Foreign Ministry which informed the world countries on the territory of which the SC unburnt fragments could fall.

At the time of the Roscosmos Operative Group activity, the IADC organized the International Test Campaign for tracking Phobos-Grunt deorbit and predicting its impact, with the participation of 11 nations-IADC members which started its work on January 2, 2012. As a result the previous information was enhanced by trajectory tracking data from many countries (including the USA, Germany, France and others) and entered into the IADC Database. After this RF SMS began to send the information to the IADC Database.

As one can see, thanks to the operative interaction of many organizations, including international ones, it became possible to solve a very complex challenge of tracking SC reentry, which presented a serious threat to inhabitants of the areas of its probable impact.

One should note that the TSNIMASH MCC made a significant contribution (ASPOS) to the Russian Express-AM4 SC splashdown operations after failure to put the spacecraft in the designated orbit and use it as designed.

First of all the TSNIMASH MCC calculated the risk of Express-AM4 collision with operating spacecraft, and as a result it was found that the given spacecraft presents a serious threat for many (486) operating spacecraft. The arising problem had to be solved as soon as possible. The two options were reviewed:

- SC removal to a disposal orbit;
- SC splashdown;

The TSNIMASH MCC analyzed a possible disposal orbit in terms of safety. As a result of the calculations made, it was found that the spacecraft on the selected orbit would threaten 37 active spacecraft. Though the number of spacecraft subject to threat presented by the Express-AM4 would have reduced greatly (almost by 13 times), the collision risk with the active spacecraft still existed. Accordingly, the most efficient decision was to execute a splashdown operation.

Thanks to coordinated operations of all campaign participants, and despite the large number of restrictions concerning the Express-AM4 space vehicle, we managed to submerge the spacecraft in a pre-assigned Pacific Ocean area. The operations were fulfilled with participation of the Toulouse and Shabolovka Mission Control Centers, in close cooperation with the TSNIMASH MCC (ASPOS), which analyzed conceivable actions, namely identification of probable splashdown areas, calculations of deceleration impulse modules and firing times. This

successful campaign proved the practicability of international cooperation in SC deorbit operations.

Another confirmation of the successful cooperation in dangerous space object deorbit tracking operations is Russia's (TSNIIMASH MCC's) participation in the international test campaigns organized by IADC. These are the Russian Phobos-Grunt deorbit tracking and the German RORSAT and American UARS tracking campaigns.

These operations were conducted under a thoroughly elaborated consistent plan, according to which each campaign member used its space monitoring assets for SC orbit determination, and then entered the obtained vectors in Internet so that the other members could use this information. The ASPOS backbone predicted space object impact area as soon as the space object orbit data came. The tables contain the prediction data obtained by the latest space object orbit determinations and the results of assessing the impact time, as compared with the data obtained by the other test campaign members.

In that way during the last couple years ASPOS participates not only in the ensuring of the Roscosmos spacecraft safety, but also in the international campaigns, like the ensuring of the ISS safe flight and the tracking of the object's reentries.

The Russian Space Monitoring System (SMS) is the second in the world in terms of number of observation facilities. On the whole it can augment the USA SMS on non-controlled orbits, when tracking extremely dangerous space objects. It may be exemplified by the Phobos-Grunt tracking when on the 1097th orbit (final one) of its service life only the Russian space monitoring facilities obtained measurement data. Moreover, while conducting joint campaigns, the leading space-faring nations established operative partnership, thus demonstrating how to solve complex tasks. Currently such a partnership is exercised only within the framework of ISS mission support operations. It implies joint orbit determination for the accuracy enhancement of dynamic operations conduct and interaction, when the ISS is in a threatening proximity with a "risk" object, thus substantially improving the mission safety.

It is likely that in the future all the world leading space-faring nations will exchange data with the purpose of establishing an international space environment information exchange system. The ASPOS OKP system, deployed at the TSNIIMASH MCC, is available for cooperation with the international partners for combining operations of the national space activity safety control systems, with the purpose of space debris risk mitigation, and can provide information support of Russia's participation in international "Impacting" space object test campaigns.

Literature:

- 1) Report, 30th IADS meeting, Monreal, 2012